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Your details ChangeYour details

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Title

Ms

First name

tshingombe tshitadi

Surname

tshitadi

Company name

engineering tshingombe

Email address

tshingombefiston@gmail.com

Phone number

0725298946

Your request ChangeYour request

Your request

Select the option that most applies to you

Request an interview with a serving Met officer for commercial purposes, such as research for a book

Details of your enquiry

tshingombe tshitadi Prospect ID : 04032024205966607380Of0884bebd2415f9d5d6b20c80a2237 Postdoctoral in 0 First Name : tshingombe Last Name : tshitadi Email : tshingombefiston@gmail.com Alternative Email : Address 1 : Address 2 : City : Johannesburg State : Country : South Africa Home Phone : Work Phone : Cell Phone : 0725298946 Fax : Age : 42 Gender : Website Address : Language : English Internal Comments : The AIU AI Program Generator creates custom program courses based on your desired work field and educational background. This intelligent tool tailors a curriculum to align with industry demands and your academic strengths, ensuring efficient learning and maximizing your potential for career success. The program generator offers a preview of potential courses at AIU, each with several lessons. Once enrolled, students can customize courses during Phase 2 by collaborating with their tutor and advisor. 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1.Topic one experimental: theoretical pratical company Overview : tshingombe fiston Sat, Nov 30, 2024, 5:38 PM to regionArevenue, regionBrevenue, tenderadvicecentre, estimations, wmcqueries, Mediadesk, SARS, me City Power is responsible for providing electrical services to property owners in the City of Johannesburg that are not serviced by Eskom. To determine if you are a City Power customer you can check your existing City of Johannesburg invoice and see if you are being billed for electricity. If you don't have an invoice or if you don't have a service connection you can check the township list, it will indicate in whose supply area the property is. The service connections we provide are divided into two categories namely Small Power Users (SPU) and Larger Power Users (LPU). A Small Power User is defined as a user who has an electrical service connection no greater than 56 kVA (3 phase, 80 ampere). In general most households would have this type of service connection. A Large Power User is defined as a user who has an electrical service connection larger than 56 kVA. In general these type of connections are used for medium and large commercial or industrial consumers as well as high density residential developments. We want to provide property owners with the services they require in as short time as possible. To assist with this, the information and documents required to make an application for electrical services are detailed in the documents on this webpage. 1. Apply to convert a SPU from postpaid to pre-paid billing 2. Apply for a new prepaid or postpaid SPU connection (this guide also covers application for alterations to a small power user connection) 3. Apply for a new LPU connection (the guide also covers applications for alterations to a large power user connection) The application form that needs to be submitted when making an new feed updates notifications Sales Nav City Power Johannesburg Visit website Home About Posts Jobs People Insights City Power Johannesburg Customer-focused energy services company, operating and maintaining the Johannesburg's electricity distribution network. Electric Power Transmission, Control, and Distribution Johannesburg, Gauteng 1K followers 1K-5K employees Visit website Home About Posts Jobs People Insights City Power Johannesburg 1,034 followers See a collection of active or past ads by City Power Johannesburg. View ad library Feed post number 1 City Power JohannesburgCity Power Johannesburg 1,034 followers1,034 followers 2w • 2 weeks ago City Power's Green Energy Future: Solar Microgrids Empower Communities hashtag#CityPowerServices hashtag#CityPowerEnergyPlan City Power's Green Energy Future: Solar Microgrids Empower Communities City Power Johannesburg By Kgagodi MadibaCity Power is taking significant strides to reduce greenhouse gas emissions and bring sustainable energy solutions to Johannesburg co Home My Network Jobs 1 1 new message notification Messaging 25 25 new notifications Notifications application can also be found with the downloadable documents on the below table. On Sat, Nov 30, 2024 at 5:11 PM tshingombe fiston wrote: https://www.sars.gov.za/businesses-and-employers/trusts/registering-as-a-trust/register-a-trust-supporting-documents/ 4 Attachments • Scanned by Gmail tshingombe fiston On Sat, Nov 30, 2024 at 5:38 PM tshingombe fiston wrote: City Power is responsible for providing electrical services to property ow Nov 30, 2024, 5:42 PM tshingombe fiston On Sat, Nov 30, 2024 at 5:38 PM tshingombe fiston wrote: City Power is responsible for providing electrical services to property ow Dec 1, 2024, 12:17 PM postmaster@sap.onmicrosoft.com Delivery has failed to these recipients or groups: SARS Human Capital and Development (System@successfactors.com) The recipient's mailbox is full and can't acce Dec 1, 2024, 12:19 PM tshingombe fiston Turn on more accessible mode Skip Ribbon Commands Skip to main content Webmail Contact Us Sign Out - HomeCurrently selected - Our Company - Company Information Dec 1, 2024, 12:52 PM Mail Delivery Subsystem Message blocked Your message to sarb-graduaterecruit@resbank.co.za has been blocked. See technical details below for more information. LEARN MORE This link will Dec 1, 2024, 12:53 PM Mail Delivery Subsystem Message blocked Your message to admni@resbank.co.za has been blocked. See technical details below for more information.

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Dec 1, 2024, 12:55 PM tshingombe fiston Dec 1, 2024, 12:55 PM electricity consumption.[30] tshingombe fiston Sat, Nov 30, 2024, 5:38 PM to regionArevenue, regionBrevenue, tenderadvicecentre, estimations, wmcqueries, Mediadesk, SARS, me City Power is responsible for providing electrical services to property owners in the City of Johannesburg that are not serviced by Eskom. To determine if you are a City Power customer you can check your existing City of Johannesburg invoice and see if you are being billed for electricity. If you don't have an invoice or if you don't have a service connection you can check the township list, it will indicate in whose supply area the property is. The service connections we provide are divided into two categories namely Small Power Users (SPU) and Larger Power Users (LPU). A Small Power User is defined as a user who has an electrical service connection no greater than 56 kVA (3 phase, 80 ampere). 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See technical details below for more information. LEARN MORE This link will Dec 1, 2024, 12:53 PM Mail Delivery Subsystem Message blocked Your message to admni@resbank.co.za has been blocked. See technical details below for more information. LEARN MORE This link will take you to a Dec 1, 2024, 12:53 PM Mail Delivery Subsystem Address not found Your message wasn't delivered to customerservice@eskom.co.za because the address couldn't be

found, or is unable to receive mail. LEARN MORE T Dec 1, 2024, 12:53 PM Mail Delivery Subsystem Address not found Your message wasn't delivered to GITServiceDesk@eskom.co.za because the address couldn't be found, or is unable to receive mail. LEARN MORE Th Dec 1, 2024, 12:53 PM postmaster@dmre.gov.za Your message to examweb@dmr.gov.za couldn't be delivered. The group examweb only accepts messages from people in its organization or on its allowed senders list Dec 1, 2024, 12:53 PM postmaster@sap.onmicrosoft.com Diagnostic information for administrators: Generating server: AS8PR02MB8519.eurprd02.prod.outlook.com System@successfactors.com Remote server returned '554 5.2. 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Supervisor Tech Instrument x 2 (Generation) Tutuka Power Station 2024/09/01 01:39 PM Engineer-in-Training-Control and Instrumentation AND-Auxiliary and Ancillary-(Peaking Durbanville)-X2 2024/09/01 01:40 PM Re Advert Senior Technician Configuration X1 (Generation) Medupi Power Station 2024/09/01 01:42 PM Engineer Prof Eng Quality of Supply (National Transmission Company South Africa) Newscastle 2024/09/01 01:43 PM Learning Programme - Graduate in Training x1, Generation, Megawatt Park 2024/09/01 01:44 PM Learning-Programme -Graduate-in-Training-x3,-Generation,-1Megawatt-Park 2024/09/01 01:45 PM Learning Programme-Graduate in Training x 3, Generation, Megawatt Park 2024/09/01 01:46 PM Learning Programme-Graduate in Training x 2, Generation, Megawatt Park 2024/09/01 01:47 PM Senior Supervisor Technical Projects (National Transmission Company South Africa)Northwest and Limpopo 2024/09/01 01:49 PM Snr-Advisor-Applications-Support-(Group-IT-DIVISION)-Megawatt-Park 2024/09/01 01:50 PM 1 - 30 Follows us on oOur Company Company Information Leadership Investors Sustainable Development CSI Media Room PAIA Eskom Heritage Photo Gallery Video Clips oAbout Electricity Electricity Tips Electricity Technologies Eskom Power Series Renewable Energy Facts & Figures Visitor Centers MODIS Fire Alerts oWhat we're doing Electricity Generation New Build Transmission Development Plan Ancillary Services GCCA Report Supply Status Info Site For IPPs School Of Welding Eskom initiatives oIDM Integrated Demand Management Energy Advice Eskom Solar Water Heating Programme Measurement Verification oCustomer Care CS Online Tarrifs And Charges MYPD3 Customer Service Information Subscribe CS Mobile Customer Feedback Customer Care Video Clips IDM oCareers Vacancies oTenders Eskom Purchasing Policies Tender Process Whats Out To Tender Supplier Registration Insurance Policies Procedures BBBEE Certificate | Terms of use Webmail | Media Info | Sustainability | Job Opportunities | Contact Us Original text Rate this translation Your feedback will be used to help improve Google Translate ... [Message clipped] View entire message Mail Delivery Subsystem Message blocked Your message to sarb-graduaterecruit@resbank.co.za has been blocked. See technical details below for more information. LEARN MORE This link will Dec 1, 2024, 12:55 PM Mail Delivery Subsystem Message blocked Your message to admni@resbank.co.za has been blocked. See technical details below for more information. LEARN MORE This link will take you to a Dec 1, 2024, 12:55 PM Mail Delivery Subsystem Address not found Your message wasn't delivered to customerservice@eskom.co.za because the address couldn't be found, or is unable to receive mail. LEARN MORE T Dec 1, 2024, 12:55 PM Mail Delivery Subsystem Address not found Your message wasn't delivered to GITServiceDesk@eskom.co.za because the address couldn't be found, or is unable to receive mail. LEARN MORE Th Dec 1, 2024, 12:55 PM postmaster@sap.onmicrosoft.com Diagnostic information for administrators: Generating server: AS1PR02MB7918.eurprd02.prod.outlook.com System@successfactors.com Remote server returned '554 5.2. Dec 1, 2024, 12:56 PM postmaster@dmre.gov.za Your message to examweb@dmr.gov.za couldn't be delivered. The group examweb only accepts messages from people in its organization or on its allowed senders list Dec 1, 2024, 12:56 PM RegionB Revenue Dec 2, 2024, 10:26 AM to SARS, RegionA, RegionB, Estimations, WMCQUERIES, Media, me On Sat, Nov 30, 2024 at 5:38 PM tshingombe fiston wrote: City Power is responsible for providing electrical services to property owners in the City of Johannesburg that are not serviced by Eskom. To determine if you are a City Power customer you can check your existing City of Johannesburg invoice and see if you are being billed for electricity. 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RegionB Revenue Dear valued customer, Please provide us with your municipal account number and describe the nature of your query in detail. Thank you for utilizing the regional Feb 5, 2025, 12:50 PM tshingombe fiston Thanks - municipality city Johannesburg - CDs R169241870 -; Feb 5, 2025, 1:19 PM RegionB Revenue Dear valued customer, Kindly provide a transfer letter The Region B Customer Service Team On Mon, Dec 2, 2024 at 10:26 AM RegionB Revenue <regionBrevenue@joburg Feb 5, 2025, 1:35 PM tshingombe fiston Thank you, will do. Feb 6, 2025, 9:33 AM RegionB Revenue Thanks City Power Johannesburg Visit website Feed post number 1 Feb 7, 2025, 8:58 AM RegionB Revenue Feb 10, 2025, 8:06 AM to me Dear valued customer, Thank you for utilizing the regional email service. Kind Regards, tshingombe fiston You are welcome. Feb 10, 2025, 6:03 PM RegionB Revenue Feb 12, 2025, 10:43 AM (12 days ago) to me Most Welcome tshingombe fiston Feb 23, 2025, 10:28 AM (1 day ago) to RegionB 2 Attachments • Scanned by Gmail tshingombe fiston Feb 23, 2025, 1:18 PM (21 hours ago) to RegionB 6 Attachments • Scanned by Gmail City Power Article Talk Read Edit View history Tools Appearance Text Small Standard Large Width Standard Wide Color (beta) Automatic Light Dark From Wikipedia, the free encyclopedia City Power Company type Electric utility Industry Electric power industry Founded January 1, 2001; 24 years ago Headquarters 40 Heronmere Road, Reuven, Johannesburg , South Africa Area served Johannesburg Key people Tshifularo Mashava (CEO) Revenue R 17 billion (2020/21) Total assets R 19.7 billion (2019/20) Number of employees 1750 (2020/21) Website citypower.co.za City Power Johannesburg (or Joburg City Power) is a state owned power utility, wholly owned by the City of Johannesburg. Its responsibilities include buying electricity from power producers and supplying it to the public, and installing and maintaining the electrical infrastructure in the city of Johannesburg. It supplies electricity to 3.2 million people in the Greater Johannesburg Metropolitan Area.[1] History Joburg City Power was established as a separate company from the City of Johannesburg on 1 January 2000. On the 19th December 2001, the National Energy Regulator of South Africa (NERSA), granted City Power a licence to trade. In 2022, it took over the electricity distribution functions from Eskom to Soweto and parts of Johannesburg, including Sandton, Orange Farm, Finetown, Ivory Park and Diepsloot; Eskom was previously responsible for supplying electricity to most parts of Johannesburg.[2][3] Corruption In 2013, a controversial R1.2 billion contract was awarded by the City of Johannesburg to Edison Power, a company owned by Vivian Reddy, a close ally of Jacob Zuma, for smart meters used by City Power customers.[4] Edison Power was initially allocated a R600-million share of an R800-million contract. Subsequently, the contract value was revised to R1.25 billion and Edison Power received the exclusive contract.[4] Load shedding Kelvin Power Station, a coal-fired power station, provides the City Johannesburg 10% of its power. City Power currently obtains 90% of its power from Eskom and 10% from the Kelvin Power Station from which it seeks to move away from.[5] In 2014, it announced that it will remotely switch off geysers "to reduce the impact of load shedding. [6] In 2021, it resolved to be an electricity generator to "reduce over-reliance on Eskom".[7] In 2023, the City of Johannesburg along with City Power aimed to cut load shedding in Johannesburg by 3 stages through the use of smart meters and the recommissioning of two existing open cycle gas turbines. It also sought to secure power on a long-term basis from independent power producers (IPPs).[8] In 2023, City Power said it had to replace more than 390 mini-substations (pole-mounted transformers), at a cost of R200 million which constituted 80% of its budget for the year. The cause of this was load shedding, theft and vandalism.[9][10][11] In September 2023, City Power announced a drive that would replace all meters with smart meters before 24 November 2024. This was due to a limitation in all meters that generate a token ID using the Standard Transfer Specification. This change would also enable City Power to remotely limit electricity usage in households whose usage is higher than normal.[12] From 6 November 2023, City Power took over management of the load shedding schedule from Eskom.[13] From 10 June 2024, City Power implemented its own form of load shedding called load reduction.[14] Electricity procurement In 2023, through grid access it aims to obtain 53MW from customer-embedded rooftop solar generation and 3.7MW from municipal building PV generation, for a total of 60MW.[2] By 2026/27, it hopes to target 480MW (with 200MW coming from households and businesses, 150MW from independent power producers on private and mining land, 50MW from financed rooftop IPP PV programmes, 27MW through municipal building PV generation, 33.5MW from landfill gas generation and solid waste-to-energy, and 20MW from natural gas generation.)[2] In July 2023, the City of Johannesburg introduced wheeling tariffs which charge both independent power producers and City Power customers to allow use of the existing grid infrastructure to supply customers with electricity.[15] In August 2023, City Power secured 92MW from four IPPs: waste-to-energy (20MW), gas-to-power (31MW) and PV solar generation (40.8MW).[16] In April 2024, the 50 MW John Ware Gas Turbine Power Station was recommissioned.[17] Revenue recuperation City Power has endeavoured to collect R8.9 billion owed

by businesses and households. It did this by first giving notices of disconnecting the power of delinquent parties, and compelling them to pay. It said it will impose penalties on businesses and residential complexes that have defaulted on their accounts and connected electricity illegally.[18] Businesses The Apartheid Museum was one of the disconnected clients, with it owing R1.8 million.[19] The Gauteng Treasury was another, with it owing over R34 million.[20] In February 2023, some of the disconnected clients were a shopping centre running an illegal connection on its meters and was penalised with a R100 000 fine, the Church of Scientology with R877 000 in arrears, a sports club in Bryanston which owed R2.3 million and the Nigerian consulate which owed R406 000.[18] In October 2023, it announced that it would give government entities Rahima Moosa Mother and Child Hospital and the Helen Joseph Hospital 14 days to settle a combined debt of R32 million.[21] In June 2024, Eskom issued an ultimatum to the City of Johannesburg (COJ) and City Power for electricity non payment. Joburg owes Eskom R3.4 billion.[22] According to the record, last payments were made in October 2023.[23] The Johannesburg High Court instructed the City of Johannesburg and City Power to immediately pay the first billion of their defaulting amount.[24] Residential customers In September 2023, City Power conducted a disconnection drive of non-paying customers in Naturena and the Lenasia Service Delivery Centre (SDC) in an attempt to collect revenue; the Lenasia SDC which includes surrounding areas like Eldorado Park, Ennerdale, Zakariyya Park and Lehae, owed R 1.3 billion.[25] The City of Johannesburg, through City Power meters, began subtracting municipal debt owed by businesses and residential customers from prepaid electricity purchases.[26] From July 2024, City Power began deducting a R230 service charge from its prepaid customers; along with an increase in the electricity price per KWh, this saw a 23.15% increase from the previous year for all customers including indigent customers (6 to 12 times the inflation rate).[27][28] Photograph your local culture, help Wikipedia and win! Contents (Top) Organization o Power transactions o Executive compensation Oversight Alternative energy promotion Nuclear energy Customer expectations See also References Electric utility Article Talk Read Edit View history Tools Appearance Text Small Standard Large Width Standard Wide Color (beta) Automatic Light Dark From Wikipedia, the free encyclopedia An electric utility, or a power company, is a company in the electric power industry (often a public utility) that engages in electricity generation and distribution of electricity for sale generally in a regulated market.[1] The electrical utility industry is a major provider of energy in most countries. Electric utilities include investor owned, publicly owned, cooperatives, and nationalized entities. They may be engaged in all or only some aspects of the industry. Electricity markets are also considered electric utilities —these entities buy and sell electricity, acting as brokers, but usually do not own or operate generation, transmission, or distribution facilities. Utilities are regulated by local and national authorities. Electric utilities are facing increasing demands[2] including aging infrastructure, reliability, and regulation. In 2009, the French company EDF was the world's largest producer of electricity.[3] Organization Power transactions An electric power system is a group of generation, transmission, distribution, communication, and other facilities that are physically connected.[4] The flow of electricity within the system is maintained and controlled by dispatch centers which can buy and sell electricity based on system requirements. Executive compensation The examples and perspective in this article may not represent a worldwide view of the subject. You may improve this article, discuss the issue on the talk page, or create a new article, as appropriate. (February 2016) (Learn how and when to remove this message) The executive compensation received by the executives in utility companies often receives the most scrutiny in the review of operating expenses. Just as regulated utilities and their governing bodies struggle to maintain a balance between keeping consumer costs reasonable and being profitable enough to attract investors, they must also compete with private companies for talented executives and then be able to retain those executives.[5] Regulated companies are less likely to use incentive-based remuneration in addition to base salaries. Executives in regulated electric utilities are less likely to be paid for their performance in bonuses or stock options.[5] They are less likely to approve compensation policies that include incentive-based pay.[5] The compensation for electric utility executives will be the lowest in regulated utilities that have an unfavorable regulatory environment. These companies have more political constraints than those in a favorable regulatory environment and are less likely to have a positive response to requests for rate increases.[6] Just as increased constraints from regulation drive compensation down for executives in electric utilities, deregulation has been shown to increase remuneration. The need to encourage risk-taking behavior in seeking new investment opportunities while keeping costs under control requires deregulated companies to offer performance-based incentives to their executives. It has been found that increased compensation is also more likely to attract executives experienced in working in competitive environments.[7] In the United States, the Energy Policy Act of 1992 removed previous barriers to wholesale competition in the electric utility industry. Currently 24 states allow for deregulated electric utilities: Ohio, Oklahoma, Oregon, Pennsylvania, Rhode Island, Texas, Virginia, Arizona, Arkansas, California, Connecticut, Delaware, Illinois, Maine, Maryland, Massachusetts, Michigan, Montana, New Hampshire, New Jersey, New Mexico, New York, and Washington D.C.[8] As electric utility monopolies have been increasingly broken up into deregulated businesses, executive compensation has risen; particularly incentive compensation.[9] Oversight Oversight is typically carried out at the national level, however it varies depending on financial support and external influences.[10] There is no existence of any influential international energy oversight organization. There does exist a World Energy Council, but its mission is mostly to advise and share new information.[11] It does not hold any kind of legislative or executive power. Alternative energy promotion Alternative energy has become more and more prevalent in recent times and as it is inherently independent of more traditional sources of energy, the market seems to have a very different structure. In the United States, to promote the production and development of alternative energies, there are many subsidies, rewards, and incentives that encourage companies to take up the challenge themselves. There is precedent for such a system working in countries like Nicaragua. In 2005, Nicaragua gave renewable energy companies tax and duty exemptions, which spurred a great deal of private investment.[12] The success in Nicaragua may not be an easily replicated situation however. The movement was known as Energiewende and it is generally considered a failure for many reasons.[13] A primary reason was that it was improperly timed and was proposed during a period in which their energy economy was under more competition. Globally, the transition of electric utilities to renewables remains slow, hindered by concurrent continued investment in the expansion of fossil fuel capacity.[14] Nuclear energy Nuclear energy may be classified as a green source depending on the country. Although there used to be much more privatization in this energy sector, after the 2011 Fukushima district nuclear power plant disaster in Japan, there has been a move away from nuclear energy itself, especially for privately owned nuclear power plants.[citation needed] The criticism being that privatization of companies tend to have the companies themselves cutting corners and costs for profits which has proven to be disastrous in the worst-case scenarios. This placed a strain on many other countries as many foreign governments felt pressured to close nuclear power plants in response to public concerns.[13] Nuclear energy however still holds a major part in many communities around the world. Customer expectations Utilities have found that it isn't simple to meet the unique needs of individual customers, whether residential, corporate, industrial, government, military, or otherwise. Customers in the twenty-first century have new and urgent expectations that demand a transformation of the electric grid. They want a system that gives them new tools, better data to help manage energy usage, advanced protections against cyberattacks, and a system that minimizes outage times and quickens power restoration.[15] See also Electrical grid Article Talk Read Edit View history Tools Appearance Text Small Standard Large Width Standard Wide Color (beta) Automatic Light Dark From Wikipedia, the free encyclopedia (Redirected from Grid access) For other uses, see Grid (disambiguation). "Power grid" redirects here. For the board game, see Power Grid. Diagram of an electrical grid (generation system in red, transmission system in blue, distribution system in green) An electrical grid (or electricity network) is an interconnected network for electricity delivery from producers to consumers. Electrical grids consist of power stations, electrical substations to step voltage up or down, electric power transmission to carry power over long distances, and finally electric power distribution to customers. In that last step, voltage is stepped down again to the required service voltage. Power stations are typically built close to energy sources and far from densely populated areas. Electrical grids vary in size and can cover whole countries or continents. From small to large there are microgrids, wide area synchronous grids, and super grids. The combined transmission and distribution network is part of electricity delivery, known as the power grid. Grids are nearly always synchronous, meaning all distribution areas operate with three phase alternating current (AC) frequencies synchronized (so that voltage swings occur at almost the same time). This allows transmission of AC power throughout the area, connecting the electricity generators with consumers. Grids can enable more efficient electricity markets. Although electrical grids are widespread, as of 2016, 1.4 billion people worldwide were not connected to an electricity grid.[1] As electrification increases, the number of people with access to grid electricity is growing. About 840 million people (mostly in Africa), which is ca. 11% of the World's population, had no access to grid electricity in 2017, down from 1.2 billion in 2010.[2] Electrical grids can be prone to malicious intrusion or attack; thus, there is a need for electric grid security. Also as electric grids modernize and introduce computer technology, cyber threats start to become a security risk.[3] Particular concerns relate to the more complex computer systems needed to manage grids.[4] Types (grouped by size) Part of a series on Power engineering Electric power conversion Voltage converter Electric power conversion HVDC converter station AC-to-AC converter

DC-to-DC converter Rectifier Inverter Electric power infrastructure Electric power system Power station Electrical grid Interconnector Demand response Electric power systems components Ring main unit Grid-tie inverter Energy storage Busbar Bus duct Recloser Protective relay v t e Microgrid Main article: Microgrid A microgrid is a local grid that is usually part of the regional wide-area synchronous grid, but which can disconnect and operate autonomously.[5] It might do this in times when the main grid is affected by outages. This is known as islanding, and it might run indefinitely on its own resources. Compared to larger grids, microgrids typically use a lower voltage distribution network and distributed generators.[6] Microgrids may not only be more resilient, but may be cheaper to implement in isolated areas. A design goal is that a local area produces all of the energy it uses.[5] Example implementations include: Hajjah and Lahj, Yemen: community-owned solar microgrids.[7] Île d'Yeu pilot program: sixty-four solar panels with a peak capacity of 23.7 kW on five houses and a battery with a storage capacity of 15 kWh.[8][9] Les Anglais, Haiti:[10] includes energy theft detection.[11] Mpeketoni, Kenya: a community-based diesel-powered micro-grid system.[12] Stone Edge Farm Winery: micro-turbine, fuel-cell, multiple battery, hydrogen electrolyzer, and PV enabled winery in Sonoma, California.[13][14] Wide area synchronous grid Main article: Wide area synchronous grid A wide area synchronous grid (also called an "interconnection" in North America) is an electrical grid at a regional scale or greater that operates at a synchronized frequency and is electrically tied together during normal system conditions. For example, there are four major interconnections in North America (the Western Interconnection, the Eastern Interconnection, the Quebec Interconnection and the Texas Interconnection). In Europe, one large grid connects most of Western Europe. These are also known as synchronous zones, the largest of which is the synchronous grid of Continental Europe (ENTSO-E) with 667 gigawatts (GW) of generation, and the widest region served being that of the IPS/UPS system serving countries of the former Soviet Union. Synchronous grids with ample capacity facilitate electricity market trading across wide areas. In the ENTSO-E in 2008, over 350,000 megawatt hours were sold per day on the European Energy Exchange (EEX).[15] Each of the interconnects in North America are run at a nominal 60 Hz, while those of Europe run at 50 Hz. Neighbouring interconnections with the same frequency and standards can be synchronized and directly connected to form a larger interconnection, or they may share power without synchronization via high-voltage direct current power transmission lines (DC ties), or with variable-frequency transformers (VFTs), which permit a controlled flow of energy while also functionally isolating the independent AC frequencies of each side. The benefits of synchronous zones include pooling of generation, resulting in lower generation costs; pooling of load, resulting in significant equalizing effects; common provisioning of reserves, resulting in cheaper primary and secondary reserve power costs; opening of the market, resulting in possibility of long-term contracts and short term power exchanges; and mutual assistance in the event of disturbances.[16] One disadvantage of a wide-area synchronous grid is that problems in one part can have repercussions across the whole grid. For example, in 2018, Kosovo used more power than it generated due to a dispute with Serbia, leading to the phase across the whole synchronous grid of Continental Europe lagging behind what it should have been. The frequency dropped to 49.996 Hz. This caused certain kinds of clocks to become six minutes slow.[17] The synchronous grids of Europe The two major and three minor interconnections of North America Major WASGs around the world Super grid Main article: Super grid One conceptual plan of a super grid linking renewable sources across North Africa, the Middle East and Europe. (DESERTEC)[18] A super grid or supergrid is a wide-area transmission network that is intended to make possible the trade of high volumes of electricity across great distances. It is sometimes also referred to as a mega grid. Super grids can support a global energy transition by smoothing local fluctuations of wind energy and solar energy. In this context, they are considered as a key technology to mitigate global warming. Super grids typically use high-voltage direct current (HVDC) to transmit electricity long distances. The latest generation of HVDC power lines can transmit energy with losses of only 1.6% per 1000 km.[19] Electric utilities between regions are many times interconnected for improved economy and reliability. Electrical interconnectors allow for economies of scale, allowing energy to be purchased from large, efficient sources. Utilities can draw power from generator reserves from a different region to ensure continuing, reliable power and diversify their loads. Interconnection also allows regions to have access to cheap bulk energy by receiving power from different sources. For example, one region may be producing cheap hydro power during high water seasons, but in low water seasons, another area may be producing cheaper power through wind, allowing both regions to access cheaper energy sources from one another during different times of the year. Neighboring utilities also help others to maintain the overall system frequency and also help manage tie transfers between utility regions.[20] Electricity Interconnection Level (EIL) of a grid is the ratio of the total interconnector power to the grid divided by the installed production capacity of the grid. Within the EU, it has set a target of national grids reaching 10% by 2020, and 15% by 2030.[21] Components Generation Main article: Electricity generation Turbo generator Electricity generation is the process of generating electric power at power stations. This is done ultimately from sources of primary energy typically with electromechanical generators driven by heat engines from fossil, nuclear, and geothermal sources, or driven by the kinetic energy of water or wind. Other power sources are photovoltaics driven by solar insolation, and grid batteries.[nb 1] The sum of the power outputs of generators on the grid is the production of the grid, typically measured in gigawatts (GW). Transmission Main article: Electric power transmission 500 kV Three-phase electric power Transmission Lines at Grand Coulee Dam; four circuits are shown; two additional circuits are obscured by trees on the right; the entire 7079 MW generation capacity of the dam is accommodated by these six circuits.Network diagram of a high voltage transmission system, showing the interconnection between the different voltage levels. This diagram depicts the electrical structure[22] of the network, rather than its physical geography. Electric power transmission is the bulk movement of electrical energy from a generating site, via a web of interconnected lines, to an electrical substation, from which is connected to the distribution system. This networked system of connections is distinct from the local wiring between high-voltage substations and customers. Transmission networks are complex with redundant pathways. Redundancy allows line failures to occur and power is simply rerouted while repairs are done. Because the power is often generated far from where it is consumed, the transmission system can cover great distances. For a given amount of power, transmission efficiency is greater at higher voltages and lower currents. Therefore, voltages are stepped up at the generating station, and stepped down at local substations for distribution to customers. Most transmission is three-phase. Three-phase, compared to single-phase, can deliver much more power for a given amount of wire, since the neutral and ground wires are shared.[23] Further, three-phase generators and motors are more efficient than their single-phase counterparts. However, for conventional conductors one of the main losses are resistive losses which are a square law on current, and depend on distance. High voltage AC transmission lines can lose 1-4% per hundred miles.[24] However, high-voltage direct current can have half the losses of AC. Over very long distances, these efficiencies can offset the additional cost of the required AC/DC converter stations at each end. Substations Main article: Electrical substation Substations may perform many different functions but usually transform voltage from low to high (step up) and from high to low (step down). Between the generator and the final consumer, the voltage may be transformed several times.[25] The three main types of substations, by function, are:[26] Step-up substation: these use transformers to raise the voltage coming from the generators and power plants so that power can be transmitted long distances more efficiently, with smaller currents. Step-down substation: these transformers lower the voltage coming from the transmission lines which can be used in industry or sent to a distribution substation. Distribution substation: these transform the voltage lower again for the distribution to end users. Aside from transformers, other major components or functions of substations include: Circuit breakers: used to automatically break a circuit and isolate a fault in the system.[27] Switches: to control the flow of electricity, and isolate equipment.[28] The substation busbar: typically a set of three conductors, one for each phase of current. The substation is organized around the buses, and they are connected to incoming lines, transformers, protection equipment, switches, and the outgoing lines.[27] Lightning arresters Capacitors for power factor correction Synchronous condensers for power factor correction and grid stability Electric power distribution Main article: Electric power distribution General layout of electricity grids. Voltages and depictions of electrical lines are typical for Germany and other European systems. Distribution is the final stage in the delivery of power; it carries electricity from the transmission system to individual consumers. Substations connect to the transmission system and lower the transmission voltage to medium voltage ranging between 2 kV and 35 kV. But the voltage levels varies very much between different countries, in Sweden medium voltage are normally 10 kV between 20 kV.[29] Primary distribution lines carry this medium voltage power to distribution transformers located near the customer's premises. Distribution transformers again lower the voltage to the utilization voltage. Customers demanding a much larger amount of power may be connected directly to the primary distribution level or the subtransmission level.[30] Distribution networks are divided into two types, radial or network.[31] In cities and towns of North America, the grid tends to follow the classic radially fed design. A substation receives its power from the transmission network, the power is stepped down with a transformer and sent to a bus from which feeders fan out in all directions across the countryside. These feeders carry three-phase power, and tend to follow the major streets near the substation. As the distance from the substation grows, the fanout continues as smaller laterals spread out to cover areas missed by the feeders. This tree-like structure grows outward from the substation, but for reliability reasons, usually contains at least one unused backup connection to a nearby substation. This connection can be enabled in case of an emergency, so that a portion of a substation's service territory can be alternatively fed by another substation. Storage Main article: Grid energy storage Energy from fossil or nuclear power plants and renewable sources is stored for use by customers. Simplified grid energy flow over the course of a day Grid energy storage (also called large-scale energy storage) is a collection of methods used for energy storage on a large scale within an electrical power grid. Electrical energy is stored during times when electricity is plentiful and inexpensive (especially from intermittent power sources such as renewable electricity from wind power, tidal power and solar power) or when demand is low, and later power is generated when demand is high, and electricity prices tend to be higher. As of 2020, the largest form of grid energy storage is dammed hydroelectricity, with both conventional hydroelectric generation as well as pumped storage hydroelectricity. Developments in battery storage have enabled commercially viable projects to store energy during peak production and release during peak demand, and for use when production unexpectedly falls giving time for slower responding resources to be brought online. Two alternatives to grid storage are the use of peaking power plants to fill in supply gaps and demand response to shift load to other times. Functionalities Demand The demand, or load on an electrical grid is the total electrical power being removed by the users of the grid. The graph of the demand over time is called the demand curve. Baseload is the minimum load on the grid over any given period, peak demand is the maximum load. Historically, baseload was commonly met by equipment that was relatively cheap to run, that ran continuously for weeks or months at a time, but globally this is becoming less common. The extra peak demand requirements are sometimes produced by expensive peaking plants that are generators optimised to come on-line quickly but these too are becoming less common. However, if the demand of electricity exceed the capacity of a local power grid, it will cause safety issue like burning out.[32] Voltage Grids are designed to supply electricity to their customers at largely constant voltages. This has to be achieved with varying demand, variable reactive loads, and even nonlinear loads, with electricity provided by generators and distribution and transmission equipment that are not perfectly reliable.[33] Often grids use tap changers on transformers near to the consumers to adjust the voltage and keep it within specification. Frequency Main article: Utility frequency In a synchronous grid all the generators must run at the same frequency, and must stay very nearly in phase with each other and the grid. Generation and consumption must be balanced across the entire grid, because energy is consumed as it is produced. For rotating generators, a local governor regulates the driving torque, maintaining almost constant rotation speed as loading changes. Energy is stored in the immediate short term by the rotational kinetic energy of the generators. Although the speed is kept largely constant, small deviations from the nominal system frequency are very important in regulating individual generators and are used as a way of assessing the equilibrium of the grid as a whole. When the grid is lightly loaded the grid frequency runs above the nominal frequency, and this is taken as an indication by Automatic Generation Control systems across the network that generators should reduce their output. Conversely, when the grid is heavily loaded, the frequency naturally slows, and governors adjust their generators so that more power is output (droop speed control). When generators have identical droop speed control settings it ensures that multiple parallel generators with the same settings share load in proportion to their rating. In addition, there's often central control, which can change the parameters of the AGC systems over timescales of a minute or longer to further adjust the regional network flows and the operating frequency of the grid. For timekeeping purposes, the nominal frequency will be allowed to vary in the short term, but is adjusted to prevent line-operated clocks from gaining or losing significant time over the course of a whole 24 hour period. An entire synchronous grid runs at the same frequency, neighbouring grids would not be synchronised even if they run at the same nominal frequency. High-voltage direct current lines or variable-frequency transformers can be used to connect two alternating current interconnection networks which are not synchronized with each other. This provides the benefit of interconnection without the need to synchronize an even wider area. For example, compare the wide area synchronous grid map of Europe with the map of HVDC lines. Capacity and firm capacity The sum of the maximum power outputs (nameplate capacity) of the generators attached to an electrical grid might be considered to be the capacity of the grid. However, in practice, they are never run flat out simultaneously. Typically, some generators are kept running at lower output powers (spinning reserve) to deal with failures as well as variation in demand. In addition generators can be off-line for maintenance or other reasons, such as availability of energy inputs (fuel, water, wind, sun etc.) or pollution constraints. Firm capacity is the maximum power output on a grid that is immediately available over a given time period, and is a far more useful figure. Production Most grid codes specify that the load is shared between the generators in merit order according to their marginal cost (i.e. cheapest first) and sometimes their environmental impact. Thus cheap electricity providers tend to be run flat out almost all the time, and the more expensive producers are only run when necessary. Failures and issues Failures are usually associated with generators or power transmission lines tripping circuit breakers due to faults leading to a loss of generation capacity for customers, or excess demand. This will often cause the frequency to reduce, and the remaining generators will react and together attempt to stabilize above the minimum. If that is not possible then a number of scenarios can occur. A large failure in one part of the grid — unless quickly compensated for — can cause current to re-route itself to flow from the remaining generators to consumers over transmission lines of insufficient capacity, causing further failures. One downside to a widely connected grid is thus the possibility of cascading failure and widespread power outage. A central authority is usually designated to facilitate communication and develop protocols to maintain a stable grid. For example, the North American Electric Reliability Corporation gained binding powers in the United States in 2006, and has advisory powers in the applicable parts of Canada and Mexico. The U.S. government has also designated National Interest Electric Transmission Corridors, where it believes transmission bottlenecks have developed. Brownout Main article: Brownout (electricity) A brownout near Tokyo Tower in Tokyo, Japan A brownout is an intentional or unintentional drop in voltage in an electrical power supply system. Intentional brownouts are used for load reduction in an emergency.[34] The reduction lasts for minutes or hours, as opposed to short-term voltage sag (or dip). The term brownout comes from the dimming experienced by incandescent lighting when the voltage sags. A voltage reduction may be an effect of disruption of an electrical grid, or may occasionally be imposed in an effort to reduce load and prevent a power outage, known as a blackout.[35] Blackout Main article: Power outage A power outage (also called a power cut, a power out, a power blackout, power failure or a blackout) is a loss of the electric power to a particular area. Power failures can be caused by faults at power stations, damage to electric transmission lines, substations or other parts of the distribution system, a short circuit, cascading failure, fuse or circuit breaker operation, and human error. Power failures are particularly critical at sites where the environment and public safety are at risk. Institutions such as hospitals, sewage treatment plants, mines, shelters and the like will usually have backup power sources such as standby generators, which will automatically start up when electrical power is lost. Other critical systems, such as telecommunication, are also required to have emergency power. The battery room of a telephone exchange usually has arrays of lead–acid batteries for backup and also a socket for connecting a generator during extended periods of outage. Load shedding Main article: Demand response Electrical generation and transmission systems may not always meet peak demand requirements — the greatest amount of electricity required by all utility customers within a given region. In these situations, overall demand must be lowered, either by turning off service to some devices or cutting back the supply voltage (brownouts), in order to prevent uncontrolled service disruptions such as power outages (widespread blackouts) or equipment damage. Utilities may impose load shedding on service areas via targeted blackouts, rolling blackouts or by agreements with specific high-use industrial consumers to turn off equipment at times of system-wide peak demand. Black start Main article: Black start Toronto during the Northeast blackout of 2003, which required black-starting of generating stations. A black start is the process of restoring an electric power station or a part of an electric grid to operation without relying on the external electric power transmission network to recover from a total or partial shutdown.[36] Normally, the electric power used within the plant is provided from the station's own generators. If all of the plant's main generators are shut down, station service power is provided by drawing power from the grid through the plant's transmission line. However, during a wide-area outage, off-site power from the grid is not available. In the absence of grid power, a so-called black start needs to be performed to bootstrap the power grid into operation. To provide a black start, some power stations have small diesel generators, normally called the black start diesel generator (BSDG), which can be used to start larger generators (of several megawatts capacity), which in turn can be used to start the main power station generators. Generating plants using steam turbines require station service power of up to 10% of their capacity for boiler feedwater pumps, boiler forced-draft combustion air blowers, and for fuel preparation. It is uneconomical to provide such a large standby capacity at each station, so black-start power must be provided over designated tie lines from another station. Often hydroelectric power plants are designated as the black-start sources to restore network interconnections. A hydroelectric station needs very little initial power to start (just enough to open the intake gates and provide excitation current to the generator field coils), and can put a large block of power on line very quickly to allow start-up of fossil-fuel or nuclear stations. Certain types of combustion turbine can be configured for black start, providing another option in places without suitable hydroelectric plants.[37] In 2017 a utility in Southern California has successfully demonstrated the use of a battery energy storage system to provide a black start, firing up a combined cycle gas turbine from an idle state.[38] Obsolescence Despite novel institutional arrangements and network designs, power delivery infrastructures is experiencing aging across the developed world. Contributing factors include: Aging equipment – older equipment has higher failure rates, leading to customer interruption rates affecting the economy and society; also, older assets and facilities lead to higher inspection maintenance costs and further repair and restoration costs. Obsolete system layout – older areas require serious additional substation sites and rights-of-way that cannot be obtained in the current area and are forced to use existing, insufficient facilities. Outdated engineering – traditional tools for power delivery planning and engineering are ineffective in addressing current problems of aged equipment, obsolete system layouts, and modern deregulated loading levels. Old cultural value – planning, engineering, operating of system using concepts and procedures that worked in vertically integrated industry exacerbate the problem under a deregulated industry.[39] Trends Demand response Demand response is a grid management technique where retail or wholesale customers are requested or incentivised either electronically or manually to reduce their load. Currently, transmission grid operators use demand response to request load reduction from major energy users such as industrial plants.[40] Technologies such as smart metering can encourage customers to use power when electricity is plentiful by allowing for variable pricing. Smart grid This section is an excerpt from Smart grid.[edit] Characteristics of a traditional centralized electrical system (left) vis-à-vis those of a smart grid (right) The smart grid is an enhancement of the 20th century electrical grid, using two-way communications and distributed so-called intelligent devices.[41] Two-way flows of electricity and information could improve the delivery network. Research is mainly focused on three systems of a smart grid – the infrastructure system, the management system, and the protection system.[42] Electronic power conditioning and control of the production and distribution of electricity are important aspects of the smart grid.[43] The smart grid represents the full suite of current and proposed responses to the challenges of electricity supply. Numerous contributions to the overall improvement of energy infrastructure efficiency are anticipated from the deployment of smart grid technology, in particular including demand-side management. The improved flexibility of the smart grid permits greater penetration of highly variable renewable energy sources such as solar power and wind power, even without the addition of energy storage. Smart grids could also monitor/ control residential devices that are noncritical during periods of peak power consumption, and return their function during nonpeak hours.[44] A smart grid includes a variety of operation and energy measures: Advanced metering infrastructure (of which smart meters are a generic name for any utility side device even if it is more capable e.g. a fiber optic router) Smart distribution boards and circuit breakers integrated with home control and demand response (behind the meter from a utility perspective) oLoad control switches and smart appliances, often financed by efficiency gains on municipal programs (e.g. PACE financing) Renewable energy resources, including the capacity to charge parked (electric vehicle) batteries or larger arrays of batteries recycled from these, or other energy storage. Energy efficient resources Electric surplus distribution by power lines and auto-smart switch Sufficient utility grade fiber broadband to connect and monitor the above, with wireless as a backup. Sufficient spare if "dark" capacity to ensure failover, often leased for revenue.[45][46] Concerns with smart grid technology mostly focus on smart meters, items enabled by them, and general security issues. Roll-out of smart grid technology also implies a fundamental re-engineering of the electricity services industry, although typical usage of the term is focused on the technical infrastructure.[47] Smart grid policy is organized in Europe as Smart Grid European Technology Platform.[48] Policy in the United States is described in Title 42 of the United States Code.[49] Grid defection Resistance to distributed generation among grid operators may encourage providers to leave the grid and instead distribute power to smaller geographies.[50][51][52] The Rocky Mountain Institute[53] and other studies[54] foresee widescale grid defection. However, grid defection may be less likely in places such as Germany that have greater power demands in the winter.[55] History Early electric energy was produced near the device or service requiring that energy. In the 1880s, electricity competed with steam, hydraulics, and especially coal gas. Coal gas was first produced on customer's premises but later evolved into gasification plants that enjoyed economies of scale. In the industrialized world, cities had networks of piped gas, used for lighting. But gas lamps produced poor light, wasted heat, made rooms hot and smoky, and gave off hydrogen and carbon monoxide. They also posed a fire hazard. In the 1880s electric lighting soon became advantageous compared to gas lighting. Electric utility companies established central stations to take advantage of economies of scale and moved to centralized power generation, distribution, and system management.[56] After the war of the currents was settled in favor of AC power, with long-distance power transmission it became possible to interconnect stations to balance the loads and improve load factors. Historically, transmission and distribution lines were owned by the same company, but starting in the 1990s, many countries have liberalized the regulation of the electricity market in ways that have led to the separation of the electricity transmission business from the distribution business.[57] In the United Kingdom, Charles Merz, of the Merz & McLellan consulting partnership, built the Neptune Bank Power Station near Newcastle upon Tyne in 1901,[58] and by 1912 had developed into the largest integrated power system in Europe.[59] Merz was appointed head of a parliamentary committee and his findings led to the Williamson Report of 1918, which in turn created the Electricity (Supply) Act 1919. The bill was the first step towards an integrated electricity system. In 1925 the Weir Committee recommended the creation of a "national gridiron" and so the Electricity (Supply) Act 1926 created the Central Electricity Board (CEB).[60] The CEB standardized the nation's electricity supply and established the first synchronized AC grid, running at 132 kilovolts and 50 hertz but initially operated as regional grids. After brief overnight interconnection in 1937 they permanently and officially joined in 1938 becoming the UK National Grid. In France, electrification began in the 1900s, with 700 communes in 1919, and 36,528 in 1938. At the same time, these close networks began to interconnect: Paris in 1907 at 12 kV, the Pyrénées in 1923 at 150 kV, and finally almost all of the country interconnected by 1938 at 220 kV. In 1946, the grid was the world's most dense. That year the state nationalised the industry, by uniting the private companies as Électricité de France. The frequency was standardised at 50 Hz, and the 225 kV network replaced 110 kV and 120 kV. Since 1956, service voltage has been standardised at 220/380 V, replacing the previous 127/220 V. During the 1970s, the 400 kV network, the new European standard, was implemented. Starting on May 29, 1986, the end user service voltage will progressively change to 230/400 V +/-10%.[61][62] In the United States in the 1920s, utilities formed joint-operations to share peak load coverage and backup power. In 1934, with the passage of the Public Utility Holding Company Act (USA), electric utilities were recognized as public goods of importance and were given outlined restrictions and regulatory oversight of their operations. The Energy Policy Act of 1992 required transmission line owners to allow electric generation companies open access to their network[56][63] and led to a restructuring of how the electric industry operated in an effort to create competition in power generation. No longer were electric utilities built as vertical monopolies, where generation, transmission and distribution were handled by a single company. Now, the three stages could be split among various companies, in an effort to provide fair access to high voltage transmission.[20][21] The Energy Policy Act of 2005 allowed incentives and loan guarantees for alternative energy production and advance innovative technologies that avoided greenhouse emissions. In China, electrification began in the 1950s.[64] In August 1961, the electrification of the Baoji-Fengzhou section of the Baocheng Railway was completed and delivered for operation, becoming China's first electrified railway.[65] From 1958 to 1998, China's electrified railway reached 6,200 miles (10,000 kilometres).[66] As of the end of 2017, this number has reached 54,000 miles (87,000 kilometres).[67] In the current railway electrification system of China, State Grid Corporation of China—Archived 2021-12-21 at the Wayback Machine—is an important power supplier. In 2019, it completed the power supply project of China's important electrified railways in its operating areas, such as Jingtong Railway, Haoji Railway, Zhengzhou–Wanzhou high-speed railway, et cetera, providing power supply guarantee for 110 traction stations, and its cumulative power line construction length reached 6,586 kilometres.[68] Contents (Top) Background References National Energy Regulator of South Africa Article Talk Read Edit View history Tools Appearance Text Small Standard Large Width Standard Wide Color (beta) Automatic Light Dark From Wikipedia, the free encyclopedia National Energy Regulator of South Africa Agency overview Formed 2005; 20 years ago Jurisdiction South Africa Headquarters Kulawula House, 526 Madiba Street, Arcadia, Pretoria Agency executives Thembani Bukula, Chairperson Nomalanga Sithole, CEO Website https://www.nersa.org.za/ National Energy Regulator of South Africa (NERSA), is the regulatory authority for the electricity supply industry in South Africa.[1] Background National Energy Regulator of South Africa was established to regulate the energy industry in South Africa and to follow government standards, laws, policies and international best practices in support of sustainable development.[2][3][4] It was established by the section 3 of the National Energy Regulator Act, 2004 (Act No. 40 of 2004). NERSA's mandate is to regulate the electricity, piped-gas and petroleum pipelines industries in terms of the 2001 Gas Act, Petroleum Pipelines act of 2003 and the Electricity Regulation Act..[5][6] In November 2020, NERSA announced it was approving the procurement of 2,500 megawatts of nuclear power by the Department of Mineral Resources and Energy skom Article Talk Read Edit View history Tools Appearance Text Small Standard Large Width Standard Wide Color (beta) Automatic Light Dark From Wikipedia, the free encyclopedia Not to be confused with other similarly-named but unrelated businesses known as Escom. Eskom Company type Public utility Traded as JSE: BIESKM Industry Energy Founded 1 March 1923; 101 years ago Headquarters Sunninghill, Sandton, South Africa Key people Mteto Nyati (Chairman) Dan Marokane (Group Chief Executive) Calib Cassim (Chief Financial Officer) Services Electricity generation, transmission and distribution Revenue R 204.3 billion (FY2021)[1] US$ 13.82 billion Net income R-18.9 billion (FY2021)[1] US$ -1.28 billion Total assets R 781 billion (FY2021)[1] US$52.84 billion Number of employees 42,749 (FY2021)[1] Subsidiaries List ASN 37121 Website www.eskom.co.za Eskom Hld SOC Ltd or Eskom is a South African electricity public utility. Eskom was established in 1923 as the Electricity Supply Commission (ESCOM) (Afrikaans: Elektrisiteitsvoorsieningskommissie (EVKOM)). Eskom represents South Africa in the Southern African Power Pool. The utility is the largest producer of electricity in Africa,[2][3] and was among the top utilities in the world in terms of generation capacity and sales. It is the largest of South Africa's state owned enterprises. Eskom operates a number of notable power stations, including Matimba Power Station and Medupi Power Station in Lephalale, Kusile Power Station in Witbank, Kendal Power Station, and Koeberg Nuclear Power Station in the Western Cape Province, the only nuclear power plant in Africa. The company is divided into Generation, Transmission and Distribution divisions, and together Eskom generates approximately 95% of electricity used in South Africa, amounting to ~45% used in Africa,[4] and emits 42% of South Africa's total greenhouse gas emissions.[5][6][7][8] By releasing 1.6 million tons of sulphur dioxide into the air in 2019, Eskom is also the largest emitter of sulphur dioxide in the power industry in the world.[9] Eskom has periodically implemented rolling blackouts since January 2008, a practice ascribed to basic dereliction of duty by former president Thabo Mbeki.[10] Implementation of new generating capacity during this period was fraught with delays and cost overruns which brought the utility to the brink of bankruptcy.[11] In 2019, it was announced that Eskom was to be split up into three distinct nationally owned entities due to huge debts and poor reliability of supply.[12] At the 2021 United Nations Climate Change Conference, a deal was announced for developed countries to fund South Africa's transition from coal power to renewable energy. However, employment in the mining sector threatens this transition.[13] History The Congella Power Station completed in 1928 was one of the first power plants built and owned by Eskom. Prior to the establishment of Eskom, the provision of electricity was dominated by municipalities and private companies. The city of Kimberley was one of the first users of public electricity when it installed electric streetlights in 1882 to reduce crime at night.[14]: 5 [15] This was followed by Cape Town in 1895 with the construction of the Graaff Electric Lighting Works to power 775 street lights. Eskom was founded by the Electricity Act of 1922 which allowed the South African Electricity Control Board to appoint Hendrik Johannes van der Bijl as chairman.[16] The company changed its name by combining the two acronyms in its previous name (ESCOM and ESKOM) in 1987 to become known as Eskom. The Electricity Act stated that Eskom could only sell electricity at cost and was exempted from tax with the firm initially raising capital through the issuing of debentures, later issuing state-guaranteed loans instead. The coal-fired Congella Power Station in Durban and Salt River Power Station in Cape Town were the first power stations built by Eskom, both completed in mid-1928.[17] One of Eskom's first power plants was a coal-fired 128 MW station in Witbank, completed in 1935 to provide power to the mining industry. The plant was built and run in partnership with the privately owned Victoria Falls and Transvaal Power Company, which owned a number of other power plants across the country. Thanks to state support, Eskom was able to buy out the Victoria Falls and Transvaal Power Company in 1948 for £14.5 million (roughly equivalent to £2.55 billion in 2017). Following World War 2, South Africa experienced power shortages that led to Eskom negotiating power saving agreements with the mining industry in June 1948.[14]: 6 First expansion period: 1960-1994 Arnot Power Station completed in 1975 was one of the first of the "six-pack" coal-fired power plants built during this period that Eskom was well known for. From 1960 to 1990 Eskom increased its installed power production capacity from 4,000 MW to 40,000 MW so as to keep up with rapid economic growth in the 1960s and 70s.[14]: 4 During the same period, Eskom established a nationwide 400 kV power network. During this period the company built a number of large standardised coal-fired power plants that could produce power at very low cost due to the large economies of scale. These plants were known colloquially as "six-packs" for the 6 large generator units they were designed to accommodate.[14]: 7 In 1974 the company was instructed to start work on Koeberg nuclear power station to both provide power to Cape Town and help facilitate the South African government's nuclear program.[14]: 7 In 1981 Eskom was involved in one of its first large financial scandals when its Assistant Chief Accountant was caught embezzling R8 million from the company[14]: 7 (equivalent to roughly R164.37 million in 2018).[18] During the 1970s the company controversially sought to increase electrical tariffs to help pay for its large expansion plans. Due to its financial situation, the government appointed Dr. W.J. de Villiers to chair a commission that recommended a number of financial and organisational changes for the company to adopt. This led to the company abandoning its no-profit objective and to raise funds by taking out international loans. The number of Eskom employees was also reduced from 66,000 to 60,000 in the late-1980s.[14]: 8 Post-1994 election period: 1994-2007 Following democratic elections in 1994 and the start of the Mandela government the company changed focus to electrification of previously neglected residential homes and to provide low cost electricity for economic growth. Following the passing of the 1998 Eskom Amendment Act government's powers to influence company policy and investment decisions were greatly expanded.[14]: 8–9 Due to the South African government's attempted privatisation of Eskom in the late 1990s during the administration of President Thabo Mbeki, Eskom requests for budget to build new stations were denied. After leaving the presidency, Mbeki would later state in December 2007 that this was an error, resulting in adverse affects for the South African economy.[19] Construction work on the Medupi (pictured) and Kusile coal-fired power stations was started in the 2007-2019 period as part of Eskom's capacity expansion program following the energy crisis. Load shedding and second expansion: 2007-present See also: South African energy crisis In February 2006, Eskom announced "load shedding" in the Western Cape province, due to issues experienced by Koeberg Nuclear Power Plant[20] this continued until June 2006. In January 2008, Eskom controversially introduced load shedding nationally (rolling blackouts) based on a rotating schedule, in periods where short supply threatened the integrity of the grid. Demand-side management has focused on encouraging consumers to conserve power during peak periods in order to reduce the incidence of load shedding. Following the national power shortage in 2007, Eskom embarked on an aggressive electricity production expansion programme during the administration of President Jacob Zuma. The Zuma administration decided to focus expansion efforts on building additional large scale six-pack coal-fired power plants.[21] In 2016, Eskom stated it intended to pursue a nuclear solution to the country's energy shortage. According to projections from late 2016, the use of nuclear power would provide over 1000GW of power by 2050. In preparation, the company launched a training program for 100 technicians, engineers and artisans that would certify them as nuclear operators.[22] In January 2018, Eskom's acting chief financial officer stated that the company could not afford a new build, following a 34% drop in interim profits due to declining sales and increasing financing costs. The government stated it would proceed with the plan but more slowly.[23] In 2017, Eskom was the focus of a major corruption scandal involving the Gupta family and the administration of then President Jacob Zuma. The National Energy Regulator of South Africa denied an application by Eskom to increase electricity tariffs by a future 19.9% for the financial year 2018/19. The regulator instead granted a 5.2% increase and gave a list of reasons for the refusal to grant higher tariffs that the South African newspaper Business Day stated painted "a picture of inefficiency, inaccurate forecasting and cost overruns" at the power utility. Part of the refusal was the finding that Eskom had 6,000 more employees than needed, costing the company R3.8 billion annually.[24] In February 2019, shortly after the announcement by government that the company would be broken up, Eskom initiated another round of emergency load shedding. Eskom stated that the 2019 load shedding was initiated due to breakdowns at power stations as well as the depletion of water and diesel resources. Other reasons cited included legacy issues from state capture corruption, coal availability, and that new power plants such as Medupi and Kusile were not yet operational.[25][26] Corruption during the Zuma administration had been noted as a major factor in the cost overruns and long delays in completing Medupi and Kusile power plants that had a knock-on effect leading to the 2019 power shortages.[26] The power shortage and related troubles at Eskom was blamed as a significant contributing factor to a 3.2% decline in GDP growth in the first quarter of 2019,[27] prompting fears of a recession in 2019.[28] In December 2019, President Ramaphosa, deputy president David Mabuza and Ministers Gwede Mantashe and Pravin Gordhan met with Eskom's board and management to discuss about the energy crises.[29] The president attributed the recent blackouts partly to sabotage at the Tutuka Power Station in Mpumalanga which had caused a loss of 2000 megawatts of electricity,[30] and announced measures to bring an end to load-shedding. Mantashe and Gordhan were tasked with presenting ways to increase electricity capacity to the cabinet, which would include self-generation.[31] Amid the crisis, Jabu Mabuza resigned from his post as chairperson of Eskom's board in January 2020.[32] Between March and July 2020 the power supply was stable due to reduced demand during the COVID-19 lockdown,[33] but on 12 July a new round of level 2 load shedding began due to the breakdown of generating units.[34] During the winter of 2023, the country experienced Stage 6 blackouts, shaving a projected 2% off the country's GDP.[35] During the worst period, power cuts lasted 12 hours a day.[36] The company faces theft of materials for resale, sabotage to force repairs to be made at corruptly inflated prices, and assassination attempts which may be motivated by the attempt to replace coal with renewable sources.[37] Logos Eskom's logo has been an integral symbol of the company since its founding. For a brief period in 1986 Eskom had no logo when it was moving away from the company's original logo of stylised letters spelling "ESC" within a circle to the more contemporary version with a blue shield with a stylised lightning bolt in its centre. The 1987 logo was replaced in 2002 with its current logo that replaced the shield with a circle but otherwise kept the logo as it was. 1923 1987 2002

Restructuring efforts Eskom's sales have been declining by about 1% per annum. The less it sells, the higher the tariff it wants, and the less it sells – the utility death spiral. Rod Crompton, Adjunct professor African Energy Leadership Centre Wits Business School, University of the Witwatersrand[38] In December 1998, a white paper prepared by the Department of Minerals and Energy recommended that the government restructure Eskom into separate generation and transmission businesses. Although the report predicted that this action would improve power supply and reliability, it was never enacted.[39] In February 2019, these plans were resurrected during the State of the Nation address. President Ramaphosa announced that the government would be splitting Eskom up into three new state-owned entities focusing on generation, transmission and distribution.[12] This was done so as to better manage the serious operational and financial problems facing the company. By the time of the speech Eskom had a total debt burden of R419 billion[12] (US$30.8 billion) and was entering a death spiral whereby there was not enough revenue to make debt repayments.[38] In a February 2019 briefing, the Department of Public Enterprises stated that Eskom was "technically insolvent" and would not be able to operate past the next three months if it did not receive additional loans.[40] Finance Minister Tito Mboweni then announced in his 2019 budget speech that government would be providing a R69 billion rand (US$5 billion) bail-out to Eskom over a three-year period so as to stabilise the company's serious financial situation.[41] Transmission Main article: National Transmission Company of South Africa As result of the restructuring, a transmission entity called the National Transmission Company of South Africa (NTCSA), a wholly-owned subsidiary of Eskom, would be given its own board, by 31 March 2020 in which the transmission legal entity would be responsible for hearing legislative amendments in accordance to government law. This new transmission entity would involve up to 6,000 people that are responsible of setting up thousands of kilometres of "wires" and transmission lines that would ensure electricity from the power stations to where power is needed.[42] As part of the Transmission Development Plan (TDP) for 2020–2029 Eskom has plans to increase its transmission infrastructure by approximately 4,800 km of extra high voltage transmission lines, and over 35,000 MVA of transformer capacity over the next 10 years. This new outline of reconstructing Eskom comes from new regulatory guidelines from the National Energy Regulator of South Africa (NERSA) to publish an annual TDP report. [citation needed] In July 2023, NERSA approved for the National Transmission Company of South Africa to operate a transmission system in South Africa.[43] In September 2023, NERSA approved the remaining trading and import/export licences.[44] COSATU response In response to feared job losses resulting from the breakup the trade union COSATU organised a national strike and called for a moratorium on retrenchments in the private and public sectors.[45][46][47] This caused to the apparent abandonment of the government's company breakup and restructuring plans.[46][48] In July 2019 the outgoing Eskom CEO announced that Eskom had entered a "death spiral" and highlighted the need for the company to restructure.[48][49] Following the appointment of André de Ruyter as Eskom CEO trade unions National Union of Mineworkers and Solidarity stated that they would fight any government restructuring efforts that might result in job losses.[50] In December 2019 COSATU suggested that money be used from the Public Investment Corporation (PIC) to reduce Eskom's debt from around R450 billion to more manageable levels.[51] In return COSTATU proposed a number of conditions that included keeping workers employed.[52] The trade union Solidarity was strongly apposed to the COSATU proposal arguing that it put the pensions of public employees at risk.[53] The country's second biggest trade union, the Federation of Unions of South Africa, was also skeptical of COSATU's proposed plan.[54] Job losses Between 2020 and 2021, two thousand employees lost their jobs at the power utility. 6000 more jobs are reportedly at risk in order for the company to continue operating.[55] Installed capacity Main article: List of power stations in South Africa Subscribers Eskom – the only electricity utility in the country – has 16,789,974 subscribers in South Africa, comprising about one-third of the population. Fossil-fuelled power stations Power plant Province Type Date commissioned (planned) Capacity (MW) (planned) Status Notes Acacia Power Station Western Cape Gas turbine 1976 171 Operational [56] [permanent dead link] Ankerlig Power Station Western Cape Gas turbine 2007 1,338 Operational [57] Arnot Power Station Mpumalanga Coal-fired 1971-1975 2,352 Operational [58][59] Camden Power Station Mpumalanga Coal-fired 1967-1969; 2005-2008 1,561 Operational [59][60] Duvha Power Station Mpumalanga Coal-fired 1980-1984 3,600 Operational [59][61][62] Gourikwa Power Station Western Cape Gas turbine 2007 746 Operational [57] Grootvlei Power Station Mpumalanga Coal-fired 1969-1977; 2008-2011 1,180 Operational [59][63] Hendrina Power Station Mpumalanga Coal-fired 1970-1976 1,893 Operational [59][64] Kendal Power Station Mpumalanga Coal-fired 1988-1992 4,116 Operational [59][65][66] Komati Power Station Mpumalanga Coal-fired 1961-1966; 2009-2013 990 Operational [59][67] Kriel Power Station Mpumalanga Coal-fired 1976-1979 3,000 Operational [59][68][69] Kusile Power Station Mpumalanga Coal-fired (2017–

2025) 3,200 (4,800) 4/6 units operational [70][71][72][73][74] Lethabo Power Station Free State Coal-fired 1985-1990 3,708 Operational [59][75] Majuba Power Station Mpumalanga Coal-fired 1996–2001 4,110 Operational [59][76][77][unreliable source?] Matimba Power Station Limpopo Coal-fired 1987-1991 3,990 Operational [59][78] Matla Power Station Mpumalanga Coal-fired 1979-1983 3,600 Operational [59][79] Medupi Power Station Limpopo Coal-fired 2015–2019 4,764 Operational [72][80][81][73][74] Port Rex Power Station Eastern Cape Gas turbine 1976 171 Operational [56] Tutuka Power Station Mpumalanga Coal-fired 1985-1990 3,654 Operational [59][82] Renewable and nuclear power stations Eskom Generation's pilot wind farm facility at Klipheuwel in the Western Cape, South Africa. Power plant Province Type Date commissioned Installed capacity (MW) Status Notes Colley Wobbles Power Station Eastern Cape Hydroelectric 1984 42 Operational Drakensberg Pumped Storage Scheme Free State Hydroelectric 1981 1,000 Operational [83] Gariep Dam Free State-Eastern Cape border Hydroelectric 1971 360 Operational [84] Ingula Pumped Storage Scheme KwaZulu-Natal Hydroelectric 2017 1,332 Operational [73][85] Koeberg Power Station Western Cape Nuclear 1984 1,860 Operational [86][87] Ncora Dam Eastern Cape Hydroelectric 1972 2.1 Operational [88] Palmiet Pumped Storage Scheme Western Cape Hydroelectric 1988 400 Operational [89][90] Sere Wind Farm Western Cape Wind Jan 2015 100 Operational [91][92][93][94] Vanderkloof Dam Northern Cape Hydroelectric 1977 240 Operational Future projects Eskom has a number of planned infrastructure projects to further expand electrical production. Tubatse Pumped Storage Scheme – 1500MWe Wind 500 – 550MWe Tasakoolo Wind farm 200 – 200Mwe Investment in renewables As of October 2019 Eskom Holdings SOC Ltd issued a tender to introduce 20 three-phase KW inverters and mountains structures. These structures are planned to distribute power to four power plants, and would introduce Eskom into the solar energy market. The African Investment Forum has announced that it has raised over $40.1 billion in investment into developing new infrastructure, related to renewable energies.[95] This is aimed to help distance itself from Eskom coal power plants, and to focus more on wind and solar developments. The African investment forum is backed up by corporate organizations and lenders, private donors, and the African Development Bank.[96] These new inverters would be align with South Africa's Integrated Resource Plan (IRP).[citation needed] South Africa's integrated resource plan The IRP supports a diverse energy mix with policy aimed to help aim to meet the need of South Africa's energy goals. The Integrated Resource Plan supports electrical infrastructure developments with an aim focused on renewable energy sources.[97] These new investments are directed towards more high efficiency, low emission standards with an emphasis on solar technologies in which 6,000 MW of new Solar PV capabilities and 14,400 MW of new wind power technologies.[98] With renewable energies, the IRP plans to increase its investment in hydro-electric power.[99] Investment in renewables, hydro, wind, solar With failing power plants and coal not working as a viable solution, progress towards a greener future is in sight for South Africa. In agreement to the Paris Agreement, South Africa needs to reduce its carbon emission and cut-back from being dependent on Coal. There is new US$11 Billion Green-Energy Initiative aimed at the development of solar and wind. This new initiative would allow loans to Eskom and below commercial rates on conditions that it would accelerate its closure of power plants and to start building renewable energy structures.[100] This plan takes the steps in moving away from coal, and investing in alternative methods that better suit their needs for the future.[citation needed] Other infrastructure In 2002, Eskom was issued a network operator licence. It embarked on a $100 million project installing fibre optic cables on 10 000 kilometres of its existing power lines for the purpose of real-time monitoring of the electrical network; 80% consists of all-dielectric lashed cabling and 10% All-dielectric self-supporting cabling. It currently has the sixth most ASN prefixes of all registered network operator licensees.[101] Corporate affairs Eskom executives including Phakamani Hadebe (CEO), front row second from the left, and Jan Oberholzer (CTO), front row far left, at a 2019 public forum in Cape Town on Eskom's financial situation. In 2011 eight out of ten Eskom board members were controversially sacked by the Zuma administration.[21] From 2015 to 2017 the Zuma administration appointed Ben Ngubane as chairperson of the board. Brian Molefe was appointed by Zuma as Eskom CEO from April 2015 to November 2016. Molefe[102] and Ngubane's[103] tenure was controversial for their involvement with the Gupta family and for allegedly allowing the company to become a vehicle for state capture.[104][105][106][107] Ngubane also controversially attempted to blacklist newspapers perceived as unfriendly to Eskom.[103] During parliament's state capture inquiry in 2017 former Eskom chairperson Zola Tsotsi (2012–2015) testified that Gupta family member Tony Gupta made threats against Tsotsi allegedly stating that Tsotsi will lose his job as he was not 'helping' the Guptas.[108] In December 2016, Matshela Koko, former head of generation for Eskom, was named as acting CEO.[109] He resigned in 2018 after being implicated in awarding contracts to a company linked to his stepdaughter.[110] Koko, along with his wife and stepdaughter, were arrested in

October 2022.[111] In early 2018, following the establishment of the Ramaphosa government, multiple members of the Eskom board and executive team were replaced by government due to allegations of corruption and mismanagement.[112] Phakamani Hadebe was made acting CEO and director of Eskom in May 2018 as part of President Ramaphosa's replacement of the company's executive team.[113] A year into his term as CEO Hadebe resigned citing poor health and the difficult circumstances of the job.[114] His resignation sparked a debate amongst political parties over the difficult state of managing the financially strained state owned company[115] as well as the lack of political cover he was given to deal with labour unions and tackle corruption.[116] Six months after Hadebe's departure, former Nampak Chief Executive[117] André de Ruyter was appointed CEO of Eskom.[118][119] De Ruyter's appointment was criticised by the EFF[120] and factions within the ANC who instead wanted a black CEO appointed to the position.[121] De Ruyter resigned in December 2022 after repeated attacks on him by Gwede Mantashe, Minister of Mineral Resources and Energy[122][123][124] partly due to de Ruyter's advocacy for replacing coal with renewables as an energy source.[125] News24 reported that he was not given the support needed to succeed in the position.[126] Shortly after the announcement that de Ruyter would be leaving Eskom it was reported that he survived a poisoning attempt after he unknowingly drank a cup of coffee at his office that was laced with cyanide.[127] Financials 2011[128] 2012[129] 2013[129] 2014[130] 2015[130] 2016[131] 2017[131] 2018[132] 2019[133] 2020[1] 2021[1] Revenue (R billion) 91.45 114.8 128.9 138.3 147.7 164.2 177.1 177.4 179.8 199.5 204.3 Operating profit (R billion) 14.5 22.3 3.99 13.2 11.1 15.7 15.5 20.5 −1.77 4.41 6.68 Net income (R billion) 8.36 13.2 5.18 7.09 3.62 5.15 0.88 −2.33 −20.7 −20.8 −18.9 Total debt (R billion) 160.3 182.6 202.9 254.8 297.4 322.7 355.3 388.7 440.6 483.7 401.8 Employee benefit expenses (R billion) 16.7 20.2 23.6 25.6 25.9 29.2 33.1 29.4 33.3 33.2 32.9 Number of employees 41,778 43,473 46,266 46,919 46,490 47,978 47,658 48,628 46,665 44,772 42,749 Electrical output capacity (GWh) 237,430 237,414 232,228 231,129 226,300 238,599 220,166 221,936 218,939 214,968 201,400 In 2018 and 2019 Eskom's negative financial situation became serious as costs started exceeding income and the company started experiencing trouble raising money. For 72 hours between 26 March and 29 March 2019 it was reported that Eskom had run out of funds thereby threatening to negatively impact the broader South African economy. The situation was alleviated once Eskom secured a R3 billion commercial loan which was paid back on 2 April after the Reserve Bank disbursed R5 billion to Eskom through an emergency provision.[134] In July 2019 Eskom announced a loss of R20.7 billion due to the cost of servicing high levels of debt, the increased cost of primary energy and unpaid municipal debts.[135] Debt In late 2016, Standard & Poor's Global Ratings downgraded Eskom's credit rating further into subinvestment grade cutting its long-term credit rating to BB – two levels below the investment threshold.[136] By 2017 increasing levels of debt and corruption scandals affecting the company has led investment bank Goldman Sachs to declare Eskom as being the "biggest risk to South Africa’s economy." The company had R413 billion in debt and planned to raise an additional R340 billion (US$26 billion) by 2022 thereby representing eight percent of South Africa's GDP. R218.2 billion of the company's debt consist of government guarantees.[137] Exacerbating the company's financial situation was a recorded R3 billion worth of irregular expenditures in 2017.[115] On 28 March 2018 Moody's Investors Service downgraded Eskom's credit rating to B2 from B1 stating that it was concerned with "the lack of any tangible financial support for the company in the February state budget".[138] On 24 November 2020, Moody's further downgraded Eskom's long-term credit rating to Caa1.[139] This places Eskom's credit within the "speculative grade" of investment, with a "very high credit risk". Due to the company's large size and important role as the region's primary energy producer President Ramaphosa stated that Eskom was "too big to fail" as the reason why government had to continue to fund it despite its serious financial situation.[140] In February 2023, with debt sitting at R423 billion, the South African government announced that, subject to approval from existing debt holders, it would be providing support worth R254 billion, including interest payments for the following three years and three capital payments of R78-billion in 2023/24, R66 billion in 2024/25 and R40-billion in 2025/26, with the intention to reduce Eskom's overall debt to R300 billion.[141] Chinese debt In July 2018 it was announced that Eskom had taken out a R33 billion loan from the Chinese government owned China Development Bank.[142] The loan conditions were controversially[143] not made public with accusations that it was an example of debt-trap diplomacy by China.[144] During the Zondo Commission of Inquiry into state corruption a senior Eskom executive stated that an additional R25 billion loan from the China-based company Huarong Energy Africa was improperly and controversially taken out by Eskom.[145] After the loan had been issued Eskom chairperson Jabu Mabuza stated to the Zondo Commission that Eskom would not be repaying the Huarong loan due to irregularities and corruption involved in the issuing of the loan.[146] Controversies Municipal debts A number of South African municipalities are in significant arrears in paying Eskom for electricity supplied to them. The large amount owed to Eskom has caused significant controversy given the state utilities financial difficulties and repeated periods of load-shedding.[147] By January 2020 South African municipalities owed Eskom a total of roughly R43 billion[148] (equivalent to US$2.88 billion). This had increased to R49.1 billion by July 2022.[149] Soweto The single largest South African municipality to owe Eskom for unpaid electricity is the City of Johannesburg Metropolitan Municipality in which Soweto owes R13 billion[150] to R16.4 billion[148] in 2019. In response, Eskom initiated a process of cutting off electricity to debtors in the city, which resulted in violent public protests.[151][152] The city has a history of non-payment dating back to the 1980s when non-payment was used as a form of non-violent protest against apartheid era policies.[153] This is thought to have cultivated a culture of non-payment.[150] Zimbabwe Power Exports 300MW of power are exported to Zimbabwe in a deal valued at US$2 million a month. At the end of November 2019 it was revealed that Zimbabwe owed $22 million in debt to Eskom (about 11 months in areas). Despite statements that Eskom continues to supply Zimbabwe during scheduled blackouts,[154] electricity is only supplied if Eskom does not need it.[155][156] Power shortage: 2007 - ongoing See also: South African energy crisis An election poster referring to the Eskom energy crisis in the run up to the 2019 general election. In the later months of 2007, South Africa started experiencing widespread rolling blackouts as supply fell behind demand, threatening to destabilise the national grid. With a reserve margin estimated at 8% or below,[157] such "load shedding" is implemented whenever generating units are taken offline for maintenance, repairs or re-fuelling (in the case of nuclear units). From February 2008 to November 2014 blackouts were temporarily halted due to reduced demand and maintenance stabilization.[158] This drop in demand was caused by many of the country's mines shutting down or slowing to help alleviate the burden. Load shedding was reintroduced in early November 2014. The Majuba power plant lost its capacity to generate power after a collapse of one of its coal storage silos on 1 November 2014. The Majuba power plant delivered approximately 10% of the country's entire capacity and the collapse halted the delivery of coal to the plant.[159] A second silo developed a major crack on 20 November causing the shut down of the plant again, this after temporary measures were instituted to deliver coal to the plant.[160] In 2016, Eskom said that unplanned outages had been reduced. In May 2016, former president Jacob Zuma said assurances had been given to him by Eskom management.[161] In June 2018, there was Stage 1 load shedding along with a strike over wages.[161] In February 2019, a new round of load shedding began due to the failure of coal burning boilers at some power stations due to poor quality coal. This resulted in long running periods of level 4 load shedding across the country in mid-March 2019, including night-time load shedding[162] and promised to report back.[161] The situation at Eskom and resulting energy crisis became a political issue during the 2019 South African general elections.[163][164][165] Sabotage In December 2019, load shedding reached a new high as Eskom introduced stage 6 load shedding for the first time.[166] Cyril Ramaphosa faced criticism as his departure for Egypt was announced shortly after the move to stage 6.[167] He returned early to address the problem, meeting on 11 December with the Eskom board. Ramaphosa then announced that there had been an element of sabotage involved, leading to the loss of 2000MW capacity. Ramaphosa faced criticism on social media, with many blaming incompetence rather than sabotage.[168] On 19 November 2021, Eskom announced that an initial forensic investigation found evidence that recent damage to a coal conveyor at Lethabo was the result of deliberate sabotage. Steel supports had been severed, causing a power supply pylon to collapse.[169][170] In a media briefing, de Ruyter commented that the matter had been referred to the Hawks for further investigation.[171] In May 2022 the Minister for Public Enterprises, Pravin Gordhan, reported to Parliament that additional incidents of cables being cut intentionally by saboteurs, rising theft at its power plants, and corruption around the supply of fuel oil, had greatly worsened the energy crisis and Eskom's ability to resolve it.[172] Corruption 2017 corruption scandal See also: Gupta family Eskom was forced to suspend its chief financial officer Anoj Singh in July 2017 when the Development Bank of South Africa threatened to recall a R15 billion loan if no action was taken against Eskom officials (including Singh) who were involved in corruption allegations involving the Gupta family.[115] In September 2017, Minister for Public Enterprises, Lynne Brown, instructed Eskom to take legal action against firms and individuals involved; ranging from Gupta family-owned consultancy firm Trillian Capital Partners Ltd. and consultancy firm McKinsey to Anoj Singh and acting chief executive Matshela Koko. A report compiled by Eskom and G9 Forensic found that the two consulting firms including Gupta owned Trillian made R1.6 billion (US$120 million) in fees with an additional R7.8 billion made from future contracts.[173] An investigation done by the amaBhungane Centre for Investigative Journalism found that the Gupta family had received contracts worth R11.7 billion from Eskom to supply coal between 2014 and 2017. With pressure for Eskom to sign the first coal supply contracts with Gupta-owned entities being applied on the state-owned firm by then President Jacob Zuma.[174] In 2019 South

African Special Investigating Unit launched an investigation into corruption related to the construction of the Medupi and Kusile power stations as a cause of repeated construction delays and project cost increases;[175] this led to the investigation of 11 contractors for allegedly stealing R139 billion (US$9.13 billion) from the projects.[175][176] In 2019, two senior Eskom managers and two business people were charged with fraud and corruption related to the construction of the Kusile power station.[177] In January 2020 South African Minister for Public Enterprises, Pravin Gordhan, stated that cost overruns and corruption during the construction of Medupi and Kusile power stations was an important reason for the dramatic increase in Eskom electricity prices.[178] 2019 Deloitte consulting lawsuit In October 2019, Eskom's chairman Jabu Mabuza filed a court affidavit at the Johannesburg High Court to recover R207 million in consulting fees from the consulting firm Deloitte. The affidavit alleged that Eskom executives had improperly awarded two consulting contracts to the consulting firm Deloitte. According to Eskom, in one contract awarded to Deloitte, Deloitte proposed a fee of R88.8-million while the competing bids from other firms were for R14.6-million and R13.3-million. In the other contract, Deloitte's bid was R79.1-million, while the other bids were for R16-million and R9.1-million.[179] In March 2020, Deloitte agreed to pay back R150 million of the R207 million sought by Eskom. However, in a joint statement, it denied being part of any corruption, and that they acknowledged that there were technical irregularities in the process of awarding the contracts.[180] In April 2020, Deloitte told AmaBhungane that the managing director for Deloitte Africa's advisory division Thiru Pillay and the lead consultant on the Eskom contract Shamal Sivasanker had resigned effective 31 March 2020 for their roles in the Eskom event.[181] In November 2021, Eskom announced that it had appointed Deloitte as its next external auditor, as its contract with Grant Thornton was expiring at the end of that month.[182] power transmission is the bulk movement of electrical energy from a generating site, such as a power plant, to an electrical substation. The interconnected lines that facilitate this movement form a transmission network. This is distinct from the local wiring between high-voltage substations and customers, which is typically referred to as electric power distribution. The combined transmission and distribution network is part of electricity delivery, known as the electrical grid. Efficient long-distance transmission of electric power requires high voltages. This reduces the losses produced by strong currents. Transmission lines use either alternating current (AC) or direct current (DC). The voltage level is changed with transformers. The voltage is stepped up for transmission, then reduced for local distribution. A wide area synchronous grid, known as an interconnection in North America, directly connects generators delivering AC power with the same relative frequency to many consumers. North America has four major interconnections: Western, Eastern, Quebec and Texas. One grid connects most of continental Europe. Historically, transmission and distribution lines were often owned by the same company, but starting in the 1990s, many countries liberalized the regulation of the electricity market in ways that led to separate companies handling transmission and distribution.[2] System A diagram of an electric power system. The transmission system is in blue. Most North American transmission lines are high-voltage three-phase AC, although single phase AC is sometimes used in railway electrification systems. DC technology is used for greater efficiency over longer distances, typically hundreds of miles. High-voltage direct current (HVDC) technology is also used in submarine power cables (typically longer than 30 miles (50 km)), and in the interchange of power between grids that are not mutually synchronized. HVDC links stabilize power distribution networks where sudden new loads, or blackouts, in one part of a network might otherwise result in synchronization problems and cascading failures. Electricity is transmitted at high voltages to reduce the energy loss due to resistance that occurs over long distances. Power is usually transmitted through overhead power lines. Underground power transmission has a significantly higher installation cost and greater operational limitations, but lowers maintenance costs. Underground transmission is more common in urban areas or environmentally sensitive locations. Electrical energy must typically be generated at the same rate at which it is consumed. A sophisticated control system is required to ensure that power generation closely matches demand. If demand exceeds supply, the imbalance can cause generation plant(s) and transmission equipment to automatically disconnect or shut down to prevent damage. In the worst case, this may lead to a cascading series of shutdowns and a major regional blackout. The US Northeast faced blackouts in 1965, 1977, 2003, and major blackouts in other US regions in 1996 and 2011. Electric transmission networks are interconnected into regional, national, and even continent-wide networks to reduce the risk of such a failure by providing multiple redundant, alternative routes for power to flow should such shutdowns occur. Transmission companies determine the maximum reliable capacity of each line (ordinarily less than its physical or thermal limit) to ensure that spare capacity is available in the event of a failure in another part of the network. Overhead Main article: Overhead power line A four-circuit, two-voltage power transmission line; Bundled 2-ways A typical ACSR. The conductor consists of seven strands of steel surrounded by four layers of aluminium. This section does not cite any sources. Please help improve this section by adding citations to reliable sources. Unsourced material may be challenged and removed. (November 2022) (Learn how and when to remove this message) High-voltage overhead conductors are not covered by insulation. The conductor material is nearly always an aluminium alloy, formed of several strands and possibly reinforced with steel strands. Copper was sometimes used for overhead transmission, but aluminum is lighter, reduces yields only marginally and costs much less. Overhead conductors are supplied by several companies. Conductor material and shapes are regularly improved to increase capacity. Conductor sizes range from 12 mm2 (#6 American wire gauge) to 1,092 mm2 (2,156,000 circular mils area), with varying resistance and current-carrying capacity. For large conductors (more than a few centimetres in diameter), much of the current flow is concentrated near the surface due to the skin effect. The center of the conductor carries little current but contributes weight and cost. Thus, multiple parallel cables (called bundle conductors) are used for higher capacity. Bundle conductors are used at high voltages to reduce energy loss caused by corona discharge. Today, transmission-level voltages are usually considered to be 110 kV and above. Lower voltages, such as 66 kV and 33 kV, are usually considered subtransmission voltages, but are occasionally used on long lines with light loads. Voltages less than 33 kV are usually used for distribution. Voltages above 765 kV are considered extra high voltage and require different designs. Overhead transmission wires depend on air for insulation, requiring that lines maintain minimum clearances. Adverse weather conditions, such as high winds and low temperatures, interrupt transmission. Wind speeds as low as 23 knots (43 km/h) can permit conductors to encroach operating clearances, resulting in a flashover and loss of supply.[3] Oscillatory motion of the physical line is termed conductor gallop or flutter depending on the frequency and amplitude of oscillation. A five-hundred kilovolt (500 kV) three-phase transmission tower in Washington State, the line is bundled 3-ways Three abreast electrical pylons in Webster, Texas Underground Main article: Undergrounding Electric power can be transmitted by underground power cables. Underground cables take up no right-of-way, have lower visibility, and are less affected by weather. However, cables must be insulated. Cable and excavation costs are much higher than overhead construction. Faults in buried transmission lines take longer to locate and repair. In some metropolitan areas, cables are enclosed by metal pipe and insulated with dielectric fluid (usually an oil) that is either static or circulated via pumps. If an electric fault damages the pipe and leaks dielectric, liquid nitrogen is used to freeze portions of the pipe to enable draining and repair. This extends the repair period and increases costs. The temperature of the pipe and surroundings are monitored throughout the repair period.[4][5][6] Underground lines are limited by their thermal capacity, which permits less overload or re-rating lines. Long underground AC cables have significant capacitance, which reduces their ability to provide useful power beyond 50 miles (80 kilometres). DC cables are not limited in length by their capacitance. History Main article: History of electric power transmission New York City streets in 1890. Besides telegraph lines, multiple electric lines were required for each class of device requiring different voltages. Commercial electric power was initially transmitted at the same voltage used by lighting and mechanical loads. This restricted the distance between generating plant and loads. In 1882, DC voltage could not easily be increased for long-distance transmission. Different classes of loads (for example, lighting, fixed motors, and traction/railway systems) required different voltages, and so used different generators and circuits.[7][8] Thus, generators were sited near their loads, a practice that later became known as distributed generation using large numbers of small generators.[9] Transmission of alternating current (AC) became possible after Lucien Gaulard and John Dixon Gibbs built what they called the secondary generator, an early transformer provided with 1:1 turn ratio and open magnetic circuit, in 1881. The first long distance AC line was 34 kilometres (21 miles) long, built for the 1884 International Exhibition of Electricity in Turin, Italy. It was powered by a 2 kV, 130 Hz Siemens & Halske alternator and featured several Gaulard transformers with primary windings connected in series, which fed incandescent lamps. The system proved the feasibility of AC electric power transmission over long distances.[8] The first commercial AC distribution system entered service in 1885 in via dei Cerchi, Rome, Italy, for public lighting. It was powered by two Siemens & Halske alternators rated 30 hp (22 kW), 2 kV at 120 Hz and used 19 km of cables and 200 parallel-connected 2 kV to 20 V step-down transformers provided with a closed magnetic circuit, one for each lamp. A few months later it was followed by the first British AC system, serving Grosvenor Gallery. It also featured Siemens alternators and 2.4 kV to 100 V step-down transformers – one per user – with shunt-connected primaries.[10] Working to improve what he considered an impractical Gaulard-Gibbs design, electrical engineer William Stanley, Jr. developed the first practical series AC transformer in 1885.[11] Working with the support of George Westinghouse, in 1886 he demonstrated a transformer-based AC lighting system in Great Barrington, Massachusetts. It was powered by a steam engine-driven 500 V Siemens generator. Voltage was stepped down to 100 volts using the Stanley transformer to power incandescent lamps at 23 businesses over 4,000 feet (1,200 m).[12] This practical demonstration of a transformer and alternating current lighting system led Westinghouse to begin installing AC systems later that year.[11] In 1888 the first designs for an AC motor appeared. These were induction motors running on polyphase current, independently invented by Galileo Ferraris and Nikola Tesla. Westinghouse licensed Tesla's design. Practical three-phase motors were designed by Mikhail Dolivo-Dobrovolsky and Charles Eugene Lancelot Brown.[13] Widespread use of such motors were delayed many years by development problems and the scarcity of polyphase power systems needed to power them.[14][15] Westinghouse alternating current polyphase generators on display at the 1893 World's Fair in Chicago, part of their Tesla Poly-phase System. Such polyphase innovations revolutionized transmission. In the late 1880s and early 1890s smaller electric companies merged into larger corporations such as Ganz and AEG in Europe and General Electric and Westinghouse Electric in the US. These companies developed AC systems, but the technical difference between direct and alternating current systems required a much longer technical merger.[16] Alternating current's economies of scale with large generating plants and long-distance transmission slowly added the ability to link all the loads. These included single phase AC systems, poly-phase AC systems, low voltage incandescent lighting, high-voltage arc lighting, and existing DC motors in factories and street cars. In what became a universal system, these technological differences were temporarily bridged via the rotary converters and motor-generators that allowed the legacy systems to connect to the AC grid.[16][17] These stopgaps were slowly replaced as older systems were retired or upgraded. The first transmission of single-phase alternating current using high voltage came in Oregon in 1890 when power was delivered from a hydroelectric plant at Willamette Falls to the city of Portland 14 miles (23 km) down river.[18] The first three-phase alternating current using high voltage took place in 1891 during the international electricity exhibition in Frankfurt. A 15 kV transmission line, approximately 175 km long, connected Lauffen on the Neckar and Frankfurt.[10][19] Transmission voltages increased throughout the 20th century. By 1914, fifty-five transmission systems operating at more than 70 kV were in service. The highest voltage then used was 150 kV.[20] Interconnecting multiple generating plants over a wide area reduced costs. The most efficient plants could be used to supply varying loads during the day. Reliability was improved and capital costs were reduced, because stand-by generating capacity could be shared over many more customers and a wider area. Remote and low-cost sources of energy, such as hydroelectric power or mine-mouth coal, could be exploited to further lower costs.[7][10] The 20th century's rapid industrialization made electrical transmission lines and grids critical infrastructure. Interconnection of local generation plants and small distribution networks was spurred by World War I, when large electrical generating plants were built by governments to power munitions factories.[21] Bulk transmission A transmission substation decreases the voltage of incoming electricity, allowing it to connect from long-distance high-voltage transmission, to local lower voltage distribution. It also reroutes power to other transmission lines that serve local markets. This is the PacifiCorp Hale Substation, Orem, Utah, US. These networks use components such as power lines, cables, circuit breakers, switches and transformers. The transmission network is usually administered on a regional basis by an entity such as a regional transmission organization or transmission system operator.[22] Transmission efficiency is improved at higher voltage and lower current. The reduced current reduces heating losses. Joule's first law states that energy losses are proportional to the square of the current. Thus, reducing the current by a factor of two lowers the energy lost to conductor resistance by a factor of four for any given size of conductor. The optimum size of a conductor for a given voltage and current can be estimated by Kelvin's law for conductor size, which states that size is optimal when the annual cost of energy wasted in resistance is equal to the annual capital charges of providing the conductor. At times of lower interest rates and low commodity costs, Kelvin's law indicates that thicker wires are optimal. Otherwise, thinner conductors are indicated. Since power lines are designed for long-term use, Kelvin's law is used in conjunction with long-term estimates of the price of copper and aluminum as well as interest rates. Higher voltage is achieved in AC circuits by using a step-up transformer. High-voltage direct current (HVDC) systems require relatively costly conversion equipment that may be economically justified for particular projects such as submarine cables and longer distance high capacity point-to-point transmission. HVDC is necessary for sending energy between unsynchronized grids. A transmission grid is a network of power stations, transmission lines, and substations. Energy is usually transmitted within a grid with three-phase AC. Single-phase AC is used only for distribution to end users since it is not usable for large polyphase induction motors. In the 19th century, two-phase transmission was used but required either four wires or three wires with unequal currents. Higher order phase systems require more than three wires, but deliver little or no benefit. The synchronous grids of

Europe While the price of generating capacity is high, energy demand is variable, making it often cheaper to import needed power than to generate it locally. Because loads often rise and fall together across large areas, power often comes from distant sources. Because of the economic benefits of load sharing, wide area transmission grids may span countries and even continents. Interconnections between producers and consumers enables power to flow even if some links are inoperative. The slowly varying portion of demand is known as the base load and is generally served by large facilities with constant operating costs, termed firm power. Such facilities are nuclear, coal or hydroelectric, while other energy sources such as concentrated solar thermal and geothermal power have the potential to provide firm power. Renewable energy sources, such as solar photovoltaics, wind, wave, and tidal, are, due to their intermittency, not considered to be firm. The remaining or peak power demand, is supplied by peaking power plants, which are typically smaller, faster-responding, and higher cost sources, such as combined cycle or combustion turbine plants typically fueled by natural gas. Long-distance transmission (hundreds of kilometers) is cheap and efficient, with costs of US$0.005–0.02 per kWh, compared to annual averaged large producer costs of US$0.01–0.025 per kWh, retail rates upwards of US$0.10 per kWh, and multiples of retail for instantaneous suppliers at unpredicted high demand moments.[23] New York often buys over 1000 MW of low-cost hydropower from Canada.[24] Local sources (even if more expensive and infrequently used) can protect the power supply from weather and other disasters that can disconnect distant suppliers. A high-power electrical transmission tower, 230 kV, double-circuit, also double-bundled Hydro and wind sources cannot be moved closer to big cities, and solar costs are lowest in remote areas where local power needs are nominal. Connection costs can determine whether any particular renewable alternative is economically realistic. Costs can be prohibitive for transmission lines, but high capacity, long distance super grid transmission network costs could be recovered with modest usage fees. Grid input This section does not cite any sources. Please help improve this section by adding citations to reliable sources. Unsourced material may be challenged and removed. (November 2022) (Learn how and when to remove this message) At power stations, power is produced at a relatively low voltage between about 2.3 kV and 30 kV, depending on the size of the unit. The voltage is then stepped up by the power station transformer to a higher voltage (115 kV to 765 kV AC) for transmission. In the United States, power transmission is, variously, 230 kV to 500 kV, with less than 230 kV or more than 500 kV as exceptions. The Western Interconnection has two primary interchange voltages: 500 kV AC at 60 Hz, and ±500 kV (1,000 kV net) DC from North to South (Columbia River to Southern California) and Northeast to Southwest (Utah to Southern California). The 287.5 kV (Hoover Dam to Los Angeles line, via Victorville) and 345 kV (Arizona Public Service (APS) line) are local standards, both of which were implemented before 500 kV became practical. Losses Transmitting electricity at high voltage reduces the fraction of energy lost to Joule heating, which varies by conductor type, the current, and the transmission distance. For example, a 100 miles (160 km) span at 765 kV carrying 1000 MW of power can have losses of 0.5% to 1.1%. A 345 kV line carrying the same load across the same distance has losses of 4.2%.[25] For a given amount of power, a higher voltage reduces the current and thus the resistive losses. For example, raising the voltage by a factor of 10 reduces the current by a corresponding factor of 10 and therefore the losses by a factor of 100, provided the same sized conductors are used in both cases. Even if the conductor size (cross-sectional area) is decreased ten-fold to match the lower current, the losses are still reduced ten-fold using the higher voltage. While power loss can also be reduced by increasing the wire's conductance (by increasing its cross-sectional area), larger conductors are heavier and more expensive. And since conductance is proportional to cross-sectional area, resistive power loss is only reduced proportionally with increasing cross-sectional area, providing a much smaller benefit than the squared reduction provided by multiplying the voltage. Long-distance transmission is typically done with overhead lines at voltages of 115 to 1,200 kV. At higher voltages, where more than 2,000 kV exists between conductor and ground, corona discharge losses are so large that they can offset the lower resistive losses in the line conductors. Measures to reduce corona losses include larger conductor diameter, hollow cores[26] or conductor bundles. Factors that affect resistance and thus loss include temperature, spiraling, and the skin effect. Resistance increases with temperature. Spiraling, which refers to the way stranded conductors spiral about the center, also contributes to increases in conductor resistance. The skin effect causes the effective resistance to increase at higher AC frequencies. Corona and resistive losses can be estimated using a mathematical model.[27] US transmission and distribution losses were estimated at 6.6% in 1997,[28] 6.5% in 2007[28] and 5% from 2013 to 2019.[29] In general, losses are estimated from the discrepancy between power produced (as reported by power plants) and power sold; the difference constitutes transmission and distribution losses, assuming no utility theft occurs. As of 1980, the longest cost-effective distance for DC transmission was

7,000 kilometres (4,300 miles). For AC it was 4,000 kilometres (2,500 miles), though US transmission lines are substantially shorter.[23] In any AC line, conductor inductance and capacitance can be significant. Currents that flow solely in reaction to these properties, (which together with the resistance define the impedance) constitute reactive power flow, which transmits no power to the load. These reactive currents, however, cause extra heating losses. The ratio of real power transmitted to the load to apparent power (the product of a circuit's voltage and current, without reference to phase angle) is the power factor. As reactive current increases, reactive power increases and power factor decreases. For transmission systems with low power factor, losses are higher than for systems with high power factor. Utilities add capacitor banks, reactors and other components (such as phase-shifters; static VAR compensators; and flexible AC transmission systems, FACTS) throughout the system help to compensate for the reactive power flow, reduce the losses in power transmission and stabilize system voltages. These measures are collectively called 'reactive support'. Transposition This section does not cite any sources. Please help improve this section by adding citations to reliable sources. Unsourced material may be challenged and removed. (November 2022) (Learn how and when to remove this message) Current flowing through transmission lines induces a magnetic field that surrounds the lines of each phase and affects the inductance of the surrounding conductors of other phases. The conductors' mutual inductance is partially dependent on the physical orientation of the lines with respect to each other. Three-phase lines are conventionally strung with phases separated vertically. The mutual inductance seen by a conductor of the phase in the middle of the other two phases is different from the inductance seen on the top/bottom. Unbalanced inductance among the three conductors is problematic because it may force the middle line to carry a disproportionate amount of the total power transmitted. Similarly, an unbalanced load may occur if one line is consistently closest to the ground and operates at a lower impedance. Because of this phenomenon, conductors must be periodically transposed along the line so that each phase sees equal time in each relative position to balance out the mutual inductance seen by all three phases. To accomplish this, line position is swapped at specially designed transposition towers at regular intervals along the line using various transposition schemes. Subtransmission A 115 kV subtransmission line in the Philippines, along with 20 kV distribution lines and a street light, all mounted on a wood subtransmission pole 115 kV H-frame transmission tower This section does not cite any sources. Please help improve this section by adding citations to reliable sources. Unsourced material may be challenged and removed. (November 2022) (Learn how and when to remove this message) Subtransmission runs at relatively lower voltages. It is uneconomical to connect all distribution substations to the high main transmission voltage, because that equipment is larger and more expensive. Typically, only larger substations connect with this high voltage. Voltage is stepped down before the current is sent to smaller substations. Subtransmission circuits are usually arranged in loops so that a single line failure does not stop service to many customers for more than a short time. Loops can be normally closed, where loss of one circuit should result in no interruption, or normally open where substations can switch to a backup supply. While subtransmission circuits are usually carried on overhead lines, in urban areas buried cable may be used. The lower-voltage subtransmission lines use less right-of-way and simpler structures; undergrounding is less difficult. No fixed cutoff separates subtransmission and transmission, or subtransmission and distribution. Their voltage ranges overlap. Voltages of 69 kV, 115 kV, and 138 kV are often used for subtransmission in North America. As power systems evolved, voltages formerly used for transmission were used for subtransmission, and subtransmission voltages became distribution voltages. Like transmission, subtransmission moves relatively large amounts of power, and like distribution, subtransmission covers an area instead of just point-to-point.[30] Transmission grid exit Substation transformers reduce the voltage to a lower level for distribution to customers. This distribution is accomplished with a combination of sub-transmission (33 to 138 kV) and distribution (3.3 to 25 kV). Finally, at the point of use, the energy is transformed to end-user voltage (100 to 4160 volts). Advantage of high-voltage transmission See also: Ideal transformer This section does not cite any sources. Please help improve this section by adding citations to reliable sources. Unsourced material may be challenged and removed. (November 2022) (Learn how and when to remove this message) High-voltage power transmission allows for lesser resistive losses over long distances. This efficiency delivers a larger proportion of the generated power to the loads. Electrical grid without a transformer Electrical grid with a transformer In a simplified model, the grid delivers electricity from an ideal voltage source with voltage , delivering a power) to a single point of consumption, modelled by a resistance , when the wires are long enough to have a significant resistance . If the resistances are in series with no intervening transformer, the circuit acts as a voltage divider, because the same current runs through the wire resistance and the powered device. As a consequence, the useful power (at the point of consumption) is: Should an ideal transformer convert high-voltage, low-current electricity into low-voltage, high-current electricity with a voltage ratio of (i.e., the voltage is divided by and the current is multiplied by in the secondary branch, compared to the primary branch), then the circuit is again equivalent to a voltage divider, but the wires now have apparent resistance of only . The useful power is then: For (i.e. conversion of high voltage to low voltage near the consumption point), a larger fraction of the generator's power is transmitted to the consumption point and a lesser fraction is lost to Joule heating. Modeling Main article: Performance and modelling of AC transmission This section does not cite any sources. Please help improve this section by adding citations to reliable sources. Unsourced material may be challenged and removed. (November 2022) (Learn how and when to remove this message) "Black box" model for transmission line The terminal characteristics of the transmission line are the voltage and current at the sending (S) and receiving (R) ends. The transmission line can be modeled as a black box and a 2 by 2 transmission matrix is used to model its behavior, as follows: The line is assumed to be a reciprocal, symmetrical network, meaning that the receiving and sending labels can be switched with no consequence. The transmission matrix T has the properties: The parameters A, B, C, and D differ depending on how the desired model handles the line's resistance (R), inductance (L), capacitance (C), and shunt (parallel, leak) conductance G. The four main models are the short line approximation, the medium line approximation, the long line approximation (with distributed parameters), and the lossless line. In such models, a capital letter such as R refers to the total quantity summed over the line and a lowercase letter such as c refers to the per-unit-length quantity. Lossless line The lossless line approximation is the least accurate; it is typically used on short lines where the inductance is much greater than the resistance. For this approximation, the voltage and current are identical at the sending and receiving ends. Voltage on sending and receiving ends for lossless line The characteristic impedance is pure real, which means resistive for that impedance, and it is often called surge impedance. When a lossless line is terminated by surge impedance, the voltage does not drop. Though the phase angles of voltage and current are rotated, the magnitudes of voltage and current remain constant along the line. For load > SIL, the voltage drops from sending end and the line consumes VARs. For load < SIL, the voltage increases from the sending end, and the line generates VARs. Short line The short line approximation is normally used for lines shorter than 80 km (50 mi). There, only a series impedance Z is considered, while C and G are ignored. The final result is that A = D = 1 per unit, B = Z Ohms, and C = 0. The associated transition matrix for this approximation is therefore: Medium line The medium line approximation is used for lines running between 80 and 250 km (50 and 155 mi). The series impedance and the shunt (current leak) conductance are considered, placing half of the shunt conductance at each end of the line. This circuit is often referred to as a nominal π (pi) circuit because of the shape (π) that is taken on when leak conductance is placed on both sides of the circuit diagram. The analysis of the medium line produces: Counterintuitive behaviors of medium-length transmission lines: voltage rise at no load or small current (Ferranti effect) receiving-end current can exceed sending-end current Long line The long line model is used when a higher degree of accuracy is needed or when the line under consideration is more than 250 km (160 mi) long. Series resistance and shunt conductance are considered to be distributed parameters, such that each differential length of the line has a corresponding differential series impedance and shunt admittance. The following result can be applied at any point along the transmission line, where is the propagation constant. To find the voltage and current at the end of the long line, should be replaced with (the line length) in all parameters of the transmission matrix. This model applies the Telegrapher's equations. High-voltage direct current Main article: High-voltage direct current High-voltage direct current (HVDC) is used to transmit large amounts of power over long distances or for interconnections between asynchronous grids. When electrical energy is transmitted over very long distances, the power lost in AC transmission becomes appreciable and it is less expensive to use direct current instead. For a long transmission line, these lower losses (and reduced construction cost of a DC line) can offset the cost of the required converter stations at each end. HVDC is used for long submarine cables where AC cannot be used because of cable capacitance.[31] In these cases special high-voltage cables are used. Submarine HVDC systems are often used to interconnect the electricity grids of islands, for example, between Great Britain and continental Europe, between Great Britain and Ireland, between Tasmania and the Australian mainland, between the North and South Islands of New Zealand, between New Jersey and New York City, and between New Jersey and Long Island. Submarine connections up to 600 kilometres (370 mi) in length have been deployed.[32] HVDC links can be used to control grid problems. The power transmitted by an AC line increases as the phase angle between source end voltage and destination ends increases, but too large a phase angle allows the systems at either end to fall out of step. Since the power flow in a DC link is controlled independently of the phases of the AC networks that it connects, this phase angle limit does not exist, and a DC link is always able to transfer its full rated power. A DC link therefore stabilizes the AC grid at either end, since power flow and phase angle can then be controlled independently. As an example, to adjust the flow of AC power on a hypothetical line between Seattle and Boston would require adjustment of the relative phase of the two regional electrical grids. This is an everyday occurrence in AC systems, but one that can become disrupted when AC system components fail and place unexpected loads on the grid. With an HVDC line instead, such an interconnection would: Convert AC in Seattle into HVDC; Use HVDC for the 3,000 miles (4,800 km) of cross-country transmission; and Convert the HVDC to locally synchronized AC in Boston, (and possibly in other cooperating cities along the transmission route). Such a system could be less prone to failure if parts of it were suddenly shut down. One example of a long DC transmission line is the Pacific DC Intertie located in the Western United States. Capacity This section does not cite any sources. Please help improve this section by adding citations to reliable sources. Unsourced material may be challenged and removed. (November 2022) (Learn how and when to remove this message) The amount of power that can be sent over a transmission line varies with the length of the line. The heating of short line conductors due to line losses sets a thermal limit. If too much current is drawn, conductors may sag too close to the ground, or conductors and equipment may overheat. For intermediate-length lines on the order of 100 kilometres (62 miles), the limit is set by the voltage drop in the line. For longer AC lines, system stability becomes the limiting factor. Approximately, the power flowing over an AC line is proportional to the cosine of the phase angle of the voltage and current at the ends. This angle varies depending on system loading. It is undesirable for the angle to approach 90 degrees, as the power flowing decreases while resistive losses remain. The product of line length and maximum load is approximately proportional to the square of the system voltage. Series capacitors or phase-shifting transformers are used on long lines to improve stability. HVDC lines are restricted only by thermal and voltage drop limits, since the phase angle is not material. Understanding the temperature distribution along the cable route became possible with the introduction of distributed temperature sensing (DTS) systems that measure temperatures all along the cable. Without them maximum current was typically set as a compromise between understanding of operation conditions and risk minimization. This monitoring solution uses passive optical fibers as temperature sensors, either inside a high-voltage cable or externally mounted on the cable insulation. For overhead cables the fiber is integrated into the core of a phase wire. The integrated Dynamic Cable Rating (DCR)/Real Time Thermal Rating (RTTR) solution makes it possible to run the network to its maximum. It allows the operator to predict the behavior of the transmission system to reflect major changes to its initial operating conditions. Reconductoring Some utilities have embraced reconductoring to handle the increase in electricity production. Reconductoring is the replacement-in-place of existing transmission lines with higher-capacity lines. Adding transmission lines is difficult due to cost, permit intervals, and local opposition. Reconductoring has the potential to double the amount of electricity that can travel across a transmission line.[33] A 2024 report found the United States behind countries like Belgium and the Netherlands in adoption of this technique to accommodate electrification and renewable energy. [34] In April 2022, the Biden Administration streamlined environmental reviews for such projects, and in May 2022 announced competitive grants for them funded by the 2021 Bipartisan Infrastructure Law and 2022 Inflation Reduction Act.[35] The rate of transmission expansion needs to double to support ongoing electrification and reach emission reduction targets. As of 2022, more than 10,000 power plant and energy storage projects were awaiting permission to connect to the US grid — 95% were zero-carbon resources. New power lines can take 10 years to plan, permit, and build.[33] Traditional power lines use a steel core surrounded by aluminum strands (Aluminium-conductor steel-reinforced cable). Replacing the steel with a lighter, stronger composite material such as carbon fiber (ACCC conductor) allows lines to operate at higher temperatures, with less sag, and doubled transmission capacity. Lowering line sag at high temperatures can prevent wildfires from starting when power lines touch dry vegetation.[34] Although advanced lines can cost 2-4x more than steel, total reconductoring costs are less than half of a new line, given savings in time, land acquisition, permitting, and construction.[33] A reconductoring project in southeastern Texas upgraded 240 miles of transmission lines at a cost of $900,000 per mile, versus a 3,600-mile greenfield project that averaged $1.9 million per mile.[33] Control This section does not cite any sources. Please help improve this section by adding citations to reliable sources. Unsourced material may be challenged and removed. (November 2022) (Learn how and when to remove this message) To ensure safe and predictable operation, system components are controlled with generators, switches, circuit breakers and loads. The voltage, power, frequency, load factor, and reliability capabilities of the transmission system are designed to provide cost effective performance. Load balancing The transmission system provides for base load and peak load capability, with margins for safety and fault tolerance. Peak load times vary by region largely due to the industry mix. In hot and cold climates home air conditioning and heating loads affect the overall load. They are typically highest in the late afternoon in the hottest part of the year and in mid-mornings and mid-evenings in the coldest part of the year. Power requirements vary by season and time of day. Distribution system designs always take the base load and the peak load into consideration. The transmission system usually does not have a large buffering capability to match loads with generation. Thus generation has to be kept matched to the load, to prevent overloading generation equipment. Multiple sources and loads can be connected to the transmission system and they must be controlled to provide orderly transfer of power. In centralized power generation, only local control of generation is necessary. This involves synchronization of the generation units. In distributed power generation the generators are geographically distributed and the process to bring them online and offline must be carefully controlled. The load control signals can either be sent on separate lines or on the power lines themselves. Voltage and frequency can be used as signaling mechanisms to balance the loads. In voltage signaling, voltage is varied to increase generation. The power added by any system increases as the line voltage decreases. This arrangement is stable in principle. Voltage-based regulation is complex to use in mesh networks, since the individual components and setpoints would need to be reconfigured every time a new generator is added to the mesh. In frequency signaling, the generating units match the frequency of the power transmission system. In droop speed control, if the frequency decreases, the power is increased. (The drop in line frequency is an indication that the increased load is causing the generators to slow down.) Wind turbines, vehicle-to-grid, virtual power plants, and other locally distributed storage and generation systems can interact with the grid to improve system operation. Internationally[where?], a slow move from a centralized to decentralized power systems have taken place. The main draw of locally distributed generation systems is that they reduce transmission losses by leading to consumption of electricity closer to where it was produced.[36] Failure protection Under excess load conditions, the system can be designed to fail incrementally rather than all at once. Brownouts occur when power supplied drops below the demand. Blackouts occur when the grid fails completely. Rolling blackouts (also called load shedding) are intentionally engineered electrical power outages, used to distribute insufficient power to various loads in turn. Communications This section does not cite any sources. Please help improve this section by adding citations to reliable sources. Unsourced material may be challenged and removed. (November 2022) (Learn how and when to remove this message) Grid operators require reliable communications to manage the grid and associated generation and distribution facilities. Fault-sensing protective relays at each end of the line must communicate to monitor the flow of power so that faulted conductors or equipment can be quickly de-energized and the balance of the system restored. Protection of the transmission line from short circuits and other faults is usually so critical that common carrier telecommunications are insufficiently reliable, while in some remote areas no common carrier is available. Communication systems associated with a transmission project may use: Microwaves Power-line communication Optical fibers Rarely, and for short distances, pilot-wires are strung along the transmission line path. Leased circuits from common carriers are not preferred since availability is not under control of the operator. Transmission lines can be used to carry data: this is called power-line carrier, or power-line communication (PLC). PLC signals can be easily received with a radio in the long wave range. High-voltage pylons carrying additional optical fibre cable in Kenya Optical fibers can be included in the stranded conductors of a transmission line, in the overhead shield wires. These cables are known as optical ground wire (OPGW). Sometimes a standalone cable is used, all-dielectric self-supporting (ADSS) cable, attached to the transmission line cross arms. Some jurisdictions, such as Minnesota, prohibit energy transmission companies from selling surplus communication bandwidth or acting as a telecommunications common carrier. Where the regulatory structure permits, the utility can sell capacity in extra dark fibers to a common carrier. Market structure Main article: Electricity market Electricity transmission is generally considered to be a natural monopoly, but one that is not inherently linked to generation.[37][38][39] Many countries regulate transmission separately from generation. Spain was the first country to establish a regional transmission organization. In that country, transmission operations and electricity markets are separate. The transmission system operator is Red Eléctrica de España (REE) and the wholesale electricity market operator is Operador del Mercado Ibérico de Energía – Polo Español, S.A. (OMEL) OMEL Holding | Omel Holding. Spain's transmission system is interconnected with those of France, Portugal, and Morocco. The establishment of RTOs in the United States was spurred by the FERC's Order 888, Promoting Wholesale Competition Through Open Access Non-discriminatory Transmission Services by Public Utilities; Recovery of Stranded Costs by Public Utilities and Transmitting Utilities, issued in 1996.[40] In the United States and parts of Canada, electric transmission companies operate independently of generation companies, but in the Southern United States vertical integration is intact. In regions of separation, transmission owners and generation owners continue to interact with each other as market participants with voting rights within their RTO. RTOs in the United States are regulated by the Federal Energy Regulatory Commission. Merchant transmission projects in the United States include the Cross Sound Cable from Shoreham, New York to New Haven, Connecticut, Neptune RTS Transmission Line from Sayreville, New Jersey, to New Bridge, New York, and Path 15 in California. Additional projects are in development or have been proposed throughout the United States, including the Lake Erie Connector, an underwater transmission line proposed by ITC Holdings Corp., connecting Ontario to load serving entities in the PJM Interconnection region.[41] Australia has one unregulated or market interconnector – Basslink – between Tasmania and Victoria. Two DC links originally implemented as market interconnectors, Directlink and Murraylink, were converted to regulated interconnectors.[42] A major barrier to wider adoption of merchant transmission is the difficulty in identifying who benefits from the facility so that the beneficiaries pay the toll. Also, it is difficult for a merchant transmission line to compete when the alternative transmission lines are subsidized by utilities with a monopolized and regulated rate base.[43] In the United States, the FERC's Order 1000, issued in 2010, attempted to reduce barriers to third party investment and creation of merchant transmission lines where a public policy need is found.[44] Transmission costs The cost of high voltage transmission is comparatively low, compared to all other costs constituting consumer electricity bills. In the UK, transmission costs are about 0.2 p per kWh compared to a delivered domestic price of around 10 p per kWh.[45] The level of capital expenditure in the electric power T&D equipment market was estimated to be $128.9 bn in 2011.[46] Health concerns Main article: Electromagnetic radiation and health Mainstream scientific evidence suggests that low-power, low-frequency, electromagnetic radiation associated with household currents and high transmission power lines does not constitute a short- or long-term health hazard. Some studies failed to find any link between living near power lines and developing any sickness or diseases, such as cancer. A 1997 study reported no increased risk of cancer or illness from living near a transmission line.[47] Other studies, however, reported statistical correlations between various diseases and living or working near power lines. No adverse health effects have been substantiated for people not living close to power lines.[48] The New York State Public Service Commission conducted a study[49] to evaluate potential health effects of electric fields. The study measured the electric field strength at the edge of an existing right-of-way on a 765 kV transmission line. The field strength was 1.6 kV/m, and became the interim maximum strength standard for new transmission lines in New York State. The opinion also limited the voltage of new transmission lines built in New York to 345 kV. On September 11, 1990, after a similar study of magnetic field strengths, the NYSPSC issued their Interim Policy Statement on Magnetic Fields. This policy established a magnetic field standard of 200 mG at the edge of the right-of-way using the winter-normal conductor rating. As a comparison with everyday items, a hair dryer or electric blanket produces a 100 mG – 500 mG magnetic field.[50][51] Applications for a new transmission line typically include an analysis of electric and magnetic field levels at the edge of rights-of-way. Public utility commissions typically do not comment on health impacts. Biological effects have been established for acute high level exposure to magnetic fields above 100 µT (1 G) (1,000 mG). In a residential setting, one study reported "limited evidence of carcinogenicity in humans and less than sufficient evidence for carcinogenicity in experimental animals", in particular, childhood leukemia, associated with average exposure to residential power-frequency magnetic field above 0.3 µT (3 mG) to 0.4 µT (4 mG). These levels exceed average residential power-frequency magnetic fields in homes, which are about 0.07 µT (0.7 mG) in Europe and 0.11 µT (1.1 mG) in North America.[52][53] The Earth's natural geomagnetic field strength varies over the surface of the planet between 0.035 mT and 0.07 mT (35 µT – 70 µT or 350 mG – 700 mG) while the international standard for continuous exposure is set at 40 mT (400,000 mG or 400 G) for the general public.[52] Tree growth regulators and herbicides may be used in transmission line right of ways,[54] which may have health effects. Specialized transmission Grids for railways Main article: Traction power network In some countries where electric locomotives or electric multiple units run on low frequency AC power, separate single phase traction power networks are operated by the railways. Prime examples are countries such as Austria, Germany and Switzerland that utilize AC technology based on 16 2/3 Hz. Norway and Sweden also use this frequency but use conversion from the 50 Hz public supply; Sweden has a 16 2/3 Hz traction grid but only for part of the system. Superconducting cables High-temperature superconductors (HTS) promise to revolutionize power distribution by providing lossless transmission. The development of superconductors with transition temperatures higher than the boiling point of liquid nitrogen has made the concept of superconducting power lines commercially feasible, at least for high-load applications.[55] It has been estimated that waste would be halved using this method, since the necessary refrigeration equipment would consume about half the power saved by the elimination of resistive losses. Companies such as

Consolidated Edison and American Superconductor began commercial production of such systems in 2007.[56] Superconducting cables are particularly suited to high load density areas such as the business district of large cities, where purchase of an easement for cables is costly.[57] HTS transmission lines[58] Location Length (km) Voltage (kV) Capacity (GW) Date Carrollton, Georgia 2000 Albany, New York[59] 0.35 34.5 0.048 2006 Holbrook, Long Island[60] 0.6 138 0.574 2008 Tres Amigas 5 Proposed 2013 Manhattan: Project Hydra Proposed 2014 Essen, Germany[61][62] 1 10 0.04 2014 Single-wire earth return Main article: Single-wire earth return This section does not cite any sources. Please help improve this section by adding citations to reliable sources. Unsourced material may be challenged and removed. (November 2022) (Learn how and when to remove this message) Single-wire earth return (SWER) or single-wire ground return is a single-wire transmission line for supplying single-phase electrical power to remote areas at low cost. It is principally used for rural electrification, but also finds use for larger isolated loads such as water pumps. Single-wire earth return is also used for HVDC over submarine power cables. Wireless power transmission Main article: Wireless power transfer This section does not cite any sources. Please help improve this section by adding citations to reliable sources. Unsourced material may be challenged and removed. (November 2022) (Learn how and when to remove this message) Both Nikola Tesla and Hidetsugu Yagi attempted to devise systems for large scale wireless power transmission in the late 1800s and early 1900s, without commercial success. In November 2009, LaserMotive won the NASA 2009 Power Beaming Challenge by powering a cable climber 1 km vertically using a ground-based laser transmitter. The system produced up to 1 kW of power at the receiver end. In August 2010, NASA contracted with private companies to pursue the design of laser power beaming systems to power low earth orbit satellites and to launch rockets using laser power beams. Wireless power transmission has been studied for transmission of power from solar power satellites to the earth. A high power array of microwave or laser transmitters would beam power to a rectenna. Major engineering and economic challenges face any solar power satellite project. Security The examples and perspective in this article may not represent a worldwide view of the subject. You may improve this article, discuss the issue on the talk page, or create a new article, as appropriate. (March 2013) (Learn how and when to remove this message) The federal government of the United States stated that the American power grid was susceptible to cyber-warfare.[63][64] The United States Department of Homeland Security works with industry to identify vulnerabilities and to help industry enhance the security of control system networks.[65] In June 2019, Russia conceded that it was "possible" its electrical grid is under cyber-attack by the United States.[66] The New York Times reported that American hackers from the United States Cyber Command planted malware potentially capable of disrupting the Russian electrical grid.[67] Records Highest capacity system: 12 GW Zhundong–Wannan (准东-皖南)±1100 kV HVDC.[68][69] Highest transmission voltage (AC): oplanned: 1.20 MV (Ultra-High Voltage) on Wardha-Aurangabad line (India), planned to initially operate at 400 kV.[70] oworldwide: 1.15 MV (Ultra-High Voltage) on Ekibastuz-Kokshetau line (Kazakhstan) Largest double-circuit transmission, Kita-Iwaki Powerline (Japan). Highest towers: Yangtze River Crossing (China) (height: 345 m or 1,132 ft) Longest power line: Inga-Shaba (Democratic Republic of Congo) (length: 1,700 kilometres or 1,056 miles) Longest span of power line: 5,376 m (17,638 ft) at Ameralik Span (Greenland, Denmark) Longest submarine cables: oNorth Sea Link, (Norway/United Kingdom) – (length of submarine cable: 720 kilometres or 447 miles) oNorNed, North Sea (Norway/Netherlands) – (length of submarine cable: 580 kilometres or 360 miles) oBasslink, Bass Strait, (Australia) – (length of submarine cable: 290 kilometres or 180 miles, total length: 370.1 kilometres or 230 miles) oBaltic Cable, Baltic Sea (Germany/Sweden) – (length of submarine cable: 238 kilometres or 148 miles, HVDC length: 250 kilometres or 155 miles, total length: 262 kilometres or 163 miles) Longest underground cables: oMurraylink, Riverland/Sunraysia (Australia) – (length of underground cable: 170 kilometres or 106 miles) See also Energy portal Dynamic demand (electric power) Demand response List of energy storage power plants Traction power network Backfeeding Conductor marking lights Double-circuit transmission line Electromagnetic Transients Program (EMTP) Flexible AC transmission system (FACTS) Geomagnetically induced current, (GIC) Graphene-clad wire Grid-tied electrical system List of high-voltage underground and submarine cables Load profile National Grid (disambiguation) Power-line communications (PLC) Power system simulation Radio frequency power transmission Wheeling (electric power transmission) References encyclopedia An electrical grid may have many types of generators and loads; generators must be controlled to maintain stable operation of the system. In an electric power system, automatic generation control (AGC) is a system for adjusting the power output of multiple generators at different power plants, in response to changes in the load. Since a power grid requires that generation and load closely balance moment by moment, frequent adjustments to the output of generators are necessary. The balance can be judged by measuring the system frequency; if it is increasing, more power is being generated than used, which causes all the machines in the system to accelerate. If the system frequency is decreasing, more load is on the system than the instantaneous generation can provide, which causes all generators to slow down. History Before the use of automatic generation control, one generating unit in a system would be designated as the regulating unit and would be manually adjusted to control the balance between generation and load to maintain system frequency at the desired value. The remaining units would be controlled with speed droop to share the load in proportion to their ratings. With automatic systems, many units in a system can participate in regulation, reducing wear on a single unit's controls and improving overall system efficiency, stability, and economy. Where the grid has tie interconnections to adjacent control areas, automatic generation control helps maintain the power interchanges over the tie lines at the scheduled levels. With computer-based control systems and multiple inputs, an automatic generation control system can take into account such matters as the most economical units to adjust, the coordination of thermal, hydroelectric, and other generation types, and even constraints related to the stability of the system and capacity of interconnections to other power grids.[1] Types Turbine-governor control Turbine generators in a power system have stored kinetic energy due to their large rotating masses. All the kinetic energy stored in a power system in such rotating masses is a part of the grid inertia. When system load increases, grid inertia is initially used to supply the load. This, however, leads to a decrease in the stored kinetic energy of the turbine generators. Since the mechanical power of these turbines correlates with the delivered electrical power, the turbine generators have a decrease in angular velocity, which is directly proportional to a decrease in frequency in synchronous generators. Steady state frequency-power relation for a turbine governor The purpose of the turbine-governor control (TGC) is to maintain the desired system frequency by adjusting the mechanical power output of the turbine.[2] These controllers have become automated and at steady state, the frequency-power relation for turbine-governor control is, where, is the change in turbine mechanical power output is the change in a reference power setting is the regulation constant which quantifies the sensitivity of the generator to a change in frequency is the change in frequency. For steam turbines, steam turbine governing adjusts the mechanical output of the turbine by increasing or decreasing the amount of steam entering the turbine via a throttle valve. Load-frequency control Load-frequency control (LFC) is employed to allow an area to first meet its own load demands, then to assist in returning the steady-state frequency of the system, Δf, to zero.[3] Load-frequency control operates with a response time of a few seconds to keep system frequency stable. Economic dispatch The goal of economic dispatch is to minimize total operating costs in an area by determining how the real power output of each generating unit will meet a given load.[4] Generating units have different costs to produce a unit of electrical energy, and incur different costs for the losses in transmitting energy to the load. An economic dispatch algorithm will run every few minutes to select the combination of generating unit power setpoints that minimizes overall cost, subject to the constraints of transmission limitation or security of the system against failures.[5] Further constraints may be imposed by the water supply of hydroelectric generation, or by the availability of sun and wind power. "Grid storage" redirects here. For data storage with grid computing, see Grid-oriented storage. Energy from fossil or nuclear power plants and renewable sources is stored for use by customers. Diagram showing flow of energy between energy storage facilities and power grids, as a function of time over a 24 hour period Grid energy storage, also known as large-scale energy storage, are technologies connected to the electrical power grid that store energy for later use. These systems help balance supply and demand by storing excess electricity from variable renewables such as solar and inflexible sources like nuclear power, releasing it when needed. They further provide essential grid services, such as helping to restart the grid after a power outage. As of 2023, the largest form of grid storage is pumped-storage hydroelectricity, with utility-scale batteries and behind-the-meter batteries coming second and third.[1] Lithium-ion batteries are highly suited for shorter duration storage up to 8 hours. Flow batteries and compressed air energy storage may provide storage for medium duration. Two forms of storage are suited for long-duration storage: green hydrogen, produced via electrolysis and thermal energy storage.[2] Energy storage is one option to making grids more flexible. An other solution is the use of more dispatchable power plants that can change their output rapidly, for instance peaking power plants to fill in supply gaps. Demand response can shift load to other times and interconnections between regions can balance out fluctuations in renewables production.[3] The price of storage technologies typically goes down with experience. For instance, lithium-ion batteries have been getting some 20% cheaper for each doubling of worldwide capacity.[4] Systems with under 40% variable renewables need only short-term storage. At 80%, medium-duration storage becomes essential and beyond 90%, long-duration storage does too. The economics of long-duration storage is challenging, and alternative flexibility options like demand response may be more economic. Roles in the power grid Any electrical power grid must match electricity production to consumption, both of which vary significantly over time. Energy derived from solar and wind sources varies with the weather on time scales ranging from less than a second to weeks or longer. Nuclear power is less flexible than fossil fuels, meaning it cannot easily match the variations in demand. Thus, low-carbon electricity without storage presents special challenges to electric utilities.[5] Electricity storage is one of the three key ways to replace flexibility from fossil fuels in the grid. Other options are demand-side response, in which consumers change when they use electricity or how much they use. For instance, households may have cheaper night tariffs to encourage them to use electricity at night. Industry and commercial consumers can also change their demand to meet supply. Improved network interconnection smooths the variations of renewables production and demand. When there is little wind in one location, another might have a surplus of production. Expansion of transmission lines usually takes a long time.[6] Potential roles of energy storage in the grid[7][8] Consumption Network Generation Short-term flexibility Increased use rooftop solar, cost reductions from time-based rates Congestion relief Renewables integration (smoothing, arbitrage) Essential grid services Backup power during outages Frequency regulation Black start System reliability and planning Creation of mini-grids Savings in transmission and distribution network Meeting peak demand Energy storage has a large set of roles in the electricity grid and can therefore provide many different services. For instance, it can arbitrage by keeping it until the electricity price rises, it can help make the grid more stable, and help reduce investment into transmission infrastructure.[9] The type of service provided by storage depends on who manages the technology, whether the technology is based alongside generation of electricity, within the network, or at the side of consumption.[8] Providing short-term flexibility is a key role for energy storage. On the generation side, it can help with the integration of variable renewable energy, storing it when there is an oversupply of wind and solar and electricity prices are low. More generally, it can exploit the changes in prices of electricity over time in the wholesale market, charging when electricity is cheap and selling when it is expensive. It can further help with grid congestion (where there is insufficient capacity on transmission lines). Consumers can use storage to use more of their self-produced electricity (for instance from rooftop solar power).[8][7] Storage can also be used to provide essential grid services. On the generation side, storage can smooth out the variations in production, for instance for solar and wind. It can assist in a black start after a power outage. On the network side, these include frequency regulation (continuously) and frequency response (after unexpected changes in supply or demand). On the consumption side, storage can help to improve the quality of the delivered electricity in less stable grids.[8][10] Investment in storage may make some investments in the transmission and distribution network unnecessary, or may allow them to be scaled down. Additionally, storage can ensure there is sufficient capacity to meet peak demand within the electricity grid. Finally, in off-grid home systems or mini-grids, electricity storage can help provide energy access in areas that were previously not connected to the electricity grid.[8] Forms Energy from sunlight or other renewable energy is converted to potential energy for storage in devices such as electric batteries. The stored potential energy is later converted to electricity that is added to the power grid, even when the original energy source is not available. In daytime, different renewable sources provide different amounts of power to the grid. At night, energy is provided by batteries that were charged during the day when renewable energy exceeded customer demand. Electricity can be stored directly for a short time in capacitors, somewhat longer electrochemically in batteries, and much longer chemically (e.g. hydrogen), mechanically (e.g. pumped hydropower) or as heat.[11] The first pumped hydroelectricity was constructed at the end of the 19th century around the Alps in Italy, Austria, and Switzerland. The technique rapidly expanded during the 1960s to 1980s nuclear boom, due to nuclear power's inability to quickly adapt to changes in electricity demand. In the 21st century, interest in storage surged due to the rise of sustainable energy sources, which are often weather-dependent.[12] Commercial batteries have been available for over a century,[13] their widespread use in the power grid is more recent, with only 1 GW available in 2013.[14] Batteries Main article: Battery energy storage system A 900 watt direct current light plant using 16 separate lead acid battery cells (32 volts) from 1917.[15] Lithium-ion batteries Lithium-ion batteries are the most commonly used batteries for grid applications, as of 2024, following the application of batteries in electric vehicles (EVs). In comparison with EVs, grid batteries require less energy density, meaning that more emphasis can be put on costs, the ability to charge and discharge often and lifespan. This has led to a shift towards lithium iron phosphate batteries (LFP batteries), which are cheaper and last longer than traditional lithium-ion batteries.[16] Costs of batteries are declining rapidly; from 2010 to 2023 costs fell by 90%.[17] As of 2024, utility-scale systems account for two thirds of added capacity, and home applications (behind-the-meter) for one third.[18] Lithium-ion batteries are highly suited to short-duration storage (50%), the temperature ratio between the two must reach a factor of 5.[61] Thermal energy storage is also used in combination with concentrated solar power (CSP). In CSP, solar energy is first converted into heat, and then either directly converted into electricity or first stored. The energy is released when there is little or no sunshine.[62] This means that CSP can be used as a dispatchable (flexible) form of generation. The energy in a CSP system can for instance be stored in molten salts or in a solid medium such as sand.[63] Finally, heating and cooling systems in buildings can be controlled to store thermal energy in either the building's mass or dedicated thermal storage tanks. This thermal storage can provide load-shifting or even more complex ancillary services by increasing power consumption (charging the storage) during off-peak times and lowering power consumption (discharging the storage) during higher-priced peak times.[64] Economics Costs Experience curve of lithium-ion batteries: the price of batteries dropped by 97% in three decades.[65][66] The levelized cost of storing electricity (LCOS) is a measure of the lifetime costs of storing electricity per MWh of electricity discharged. It includes investment costs, but also operational costs and charging costs.[67] It depends highly on storage type and purpose; as subsecond-scale frequency regulation, minute/hour-scale peaker plants, or day/week-scale season storage.[68][69][70] For power applications (for instance around ancillary services or black starts), a similar metric is the annuitized capacity cost (ACC), which measures the lifetime costs per kW. ACC is lowest when there are few cycles (<300) and when the discharge is less than one hour. This is because the technology is reimbursed only when it provides spare capacity, not when it is discharged.[71] The cost of storage is coming down following technology-dependent experience curves, the price drop for each doubling in cumulative capacity (or experience). Lithium-ion battery prices fast: the price utitlities pay for them falls 19% with each doubling of capacity. Hydrogen production via electrolysis has a similar learning rate, but it is much more uncertain. Vanadium-flow batteries typically get 14% cheaper for each doubling of capacity. Pumped hydropower has not seen prices fall much with increased experience.[4] Market and system value There are four categories of services which provide economic value for storage: those related to power quality (such as frequency regulation), reliability (ensuring peak demand can be met), better use of assets in the system (e.g. avoiding transmission investments) and arbitrage (exploiting price differences over time). Before 2020, most value for storage was in providing power quality services. Arbitrage is the service with the largest economic potential for storage applications.[72] Storage requirements based on the share of variable renewable energy (VRE). For energy storage, this is the energy stored at a given time, not the total over the year[73] VRE share Power (% of peak demand) Energy storage (% of annual demand) 50% Less than 20% 0.02% 80% 20–50% 0.03–0.1% 90% 25–75% 0.05–0.2% In systems with under 40% of variable renewables, only short-term storage (of less than 4 hours) is needed for integration. When the share of variable renewables climbs to 80%, medium-duration storage (between 4 and 16 hours, for instance compressed air) is needed. Above 90%, large-scale long-duration storage is required.[74] The economics of long-duration storage is challenging even then, as the costs are high. Alternative flexibility options, such as demand response, network expansions or flexible generation (geothermal or fossil gas with carbon capture and storage) may be lower-cost.[75] Like with renewables, storage will "cannibalise" its own income, but even more strongly. That is, with more storage on the market, there is less of an opportunity to do arbitrage or deliver other services to the grid.[76] How markets are designed impacts revenue potential too. The income from arbitrage is quite variable between years, whereas markets that have capacity payments likely show less volatility.[77] Electricity storage is not 100% efficient, so more electricity needs to be bought than can be sold. This implies that if there is only a small variation in price, it may not be economical to charge and discharge. For instance, if the storage application is 75% efficient, the price at which the electricity is sold needs to be at least 1.33 higher than the price for which it was bought.[78] Typically, electricity prices vary most between day and night, which means that storage up to 8 hours has relatively high potential for profit. Article Talk Read Edit View history Tools Appearance Text Small Standard Large Width Standard Wide Color (beta) Automatic Light Dark From Wikipedia, the free encyclopedia Diagram comparing losses from conventional generation vs. cogeneration Part of a series on Sustainable energy Energy conservation Renewable energy Sustainable transport Category Renewable energy portal v t e Cogeneration or combined heat and power (CHP) is the use of a heat engine[1] or power station to generate electricity and useful heat at the same time. Cogeneration is a more efficient use of fuel or heat, because otherwise-wasted heat from electricity generation is put to some productive use. Combined heat and power (CHP) plants recover otherwise wasted thermal energy for heating. This is also called combined heat and power district heating. Small CHP plants are an example of decentralized energy.[2] By-product heat at moderate temperatures (100–180 °C (212–356 °F) can also be used in absorption refrigerators for cooling. The supply of high-temperature heat first drives a gas or steam turbine-powered generator. The resulting low-temperature waste heat is then used for water or space heating. At smaller scales (typically below 1 MW), a gas engine or diesel engine may be used. Cogeneration is also common with geothermal power plants as they often produce relatively low grade heat. Binary cycles may be necessary to reach acceptable thermal efficiency for electricity generation at all. Cogeneration is less commonly employed in nuclear power plants as NIMBY and safety considerations have often kept them further from population centers than comparable chemical power plants and district heating is less efficient in lower population density areas due to transmission losses. Cogeneration was practiced in some of the earliest installations of electrical generation. Before central stations distributed power, industries generating their own power used exhaust steam for process heating. Large office and apartment buildings, hotels, and stores commonly generated their own power and used waste steam for building heat. Due to the high cost of early purchased power, these CHP operations continued for many years after utility electricity became available.[3] Overview Masnedø CHP power station in Denmark. This station burns straw as fuel. The adjacent greenhouses are heated by district heating from the plant. Many process industries, such as chemical plants, oil refineries and pulp and paper mills, require large amounts of process heat for such operations as chemical reactors, distillation columns, steam driers and other uses. This heat, which is usually used in the form of steam, can be generated at the typically low pressures used in heating, or can be generated at much higher pressure and passed through a turbine first to generate electricity. In the turbine the steam pressure and temperature is lowered as the internal energy of the steam is converted to work. The lower-pressure steam leaving the turbine can then be used for process heat. Steam turbines at thermal power stations are normally designed to be fed high-pressure steam, which exits the turbine at a condenser operating a few degrees above ambient temperature and at a few millimeters of mercury absolute pressure. (This is called a condensing turbine.) For all practical purposes this steam has negligible useful energy before it is condensed. Steam turbines for cogeneration are designed for extraction of some steam at lower pressures after it has passed through a number of turbine stages, with the un-extracted steam going on through the turbine to a condenser. In this case, the extracted steam causes a mechanical power loss in the downstream stages of the turbine. Or they are designed, with or without extraction, for final exhaust at back pressure (non-condensing).[4][5] The extracted or exhaust steam is used for process heating. Steam at ordinary process heating conditions still has a considerable amount of enthalpy that could be used for power generation, so cogeneration has an opportunity cost. A typical power generation turbine in a paper mill may have extraction pressures of 160 and 60 psi (1.10 and 0.41 MPa). A typical back pressure may be 60 psi (0.41 MPa). In practice these pressures are custom designed for each facility. Conversely, simply generating process steam for industrial purposes instead of high enough pressure to generate power at the top end also has an opportunity cost (See: Steam supply and exhaust conditions). The capital and operating cost of high-pressure boilers, turbines, and generators is substantial. This equipment is normally operated continuously, which usually limits self-generated power to large-scale operations. A cogeneration plant in Metz, France. The 45 MW boiler uses waste wood biomass as an energy source, providing electricity and heat for 30,000 dwellings. A combined cycle (in which several thermodynamic cycles produce electricity), may also be used to extract heat using a heating system as condenser of the power plant's bottoming cycle. For example, the RU-25 MHD generator in Moscow heated a boiler for a conventional steam powerplant, whose condensate was then used for space heat. A more modern system might use a gas turbine powered by natural gas, whose exhaust powers a steam plant, whose condensate provides heat. Cogeneration plants based on a combined cycle power unit can have thermal efficiencies above 80%. The viability of CHP (sometimes termed utilisation factor), especially in smaller CHP installations, depends on a good baseload of operation, both in terms of an on-site (or near site) electrical demand and heat demand. In practice, an exact match between the heat and electricity needs rarely exists. A CHP plant can either meet the need for heat (heat driven operation) or be run as a power plant with some use of its waste heat, the latter being less advantageous in terms of its utilisation factor and thus its overall efficiency. The viability can be greatly increased where opportunities for trigeneration exist. In such cases, the heat from the CHP plant is also used as a primary energy source to deliver cooling by means of an absorption chiller. CHP is most efficient when heat can be used on-site or very close to it. Overall efficiency is reduced when the heat must be transported over longer distances. This requires heavily insulated pipes, which are expensive and inefficient; whereas electricity can be transmitted along a comparatively simple wire, and over much longer distances for the same energy loss. A car engine becomes a CHP plant in winter when the reject heat is useful for warming the interior of the vehicle. The example illustrates the point that deployment of CHP depends on heat uses in the vicinity of the heat engine. Thermally enhanced oil recovery (TEOR) plants often produce a substantial amount of excess electricity. After generating electricity, these plants pump leftover steam into heavy oil wells so that the oil will flow more easily, increasing production. Cogeneration plants are commonly found in district heating systems of cities, central heating systems of larger buildings (e.g. hospitals, hotels, prisons) and are commonly used in the industry in thermal production processes for process water, cooling, steam production or CO2 fertilization. Rostock Power Station, a bituminous coal-fired combined heat and power plant in Germany Trigeneration or combined cooling, heat and power (CCHP) refers to the simultaneous generation of electricity and useful heating and cooling from the combustion of a fuel or a solar heat collector. The terms cogeneration and trigeneration can also be applied to the power systems simultaneously generating electricity, heat, and industrial chemicals (e.g., syngas). Trigeneration differs from cogeneration in that the waste heat is used for both heating and cooling, typically in an absorption refrigerator. Combined cooling, heat, and power systems can attain higher overall efficiencies than cogeneration or traditional power plants. In the United States, the application of trigeneration in buildings is called building cooling, heating, and power. Heating and cooling output may operate concurrently or alternately depending on need and system construction. Types of plants Hanasaari Power Plant, a coal-fired cogeneration power plant in Helsinki, Finland Topping cycle plants primarily produce electricity from a steam turbine. Partly expanded steam is then condensed in a heating condensor at a temperature level that is suitable e.g. district heating or water desalination. Bottoming cycle plants produce high temperature heat for industrial processes, then a waste heat recovery boiler feeds an electrical plant. Bottoming cycle plants are only used in industrial processes that require very high temperatures such as furnaces for glass and metal manufacturing, so they are less common. Large cogeneration systems provide heating water and power for an industrial site or an entire town. Common CHP plant types are: Gas turbine CHP plants using the waste heat in the flue gas of gas turbines. The fuel used is typically natural gas. Gas engine CHP plants use a reciprocating gas engine, which is generally more competitive than a gas turbine up to about 5 MW. The gaseous fuel used is normally natural gas. These plants are generally manufactured as fully packaged units that can be installed within a plantroom or external plant compound with simple connections to the site's gas supply, electrical distribution network and heating systems. Typical outputs and efficiencies see [6] Typical large example see [7] Biofuel engine CHP plants use an adapted reciprocating gas engine or diesel engine, depending upon which biofuel is being used, and are otherwise very similar in design to a Gas engine CHP plant. The advantage of using a biofuel is one of reduced fossil fuel consumption and thus reduced carbon emissions. These plants are generally manufactured as fully packaged units that can be installed within a plantroom or external plant compound with simple connections to the site's electrical distribution and heating systems. Another variant is the wood gasifier CHP plant whereby a wood pellet or wood chip biofuel is gasified in a zero oxygen high temperature environment; the resulting gas is then used to power the gas engine. Combined cycle power plants adapted for CHP Molten-carbonate fuel cells and solid oxide fuel cells have a hot exhaust, very suitable for heating. Steam turbine CHP plants that use the heating system as the steam condenser for the steam turbine Nuclear power plants, similar to other steam turbine power plants, can be fitted with extractions in the turbines to bleed partially expanded steam to a heating system. With a heating system temperature of 95 °C it is possible to extract about 10 MW heat for every MW electricity lost. With a temperature of 130 °C the gain is slightly smaller, about 7 MW for every MWe lost.[8] A review of cogeneration options is in [9] Czech research team proposed a "Teplator" system where heat from spent fuel rods is recovered for the purpose of residential heating.[10] Smaller cogeneration units may use a reciprocating engine or Stirling engine. The heat is removed from the exhaust and radiator. The systems are popular in small sizes because small gas and diesel engines are less expensive than small gas- or oil-fired steam-electric plants. Some cogeneration plants are fired by biomass,[11] or industrial and municipal solid waste (see incineration). Some CHP plants use waste gas as the fuel for electricity and heat generation. Waste gases can be gas from animal waste, landfill gas, gas from coal mines, sewage gas, and combustible industrial waste gas.[12] Some cogeneration plants combine gas and solar photovoltaic generation to further improve technical and environmental performance.[13] Such hybrid systems can be scaled down to the building level[14] and even individual homes.[15] MicroCHP Micro combined heat and power or 'Micro cogeneration" is a so-called distributed energy resource (DER). The installation is usually less than 5 kWe in a house or small business. Instead of burning fuel to merely heat space or water, some of the energy is converted to electricity in addition to heat. This electricity can be used within the home or business or, if permitted by the grid management, sold back into the electric power grid. Delta-ee consultants stated in 2013 that with 64% of global sales the fuel cell micro-combined heat and power passed the conventional systems in sales in 2012. [16] 20,000 units were sold in Japan in 2012 overall within the Ene Farm project. With a Lifetime of around

60,000 hours. For PEM fuel cell units, which shut down at night, this equates to an estimated lifetime of between ten and fifteen years.[17] For a price of $22,600 before installation.[18] For 2013 a state subsidy for 50,000 units is in place.[17] MicroCHP installations use five different technologies: microturbines, internal combustion engines, stirling engines, closed-cycle steam engines, and fuel cells. One author indicated in 2008 that MicroCHP based on Stirling engines is the most cost-effective of the so-called microgeneration technologies in abating carbon emissions.[19] A 2013 UK report from Ecuity Consulting stated that MCHP is the most cost-effective method of using gas to generate energy at the domestic level.[20][21] However, advances in reciprocation engine technology are adding efficiency to CHP plants, particularly in the biogas field.[22] As both MiniCHP and CHP have been shown to reduce emissions [23] they could play a large role in the field of CO2 reduction from buildings, where more than 14% of emissions can be saved using CHP in buildings.[24] The University of Cambridge reported a cost-effective steam engine MicroCHP prototype in 2017 which has the potential to be commercially competitive in the following decades.[25] Quite recently, in some private homes, fuel cell micro-CHP plants can now be found, which can operate on hydrogen, or other fuels as natural gas or LPG.[26][27] When running on natural gas, it relies on steam reforming of natural gas to convert the natural gas to hydrogen prior to use in the fuel cell. This hence still emits CO2 (see reaction) but (temporarily) running on this can be a good solution until the point where the hydrogen is starting to be distributed through the (natural gas) piping system. Another MicroCHP example is a natural gas or propane fueled Electricity Producing Condensing Furnace. It combines the fuel saving technique of cogeneration meaning producing electric power and useful heat from a single source of combustion. The condensing furnace is a forced-air gas system with a secondary heat exchanger that allows heat to be extracted from combustion products down to the ambient temperature along with recovering heat from the water vapor. The chimney is replaced by a water drain and vent to the side of the building. Trigeneration Trigeneration cycle A plant producing electricity, heat and cold is called a trigeneration[28] or polygeneration plant. Cogeneration systems linked to absorption chillers or adsorption chillers use waste heat for refrigeration.[29] Combined heat and power district heating See also: District heating In the United States, Consolidated Edison distributes 66 billion kilograms of 350 °F (177 °C) steam each year through its seven cogeneration plants to 100,000 buildings in Manhattan—the biggest steam district in the United States. The peak delivery is 10 million pounds per hour (or approximately 2.5 GW).[30][31] Industrial CHP Cogeneration is still common in pulp and paper mills, refineries and chemical plants. In this "industrial cogeneration/CHP", the heat is typically recovered at higher temperatures (above 100 °C) and used for process steam or drying duties. This is more valuable and flexible than low-grade waste heat, but there is a slight loss of power generation. The increased focus on sustainability has made industrial CHP more attractive, as it substantially reduces carbon footprint compared to generating steam or burning fuel on-site and importing electric power from the grid. Smaller industrial co-generation units have an output capacity of 5–25 MW and represent a viable off-grid option for a variety of remote applications to reduce carbon emissions.[32] Utility pressures versus self generated industrial Industrial cogeneration plants normally operate at much lower boiler pressures than utilities. Among the reasons are: 1.Cogeneration plants face possible contamination of returned condensate. Because boiler feed water from cogeneration plants has much lower return rates than 100% condensing power plants, industries usually have to treat proportionately more boiler make up water. Boiler feed water must be completely oxygen free and de-mineralized, and the higher the pressure the more critical the level of purity of the feed water.[5] 2.Utilities are typically larger scale power than industry, which helps offset the higher capital costs of high pressure. 3.Utilities are less likely to have sharp load swings than industrial operations, which deal with shutting down or starting up units that may represent a significant percent of either steam or power demand. Heat recovery steam generators A heat recovery steam generator (HRSG) is a steam boiler that uses hot exhaust gases from the gas turbines or reciprocating engines in a CHP plant to heat up water and generate steam. The steam, in turn, drives a steam turbine or is used in industrial processes that require heat. HRSGs used in the CHP industry are distinguished from conventional steam generators by the following main features: The HRSG is designed based upon the specific features of the gas turbine or reciprocating engine that it will be coupled to. Since the exhaust gas temperature is relatively low, heat transmission is accomplished mainly through convection. The exhaust gas velocity is limited by the need to keep head losses down. Thus, the transmission coefficient is low, which calls for a large heating surface area. Since the temperature difference between the hot gases and the fluid to be heated (steam or water) is low, and with the heat transmission coefficient being low as well, the evaporator and economizer are designed with plate fin heat exchangers. Cogeneration using biomass Biomass refers to any plant or animal matter in which it is possible to be reused as a source of heat or electricity, such as sugarcane, vegetable oils, wood, organic waste and residues from the food or agricultural industries. Brazil is now considered a world reference in terms of energy generation from biomass.[33] A growing sector in the use of biomass for power generation is the sugar and alcohol sector, which mainly uses sugarcane bagasse as fuel for thermal and electric power generation.[34] Power cogeneration in the sugar and alcohol sector In the sugarcane industry, cogeneration is fueled by the bagasse residue of sugar refining, which is burned to produce steam. Some steam can be sent through a turbine that turns a generator, producing electric power.[35] Energy cogeneration in sugarcane industries located in Brazil is a practice that has been growing in last years. With the adoption of energy cogeneration in the sugar and alcohol sector, the sugarcane industries are able to supply the electric energy demand needed to operate, and generate a surplus that can be commercialized.[36][37] Advantages of the cogeneration using sugarcane bagasse In comparison with the electric power generation by means of fossil fuel-based thermoelectric plants, such as natural gas, the energy generation using sugarcane bagasse has environmental advantages due to the reduction of CO2 emissions.[38] In addition to the environmental advantages, cogeneration using sugarcane bagasse presents advantages in terms of efficiency comparing to thermoelectric generation, through the final destination of the energy produced. While in thermoelectric generation, part of the heat produced is lost, in cogeneration this heat has the possibility of being used in the production processes, increasing the overall efficiency of the process.[38] Disadvantages of the cogeneration using sugarcane bagasse In sugarcane cultivation, is usually used potassium source's containing high concentration of chlorine, such as potassium chloride (KCl). Considering that KCl is applied in huge quantities, sugarcane ends up absorbing high concentrations of chlorine.[39] Due to this absorption, when the sugarcane bagasse is burned in the power cogeneration, dioxins [39] and methyl chloride [40] ends up being emitted. In the case of dioxins, these substances are considered very toxic and cancerous.[41][42][43] In the case of methyl chloride, when this substance is emitted and reaches the stratosphere, it ends up being very harmful for the ozone layer, since chlorine when combined with the ozone molecule generates a catalytic reaction leading to the breakdown of ozone links.[40] After each reaction, chlorine starts a destructive cycle with another ozone molecule. In this way, a single chlorine atom can destroy thousands of ozone molecules. As these molecules are being broken, they are unable to absorb the ultraviolet rays. As a result, the UV radiation is more intense on Earth and there is a worsening of global warming.[40] Comparison with a heat pump A heat pump may be compared with a CHP unit as follows. If, to supply thermal energy, the exhaust steam from the turbo-generator must be taken at a higher temperature than the system would produce most electricity at, the lost electrical generation is as if a heat pump were used to provide the same heat by taking electrical power from the generator running at lower output temperature and higher efficiency.[44] Typically for every unit of electrical power lost, then about 6 units of heat are made available at about 90 °C (194 °F). Thus CHP has an effective Coefficient of Performance (COP) compared to a heat pump of 6.[45] However, for a remotely operated heat pump, losses in the electrical distribution network would need to be considered, of the order of 6%. Because the losses are proportional to the square of the current, during peak periods losses are much higher than this and it is likely that widespread (i.e. citywide application of heat pumps) would cause overloading of the distribution and transmission grids unless they were substantially reinforced. It is also possible to run a heat driven operation combined with a heat pump, where the excess electricity (as heat demand is the defining factor on se[clarification needed]) is used to drive a heat pump. As heat demand increases, more electricity is generated to drive the heat pump, with the waste heat also heating the heating fluid. As the efficiency of heat pumps depends on the difference between hot end and cold end temperature (efficiency rises as the difference decreases) it may be worthwhile to combine even relatively low grade waste heat otherwise unsuitable for home heating with heat pumps. For example, a large enough reservoir of cooling water at 15 °C (59 °F) can significantly improve efficiency of heat pumps drawing from such a reservoir compared to air source heat pumps drawing from cold air during a −20 °C (−4 °F) night. In the summer when there's both demand for air conditioning and warm water, the same water may even serve as both a "dump" for the waste heat rejected by a/c units and as a "source" for heat pumps providing warm water. Those considerations are behind what is sometimes called "cold district heating" using a "heat" source whose temperature is well below those usually employed in district heating.[46] Distributed generation Most industrial countries generate the majority of their electrical power needs in large centralized facilities with capacity for large electrical power output. These plants benefit from economy of scale, but may need to transmit electricity across long distances causing transmission losses. Cogeneration or trigeneration production is subject to limitations in the local demand and thus may sometimes need to reduce (e.g., heat or cooling production to match the demand). An example of cogeneration with trigeneration applications in a major city is the New York City steam system. Thermal efficiency Every heat engine is subject to the theoretical efficiency limits of the Carnot cycle or subset Rankine cycle in the case of steam turbine power plants or Brayton cycle in gas turbine with steam turbine plants. Most of the efficiency loss with steam power generation is associated with the latent heat of vaporization of steam that is not recovered when a turbine exhausts its low temperature and pressure steam to a condenser. (Typical steam to condenser would be at a few millimeters absolute pressure and on the order of 5 °C (41 °F) hotter than the cooling water temperature, depending on the condenser capacity.) In cogeneration this steam exits the turbine at a higher temperature where it may be used for process heat, building heat or cooling with an absorption chiller. The majority of this heat is from the latent heat of vaporization when the steam condenses. Thermal efficiency in a cogeneration system is defined as: Where: = Thermal efficiency = Total work output by all systems = Total heat input into the system Heat output may also be used for cooling (for example, in summer), thanks to an absorption chiller. If cooling is achieved in the same time, thermal efficiency in a trigeneration system is defined as: Where: = Thermal efficiency = Total work output by all systems = Total heat input into the system Typical cogeneration models have losses as in any system. The energy distribution below is represented as a percent of total input energy:[47] Electricity = 45% Heat + Cooling = 40% Heat losses = 13% Electrical line losses = 2% Conventional central coal- or nuclear-powered power stations convert about 33–45% of their input heat to electricity.[48][5] Brayton cycle power plants operate at up to 60% efficiency. In the case of conventional power plants, approximately 10-15% of this heat is lost up the stack of the boiler. Most of the remaining heat emerges from the turbines as low-grade waste heat with no significant local uses, so it is usually rejected to the environment, typically to cooling water passing through a condenser.[5] Because turbine exhaust is normally just above ambient temperature, some potential power generation is sacrificed in rejecting higher-temperature steam from the turbine for cogeneration purposes.[49] For cogeneration to be practical power generation and end use of heat must be in relatively close proximity (<2 km typically). Even though the efficiency of a small distributed electrical generator may be lower than a large central power plant, the use of its waste heat for local heating and cooling can result in an overall use of the primary fuel supply as great as 80%.[48] This provides substantial financial and environmental benefits. Costs See also: Cost of electricity by source Typically, for a gas-fired plant the fully installed cost per kW electrical is around £400/kW (US$577), which is comparable with large central power stations.[50] History Cogeneration in Europe A cogeneration thermal power plant in Ferrera Erbognone (PV), Italy This section needs to be updated. Please help update this article to reflect recent events or newly available information. (May 2021) The EU has actively incorporated cogeneration into its energy policy via the CHP Directive. In September 2008 at a hearing of the European Parliament's Urban Lodgment Intergroup, Energy Commissioner Andris Piebalgs is quoted as saying, “security of supply really starts with energy efficiency.”[51] Energy efficiency and cogeneration are recognized in the opening paragraphs of the European Union's Cogeneration Directive 2004/08/EC. This directive intends to support cogeneration and establish a method for calculating cogeneration abilities per country. The development of cogeneration has been very uneven over the years and has been dominated throughout the last decades by national circumstances. The European Union generates 11% of its electricity using cogeneration.[52] However, there is large difference between Member States with variations of the energy savings between 2% and 60%. Europe has the three countries with the world's most intensive cogeneration economies: Denmark, the Netherlands and Finland.[53] Of the 28.46 TWh of electrical power generated by conventional thermal power plants in Finland in 2012, 81.80% was cogeneration.[54] Other European countries are also making great efforts to increase efficiency. Germany reported that at present, over 50% of the country's total electricity demand could be provided through cogeneration. So far, Germany has set the target to double its electricity cogeneration from 12.5% of the country's electricity to 25% of the country's electricity by 2020 and has passed supporting legislation accordingly.[55] The UK is also actively supporting combined heat and power. In light of UK's goal to achieve a 60% reduction in carbon dioxide emissions by 2050, the government has set the target to source at least 15% of its government electricity use from CHP by 2010. [56] Other UK measures to encourage CHP growth are financial incentives, grant support, a greater regulatory framework, and government leadership and partnership. According to the IEA 2008 modeling of cogeneration expansion for the G8 countries, the expansion of cogeneration in France, Germany, Italy and the UK alone would effectively double the existing primary fuel savings by 2030. This would increase Europe's savings from today's 155.69 Twh to 465 Twh in 2030. It would also result in a 16% to 29% increase in each country's total cogenerated electricity by 2030. Governments are being assisted in their CHP endeavors by organizations like COGEN Europe who serve as an information hub for the most recent updates within Europe's energy policy. COGEN is Europe's umbrella organization representing the interests of the cogeneration industry. The European public–private partnership Fuel Cells and Hydrogen Joint

Undertaking Seventh Framework Programme project ene.field deploys in 2017[57] up 1,000 residential fuel cell Combined Heat and Power (micro-CHP) installations in 12 states. Per 2012 the first 2 installations have taken place.[58][59][60] Cogeneration in the United Kingdom In the United Kingdom, the Combined Heat and Power Quality Assurance scheme regulates the combined production of heat and power. It was introduced in 1996. It defines, through calculation of inputs and outputs, "Good Quality CHP" in terms of the achievement of primary energy savings against conventional separate generation of heat and electricity. Compliance with Combined Heat and Power Quality Assurance is required for cogeneration installations to be eligible for government subsidies and tax incentives.[61] Cogeneration in the United States The 250 MW Kendall Cogeneration Station plant in Cambridge, Massachusetts Perhaps the first modern use of energy recycling was done by Thomas Edison. His 1882 Pearl Street Station, the world's first commercial power plant, was a combined heat and power plant, producing both electricity and thermal energy while using waste heat to warm neighboring buildings.[62] Recycling allowed Edison's plant to achieve approximately 50 percent efficiency. By the early 1900s, regulations emerged to promote rural electrification through the construction of centralized plants managed by regional utilities. These regulations not only promoted electrification throughout the countryside, but they also discouraged decentralized power generation, such as cogeneration. By 1978, Congress recognized that efficiency at central power plants had stagnated and sought to encourage improved efficiency with the Public Utility Regulatory Policies Act (PURPA), which encouraged utilities to buy power from other energy producers. Cogeneration plants proliferated, soon producing about 8% of all energy in the United States.[63] However, the bill left implementation and enforcement up to individual states, resulting in little or nothing being done in many parts of the country. [citation needed] The United States Department of Energy has an aggressive goal of having CHP constitute 20% of generation capacity by 2030.[citation needed] Eight Clean Energy Application Centers[64] have been established across the nation. Their mission is to develop the required technology application knowledge and educational infrastructure necessary to lead "clean energy" (combined heat and power, waste heat recovery, and district energy) technologies as viable energy options and reduce any perceived risks associated with their implementation. The focus of the Application Centers is to provide an outreach and technology deployment program for end users, policymakers, utilities, and industry stakeholders. High electric rates in New England and the Middle Atlantic make these areas of the United States the most beneficial for cogeneration.[65][66] 5.ISBN 978-0-8493-2274-7 6. v t e Electricity delivery Concepts Automatic generation control Backfeeding Base load Demand factor Droop speed control Electric power Electric power quality Electrical fault Energy demand management Energy return on investment Grid code Grid energy storage Grid strength Home energy storage Load-following Merit order Nameplate capacity Peak demand Power factor Power-flow study Repowering Utility frequency Variability Vehicle-to-grid Sources Non-renewable Fossil fuel power station oCoal oNatural gas oOil shale oPetroleum Nuclear Renewable Biofuel Biogas Biomass Geothermal Hydro Marine oCurrent oOsmotic oThermal oTidal oWave Solar Sustainable biofuel Wind Generation AC power Cogeneration Combined cycle Cooling tower Induction generator Micro CHP Microgeneration Rankine cycle Three-phase electric power Virtual power plant Transmission and distribution Demand response Distributed generation Dynamic demand Electric power distribution Electric power system Electric power transmission Electrical busbar system Electrical grid Electrical substation Electricity retailing High-voltage direct current High-voltage shore connection Interconnector Load management Mains electricity by country Overhead power line Power station Pumped hydro Single-wire earth return Smart grid Super grid Transformer Transmission system operator (TSO) Transmission tower Utility pole Failure modes Black start Brownout Cascading failure Power outage oRolling blackout Protective devices Arc-fault circuit interrupter Circuit breaker oEarth-leakage oSulfur hexafluoride Generator interlock kit Numerical relay Power system protection Protective relay Residual-current device (GFI) Economics and policies Availability factor Capacity factor Carbon offsets and credits Cost of electricity by source Energy subsidies Environmental tax Feed-in tariff Fossil fuel phase-out Load factor Net metering Pigouvian tax Renewable Energy Certificates Renewable energy commercialization Renewable Energy Payments Spark/Dark/Quark/Bark spread Statistics and production Electric energy consumption List of electricity sectors Contents (Top) Types Protecting the power system from outages Protecting computer systems from power outages Restoring power after a wide-area outage Blackout inevitability and electric sustainability o Self-organized criticality o OPA model o Mitigation of power outage frequency Key performance indicators See also References External links Power outage Article Talk Read Edit View history Tools Appearance Text

Small Standard Large Width Standard Wide Color (beta) Automatic Light Dark From Wikipedia, the free encyclopedia This article is about accidental power failures. For intentionally engineered ones, see rolling blackout. For other uses, see Power Outage (disambiguation). "Power cut" redirects here. For the 2012 Punjabi film, see Power Cut. Vehicle lights provided the only illumination during the 2009 Ecuador electricity crisis. A power outage, also called a powercut, a power out, a power failure, a power blackout, a power loss, a blackout or a power drought — is the loss of the electrical power network supply to an end user. There are many causes of power failures in an electricity network. Examples of these causes include faults at power stations, damage to electric transmission lines, substations or other parts of the distribution system, a short circuit, cascading failure, fuse or circuit breaker operation. Power failures are particularly critical at sites where the environment and public safety are at risk. Institutions such as hospitals, sewage treatment plants, and mines will usually have backup power sources such as standby generators, which will automatically start up when electrical power is lost. Other critical systems, such as telecommunication, are also required to have emergency power. The battery room of a telephone exchange usually has arrays of lead–acid batteries for backup and also a socket for connecting a generator during extended periods of outage. During a power outage, there is a disruption in the supply of electricity, resulting in a loss of power to homes, businesses, and other facilities. Power outages can occur for various reasons, including severe weather conditions (e.g. storms, hurricanes, or blizzards), earthquakes, equipment failure, grid overload, or planned maintenance. Types Blackout Transient fault Power outages are categorized into three different phenomena, relating to the duration and effect of the outage: A transient fault is a loss of power typically caused by a fault on a power line, e.g. a short circuit or flashover. Power is automatically restored once the fault is cleared. A brownout is a drop in voltage in an electrical power supply. The term brownout comes from the dimming experienced by incandescent lighting when the voltage sags. Brownouts can cause poor performance of equipment or even incorrect operation. A blackout is the total loss of power to a wider area and of long duration.[1] It is the most severe form of power outage that can occur. Blackouts which result from or result in power stations tripping are particularly difficult to recover from quickly. Outages may last from a few minutes to a few weeks depending on the nature of the blackout and the configuration of the electrical network. Rolling blackouts occur when demand for electricity exceeds supply, and allow some customers to receive power at the required voltage at the expense of other customers who get no power at all. They are a common occurrence in developing countries, and may be scheduled in advance or occur without warning. They have also occurred in developed countries, for example in the California electricity crisis of 2000–2001, when government deregulation destabilized the wholesale electricity market. Blackouts are also used as a public safety measure, such as to prevent a gas leak from catching fire (for example, power was cut to several towns in response to the Merrimack Valley gas explosions), or to prevent wildfires around poorly maintained transmission lines (such as during the 2019 California power shutoffs). Protecting the power system from outages Tree limbs creating a short circuit in power lines during a storm. This typically results in a power outage in the area supplied by these lines In power supply networks, the power generation and the electrical load (demand) must be very close to equal every second to avoid overloading of network components, which can severely damage them. Protective relays and fuses are used to automatically detect overloads and to disconnect circuits at risk of damage. Under certain conditions, a network component shutting down can cause current fluctuations in neighboring segments of the network leading to a cascading failure of a larger section of the network. This may range from a building, to a block, to an entire city, to an entire electrical grid. Modern power systems are designed to be resistant to this sort of cascading failure, but it may be unavoidable (see below). Moreover, since there is no short-term economic benefit to preventing rare large-scale failures, researchers have expressed concern that there is a tendency to erode the resilience of the network over time, which is only corrected after a major failure occurs.[citation needed] In a 2003 publication, Carreras and co-authors claimed that reducing the likelihood of small outages only increases the likelihood of larger ones.[2] In that case, the short-term economic benefit of keeping the individual customer happy increases the likelihood of large-scale blackouts. The Senate Committee on Energy and Natural Resources held a hearing in October 2018 to examine "black start", the process of restoring electricity after a system-wide power loss. The hearing's purpose was for Congress to learn about what the backup plans are in the electric utility industry in the case that the electric grid is damaged. Threats to the electrical grid include cyberattacks, solar storms, and severe weather, among others. For example, the "Northeast Blackout of 2003" was caused when overgrown trees touched high-voltage power lines. Around 55 million people in the U.S. and Canada lost power, and restoring it cost around $6 billion.[3] Protecting computer systems from power outages Computer systems and other electronic devices containing logic circuitry are susceptible to data loss or hardware damage that can be caused by the sudden loss of power. These can include data networking equipment, video projectors, alarm systems as well as computers. To protect computer systems against this, the use of an uninterruptible power supply or 'UPS' can provide a constant flow of electricity if a primary power supply becomes unavailable for a short period of time. To protect against surges (events where voltages increase for a few seconds), which can damage hardware when power is restored, a special device called a surge protector that absorbs the excess voltage can be used. Restoring power after a wide-area outage Restoring power after a wide-area outage can be difficult, as power stations need to be brought back online. Normally, this is done with the help of power from the rest of the grid. In the total absence of grid power, a so-called black start needs to be performed to bootstrap the power grid into operation. The means of doing so will depend greatly on local circumstances and operational policies, but typically transmission utilities will establish localized 'power islands' which are then progressively coupled together. To maintain supply frequencies within tolerable limits during this process, demand must be reconnected at the same pace that generation is restored, requiring close coordination between power stations, transmission and distribution organizations. Blackout inevitability and electric sustainability Comparison of duration of power outages (SAIDI value), in 2014. Self-organized criticality Further information: Self-organized criticality control It has been argued on the basis of historical data[4] and computer modeling[5][6] that power grids are self-organized critical systems. These systems exhibit unavoidable[7] disturbances of all sizes, up to the size of the entire system. This phenomenon has been attributed to steadily increasing demand/load, the economics of running a power company, and the limits of modern engineering.[8] While blackout frequency has been shown to be reduced by operating it further from its critical point, it generally is not economically feasible, causing providers to increase the average load over time or upgrade less often resulting in the grid moving itself closer to its critical point. Conversely, a system past the critical point will experience too many blackouts leading to system-wide upgrades moving it back below the critical point. The term critical point of the system is used here in the sense of statistical physics and nonlinear dynamics, representing the point where a system undergoes a phase transition; in this case the transition from a steady reliable grid with few cascading failures to a very sporadic unreliable grid with common cascading failures. Near the critical point the relationship between blackout frequency and size follows a power-law distribution.[6][8] Cascading failure becomes much more common close to this critical point. The power-law relationship is seen in both historical data and model systems.[8] The practice of operating these systems much closer to their maximum capacity leads to magnified effects of random, unavoidable disturbances due to aging, weather, human interaction etc. While near the critical point, these failures have a greater effect on the surrounding components due to individual components carrying a larger load. This results in the larger load from the failing component having to be redistributed in larger quantities across the system, making it more likely for additional components not directly affected by the disturbance to fail, igniting costly and dangerous cascading failures.[8] These initial disturbances causing blackouts are all the more unexpected and unavoidable due to actions of the power suppliers to prevent obvious disturbances (cutting back trees, separating lines in windy areas, replacing aging components etc.). The complexity of most power grids often makes the initial cause of a blackout extremely hard to identify. Leaders are dismissive of system theories that conclude that blackouts are inevitable, but do agree that the basic operation of the grid must be changed. The Electric Power Research Institute champions the use of smart grid features such as power control devices employing advanced sensors to coordinate the grid.[9] Others advocate greater use of electronically controlled high-voltage direct current (HVDC) firebreaks to prevent disturbances from cascading across AC lines in a wide area grid.[10] OPA model In 2002, researchers at Oak Ridge National Laboratory (ORNL), Power System Engineering Research Center of the University of Wisconsin (PSerc), [11] and the University of Alaska Fairbanks proposed a mathematical model for the behavior of electrical distribution systems.[12][13] This model has become known as the OPA model, a reference to the names of the authors' institutions. OPA is a cascading failure model. Other cascading failure models include Manchester, Hidden failure, CASCADE, and Branching.[14] The OPA model was quantitatively compared with a complex networks model of a cascading failure – Crucitti–Latora–Marchiori (CLM) model,[15] showing that both models exhibit similar phase transitions in the average network damage (load shed/ demand in OPA, path damage in CLM), with respect to transmission capacity.[16] Mitigation of power outage frequency The effects of trying to mitigate cascading failures near the critical point in an economically feasible fashion are often shown to not be beneficial and often even detrimental. Four mitigation methods have been tested using the OPA blackout model:[2] Increase critical number of failures causing cascading blackouts – Shown to decrease the frequency of smaller blackouts but increase that of larger blackouts. Increase individual power line max load – Shown to increase the frequency of smaller blackouts and decrease that of larger blackouts. Combination of increasing critical number and max load of lines – Shown to have no significant effect on either size of blackout. The resulting minor reduction in the frequency of blackouts is projected to not be worth the cost of the implementation. Increase the excess power available to the grid – Shown to decrease the frequency of smaller blackouts but increase that of larger blackouts. In addition to the finding of each mitigation strategy having a cost-benefit relationship with regards to frequency of small and large blackouts, the total number of blackout events was not significantly reduced by any of the above-mentioned mitigation measures.[2] A complex network-based model to control large cascading failures (blackouts) using local information only was proposed by A. E. Motter.[17] In 2015, one of the solutions proposed to reduce the impact of power outage was introduced by M. S. A smart meter is an electronic device that records information—such as consumption of electric energy, voltage levels, current, and power factor—and communicates the information to the consumer and electricity suppliers. Advanced metering infrastructure (AMI) differs from automatic meter reading (AMR) in that it enables two-way communication between the meter and the supplier. Description The term smart meter often refers to an electricity meter, but it also may mean a device measuring natural gas, water or district heating consumption.[1][2] More generally, a smart meter is an electronic device that records information such as consumption of electric energy, voltage levels, current, and power factor. Smart meters communicate the information to the consumer for greater clarity of consumption behavior, and electricity suppliers for system monitoring and customer billing. Smart meters typically record energy near real-time, and report regularly, in short intervals throughout the day.[3] Smart meters enable two-way communication between the meter and the central system. Smart meters may be part of a smart grid, but do not themselves constitute a smart grid.[4] Such an advanced metering infrastructure (AMI) differs from automatic meter reading (AMR) in that it enables two-way communication between the meter and the supplier. Communications from the meter to the network may be wireless, or via fixed wired connections such as power line carrier (PLC). Wireless communication options in common use include cellular communications, Wi-Fi (readily available), wireless ad hoc networks over Wi-Fi, wireless mesh networks, low power long-range wireless (LoRa), Wize (high radio penetration rate, open, using the frequency 169 MHz) Zigbee (low power, low data rate wireless), and Wi-SUN (Smart Utility Networks). Similar meters, usually referred to as interval or time-of-use meters, have existed for years, but smart meters usually involve real-time or near real-time sensors, power outage notification, and power quality monitoring. These additional features are more than simple automated meter reading (AMR). They are similar in many respects to Advanced Metering Infrastructure (AMI) meters. Interval and time-of-use meters historically have been installed to measure commercial and industrial customers, but may not have automatic reading.[citation needed] Research by the UK consumer group Which?, showed that as many as one in three confuse smart meters with energy monitors, also known as in-home display monitors.[5][when?] History In 1972, Theodore Paraskevakos, while working with Boeing in Huntsville, Alabama, developed a sensor monitoring system that used digital transmission for security, fire, and medical alarm systems as well as meter reading capabilities. This technology was a spin-off from the automatic telephone line identification system, now known as Caller ID. In 1974, Paraskevakos was awarded a U.S. patent for this technology.[6] In 1977, he launched Metretek, Inc.,[7] which developed and produced the first smart meters.[8] Since this system was developed pre-Internet, Metretek utilized the IBM series 1 mini-computer. For this approach, Paraskevakos and Metretek were awarded multiple patents.[9] The installed base of smart meters in Europe at the end of 2008 was about 39 million units, according to analyst firm Berg Insight.[10] Globally, Pike Research found that smart meter shipments were 17.4 million units for the first quarter of 2011.[11] Visiongain determined that the value of the global smart meter market would reach US$7 billion in 2012.[12] H.M. Zahid Iqbal, M. Waseem, and Dr. Tahir Mahmood, researchers of University of Engineering & Technology Taxila, Pakistan, introduced the concept of Smart Energy Meters in 2013. Their article, "Automatic Energy Meter Reading using Smart Energy Meter" outlined the key features of Smart Energy Meter including Automatic remote meter reading via GSM for utility companies and customers, Real-time monitoring of a customer's running load, Remote disconnection and reconnection of customer connections by the utility company and Convenient billing, eliminating the need of meter readers to physically visit the customers for billing. As of January 2018, over 99 million electricity meters were deployed across the European Union, with an estimated 24 million more to be installed by the end of 2020. The European Commission DG Energy estimates the 2020 installed base to have required €18.8 billion in investment, growing to €40.7 billion by 2030, with a total deployment of 266 million smart meters.[13] By the end of 2018, the U.S. had over 86 million smart meters installed.[14] In 2017, there were 665 million smart meters installed globally.[15] Revenue generation is expected to grow from $12.8 billion in 2017 to $20 billion by 2022.[16] Purpose Since the inception of electricity deregulation and market-driven pricing throughout the world, utilities have been looking for a means to match consumption with generation. Non-smart electrical and gas meters only measure total consumption, providing no information of when the energy was consumed.[17] Smart meters provide a way of measuring electricity consumption in near real-time. This allows utility companies to charge different prices for consumption according to the time of day and the season.[18] It also facilitates more accurate cash-flow models for utilities. Since smart meters can be read remotely, labor costs are reduced for utilities. Smart metering offers potential benefits to customers. These include, a) an end to estimated bills, which are a major source of complaints for many customers b) a tool to help consumers better manage their energy purchases—smart meters with a display outside their homes could provide up-to-date information on gas and electricity consumption and in doing so help people to manage their energy use and reduce their energy bills. With regards to consumption reduction, this is critical for understanding the benefits of smart meters because the relatively small percentage benefits in terms of savings are multiplied by millions of users.[19] Smart meters for water consumption can also provide detailed and timely information about customer water use and early notification of possible water leaks in their premises.[20] Electricity pricing usually peaks at certain predictable times of the day and the season. In particular, if generation is constrained, prices can rise if power from other jurisdictions or more costly generation is brought online. Proponents assert that billing customers at a higher rate for peak times encourages consumers to adjust their consumption habits to be more responsive to market prices and assert further, that regulatory and market design agencies hope these "price signals" could delay the construction of additional generation or at least the purchase of energy from higher-priced sources, thereby controlling the steady and rapid increase of electricity prices.[citation needed] An academic study based on existing trials showed that homeowners' electricity consumption on average is reduced by approximately 3-5% when provided with real-time feedback.[21] Another advantage of smart meters that benefits both customers and the utility is the monitoring capability they provide for the whole electrical system. As part of an AMI, utilities can use the real-time data from smart meters measurements related to current, voltage, and power factor to detect system disruptions more quickly, allowing immediate corrective action to minimize customer impact such as blackouts. Smart meters also help utilities understand the power grid needs with more granularity than legacy meters. This greater understanding facilitates system planning to meet customer energy needs while reducing the likelihood of additional infrastructure investments, which eliminates unnecessary spending or energy cost increases.[22] Though the task of meeting national electricity demand with accurate supply is becoming ever more challenging as intermittent renewable generation sources make up a greater proportion of the energy mix, the real-time data provided by smart meters allow grid operators to integrate renewable energy onto the grid in order to balance the networks. As a result, smart meters are considered an essential technology to the decarbonisation of the energy system. [23] Advanced metering infrastructure Advanced metering infrastructure (AMI) refers to systems that measure, collect, and analyze energy usage, and communicate with metering devices such as electricity meters, gas meters, heat meters, and water meters, either on request or on a schedule. These systems include hardware, software, communications, consumer energy displays and controllers, customer associated systems, meter data management software, and supplier business systems. Government agencies and utilities are turning toward advanced metering infrastructure (AMI) systems as part of larger "smart grid" initiatives. AMI extends automatic meter reading (AMR) technology by providing two-way meter communications, allowing commands to be sent toward the home for multiple purposes, including time-based pricing information, demand-response actions, or remote service disconnects. Wireless technologies are critical elements of the neighborhood network, aggregating a mesh configuration of up to thousands of meters for back haul to the utility's IT headquarters. The network between the measurement devices and business systems allows the collection and distribution of information to customers, suppliers, utility companies, and service providers. This enables these businesses to participate in demand response services. Consumers can use the information provided by the system to change their normal consumption patterns to take advantage of lower prices. Pricing can be used to curb the growth of peak demand consumption. AMI differs from traditional automatic meter reading (AMR) in that it enables two-way communications with the meter. Systems only capable of meter readings do not qualify as AMI systems.[24] Typical smart meter ami diagram AMI implementation relies on four key components: Physical Layer Connectivity, which establishes connections between smart meters and networks, Communication Protocols to ensure secure and efficient data transmission, Server Infrastructure, which consists of centralized or distributed servers to store, process, and manage data for billing, monitoring, and demand response; and Data Analysis, where analytical tools provide insights, load forecasting, and anomaly detection for optimized energy management. Together, these components help utilities and consumers monitor and manage energy use efficiently, supporting smarter grid management.[25] Physical Layer Connectivity Communication is a cornerstone of smart meter technology, enabling reliable and secure data transmission to central systems. However, the diversity of environments in which smart meters operate presents significant challenges. Solutions to these challenges encompass a range of communication methods[26] including Power-line communication[27] (PLC), Cellular network,[28] Wireless mesh network,[29] Short-range,[29] and satellite[citation needed]: Power-line communication for Smart Metering Power Line Communication (PLC)[a] stands out among smart metering connectivity technologies because it leverages existing electrical power infrastructure for data transmission. Unlike cellular, radio-frequency (RF), or Wi-Fi-based solutions, PLC does not require building or maintaining separate communication networks, making it inherently more cost-effective and easier to scale. Two major PLC standards in smart metering are G3-PLC and the PRIME Alliance protocol.[27] G3-PLC supports IPv6-based communications and adaptive data rates, providing robust performance even in noisy environments, while PRIME (PoweRline Intelligent Metering Evolution) focuses on efficient, high-speed communication with low-cost implementation. PLC-based smart metering is deployed extensively in regions [30][31] like Europe, South America, and parts of Asia where dense infrastructure supports its use. Utilities favor PLC for its reliability in urban environments and for connecting large numbers of meters within smart grid networks. An important feature of G3-PLC and PRIME is their ability to enable mesh networking (also called multi-hop), where smart meters act as repeaters for other meters in the network. This functionality allows meters to relay data from neighboring meters to ensure that the information reaches the Data Concentrator Unit (DCU), even if direct communication is not possible due to distance or signal obstructions. This approach enhances network reliability and coverage, particularly in dense urban environments or geographically challenging areas.[32] Cellular Network (GPRS, NB-IoT, LTE-M): "Cellular technologies are highly scalable and secure. With national coverage, cellular connectivity can support a large number of meters in densely populated areas as well as reach those in remote locations."[28] Wireless mesh network (e.g. Wirepas[33] and Wi-Sun[34]): Ideal for urban areas, where devices can relay data to optimize coverage and reliability. It is mostly used for Water Meter and Gas Meter Short-range: such as Wireless M-Bus (WMBUS) are commonly used in smart metering applications to enable reliable, low-power communication between utility meters and local data collectors within buildings or neighborhoods. Hybrid PLC/RF PRIME and G3-PLC standards defines an integrated approach for seamless integration of PLC and wireless communication, enhancing reliability and flexibility in smart grids. [35] Additional options, such as Wi-Fi[citation needed] and internet-based networks, are also in use. However, no single communication solution is universally optimal. The challenges faced by rural utilities differ significantly from those of urban counterparts or utilities in remote, mountainous, or poorly serviced areas. Smart meters often extend their functionality through integration into Home Area Networks (HANs). These networks enable communication within the household and may include: In-Premises Displays: Providing real-time energy usage insights for consumers. Hubs: Interfacing multiple meters with the central head-end system.[citation needed] Technologies used in HANs vary globally but typically include PLC, wireless ad hoc networks, and Zigbee. By leveraging appropriate connectivity solutions, smart meters can address diverse environmental and infrastructural needs while delivering seamless communication and enhanced functionality.[citation needed] Smart meters used as a gateway for water and gas meters Electricity smart meters start to be utilized as gateways for gas and water meters, creating integrated smart metering systems.[36] In this configuration, gas and water meters communicate with the electricity meter using Wireless M-Bus (Wireless Meter-Bus), a European standard (EN 13757-4) designed for secure and efficient data transmission between utility meters and data collectors. The electricity meter then aggregates this data and transmits it to the central utility network via Power Line Communication (PLC), which leverages existing electrical wiring for data transfer. Communication Protocols Smart meter communication protocols are essential for enabling reliable, efficient, and secure data exchange between meters, utilities, and other components of advanced metering infrastructure (AMI). These protocols address the diverse requirements of global markets, supporting various communication methods, from optical ports and serial connections to power line communication (PLC) and wireless networks. Below is an overview of key protocols, including ANSI standards widely used in North America, IEC protocols prevalent in Europe, the globally recognized OSGP for smart grid applications, and the PLC-focused Meters and More, each designed to meet specific needs in energy monitoring and management. Typical communication stacks from Smart Meter to DC IEC 62056 "IEC 62056 is the most widely adopted protocol"[37] for smart meter communication, enabling reliable, two-way data exchange within Advanced Metering Infrastructure (AMI) systems. It encompasses the DLMS/COSEM protocol for structuring and managing metering data. "It is widely used because of its flexibility, scalability, and ability to support different communication media such as Power Line Communication (PLC), TCP/IP, and wireless networks.".[37] It also supports data transmission over serial connections using ASCII or binary formats, with physical media options such as modulated light (via LED and photodiode) or wired connections (typically EIA-485).[38] ANSI C12.18 ANSI C12.18 is an ANSI Standard that describes a protocol used for two-way communications with a meter, mostly used in North American markets. The C12.18 Standard is written specifically for meter communications via an ANSI Type 2 Optical Port, and specifies lower-level protocol details. ANSI C12.19 specifies the data tables that are used. ANSI C12.21 is an extension of C12.18 written for modem instead of optical communications, so it is better suited to automatic meter reading. ANSI C12.22 is the communication protocol for remote communications.[39] OSGP The Open Smart Grid Protocol (OSGP) is a family of specifications published by the European Telecommunications Standards Institute (ETSI) used in conjunction with the ISO/IEC 14908 control networking standard for smart metering and smart grid applications. Millions of smart meters based on OSGP are deployed worldwide.[40] On July 15, 2015, the OSGP Alliance announced the release of a new security protocol (OSGP-AES-128-PSK) and its availability from OSGP vendors.[41] This deprecated the original OSGP-RC4-PSK security protocol which had been identified to be vulnerable.[42][43] Meters and More "Meters and More was created in 2010 from the coordinated work between Enel and Endesa to adopt, maintain and evolve the field-proven Meters and More open communication protocol for smart grid solutions." .[44] In 2010, the Meters and More Association was established to promote the protocol globally, ensuring interoperability and efficiency in power line communication (PLC)-based smart metering systems. Meters and More is an open communication protocol designed for advanced metering infrastructure (AMI). It facilitates reliable, high-speed data exchange over PLC networks, focusing on energy monitoring, demand response, and secure two-way communication between utilities and consumers. Unlike DLMS/COSEM, which is a globally standardized and versatile protocol supporting multiple utilities (electricity, gas, and water), Meters and More is tailored specifically for PLC-based systems, emphasizing efficiency, reliability, and ease of deployment in electricity metering. There is a growing trend toward the use of TCP/IP technology as a common communication platform for Smart Meter applications, so that utilities can deploy multiple communication systems, while using IP technology as a common management platform.[45][46] A universal metering interface would allow for development and mass production of smart meters and smart grid devices prior to the communication standards being set, and then for the relevant communication modules to be easily added or switched when they are. This would lower the risk of investing in the wrong standard as well as permit a single product to be used globally even if regional communication standards vary.[47] Server Infrastructure for Smart Meter AMI In Advanced Metering Infrastructure (AMI), the server infrastructure is crucial for managing, storing, and processing the large volumes of data generated by smart meters. This infrastructure ensures seamless communication between smart meters, utility providers, and end-users, supporting real-time monitoring, billing, and grid management. Key Components of AMI Server Infrastructure Data Concentrator A Data Concentrator Unit (DCU) aggregates data from multiple smart meters within a localized area (e.g., a neighborhood or building) before transmitting it to the central server. Data concentrators reduce the communication load on the network and help overcome connectivity challenges by acting as intermediaries between smart meters and the head-end system (HES). They typically support communication protocols like IEC 62056, DLMS/COSEM[48] Head-End System (HES) The HES is responsible for collecting, validating, and managing data received from data concentrators and smart meters. It serves as the central communication hub, facilitating two-way communication between the smart meters and the utility's central servers. The HES supports meter configuration, firmware updates, and real-time data retrieval, ensuring data integrity and security.[49] Meter Data Management System (MDMS) The MDMS is a specialized software platform that stores and processes large volumes of meter data collected by the HES. Key functions of the MDMS include data validation, estimation, and editing, as well as billing preparation, load analysis, and anomaly detection. The MDMS integrates with other utility systems, such as billing, customer relationship management (CRM), and demand response systems, to enable efficient energy management. [50] Data Analytics Data analytics for smart meters leverages machine learning to extract insights from energy consumption data. Key applications include demand forecasting, dynamic pricing, Energy Disaggregation, and fault detection, enabling optimized grid performance and personalized energy management. These techniques drive efficiency, cost savings, and sustainability in modern energy systems. "Energy Disaggregation, or the breakdown of your energy use based on specific appliances or devices",[51] is an exploratory technique for analyzing energy consumption in households, commercial buildings, and industrial settings. By using data from a single energy meter, it employs algorithms and machine learning to estimate individual appliance usage without separate monitors. Known as Non-Intrusive Load Monitoring

(NILM), this emerging method offers insights into energy efficiency, helping users optimize usage and reduce costs. While promising, energy disaggregation is still being refined for accuracy and scalability as part of smart energy management innovations.[52] Data management The other critical technology for smart meter systems is the information technology at the utility that integrates the Smart Meter networks with utility applications, such as billing and CIS. This includes the Meter Data Management system. This section may contain material not related to the topic of the article. Please help improve this section or discuss this issue on the talk page. (December 2024) (Learn how and when to remove this message) It also is essential for smart grid implementations that power line communication (PLC) technologies used within the home over a Home Area Network (HAN), are standardized and compatible. The HAN allows HVAC systems and other household appliances to communicate with the smart meter, and from there to the utility. Currently there are several broadband or narrowband standards in place, or being developed, that are not yet compatible. To address this issue, the National Institute for Standards and Technology (NIST) established the PAP15 group, which studies and recommends coexistence mechanisms with a focus on the harmonization of PLC Standards for the HAN. The objective of the group is to ensure that all PLC technologies selected for the HAN coexist as a minimum. The two leading broadband PLC technologies selected are the HomePlug AV / IEEE 1901 and ITU-T G.hn technologies.[53] Technical working groups within these organizations are working to develop appropriate coexistence mechanisms. The HomePlug Powerline Alliance has developed a new standard for smart grid HAN communications called the HomePlug Green PHY specification. It is interoperable and coexistent with the widely deployed HomePlug AV technology and with the latest IEEE 1901 global Standard and is based on Broadband OFDM technology. ITU-T commissioned in 2010 a new project called G.hnem, to address the home networking aspects of energy management, built upon existing Low Frequency Narrowband OFDM technologies. Opposition and concerns Some groups have expressed concerns regarding the cost, health, fire risk,[54] security and privacy effects of smart meters[55] and the remote controllable "kill switch" that is included with most of them. Many of these concerns regard wireless-only smart meters with no home energy monitoring or control or safety features. Metering-only solutions, while popular with utilities because they fit existing business models and have cheap up-front capital costs, often result in such "backlash". Often the entire smart grid and smart building concept is discredited in part by confusion about the difference between home control and home area network technology and AMI. The (now former) attorney general of Connecticut has stated that he does not believe smart meters provide any financial benefit to consumers,[56] however, the cost of the installation of the new system is absorbed by those customers. Security Smart meters expose the power grid to cyberattacks that could lead to power outages, both by cutting off people's electricity[57] and by overloading the grid.[58] However many cyber security experts state that smart meters of UK and Germany have relatively high cybersecurity and that any such attack there would thus require extraordinarily high efforts or financial resources.[59][60][61] The EU Cyber security Act took effect in June 2019, which includes Directive on Security Network and Information Systems establishing notification and security requirements for operators of essential services.[62] Through the Smartgrid Cybersecurity Committee, the U.S. Department of Energy published cybersecurity guidelines for grid operators in 2010 and updated them in 2014. The guidelines "...present an analytical framework that organizations can use to develop effective cybersecurity strategies..."[63] Implementing security protocols that protect these devices from malicious attacks has been problematic, due to their limited computational resources and long operational life.[64] The current version of IEC 62056 includes the possibility to encrypt, authenticate, or sign the meter data. One proposed smart meter data verification method involves analyzing the network traffic in real-time to detect anomalies using an Intrusion Detection System (IDS). By identifying exploits as they are being leveraged by attackers, an IDS mitigates the suppliers' risks of energy theft by consumers and denial-of-service attacks by hackers.[65] Energy utilities must choose between a centralized IDS, embedded IDS, or dedicated IDS depending on the individual needs of the utility. Researchers have found that for a typical advanced metering infrastructure, the centralized IDS architecture is superior in terms of cost efficiency and security gains.[64] In the United Kingdom, the Data Communication Company, which transports the commands from the supplier to the smart meter, performs an additional anomaly check on commands issued (and signed) by the energy supplier. As Smart Meter devices are Intelligent Measurement Devices which periodically record the measured values and send the data encrypted to the Service Provider, therefore in Switzerland these devices need to be evaluated by an evaluation Laboratory, and need to be certified by METAS from 01.01.2020 according to Prüfmethodologie (Test Methodology for Execution of Data Security Evaluation of Swiss Smart Metering Components). According to a report published by Brian Krebs, in 2009 a Puerto Rico electricity supplier asked the FBI to investigate large-scale thefts of electricity related to its smart meters. The FBI found that former employees of the power company and the company that made the meters were being paid by consumers to reprogram the devices to show incorrect results, as well as teaching people how to do it themselves.[66] Several hacking tools that allow security researchers and penetration testers verify the security of electric utility smart meters have been released so far.[67] Health Most health concerns about the meters arise from the pulsed radiofrequency (RF) radiation emitted by wireless smart meters.[68] Members of the California State Assembly asked the California Council on Science and Technology (CCST) to study the issue of potential health impacts from smart meters, in particular whether current FCC standards are protective of public health.[69] The CCST report in April 2011 found no health impacts, based both on lack of scientific evidence of harmful effects from radio frequency (RF) waves and that the RF exposure of people in their homes to smart meters is likely to be minuscule compared to RF exposure to cell phones and microwave ovens.[70] Daniel Hirsch, retired director of the Program on Environmental and Nuclear Policy at UC Santa Cruz, criticized the CCST report on the grounds that it did not consider studies that suggest the potential for non-thermal health effects such as latent cancers from RF exposure. Hirsch also stated that the CCST report failed to correct errors in its comparison to cell phones and microwave ovens and that, when these errors are corrected, smart meters "may produce cumulative whole-body exposures far higher than that of cell phones or microwave ovens."[71] The Federal Communications Commission (FCC) has adopted recommended Permissible Exposure Limit (PEL) for all RF transmitters (including smart meters) operating at frequencies of 300 kHz to 100 GHz. These limits, based on field strength and power density, are below the levels of RF radiation that are hazardous to human health.[72] Other studies substantiate the finding of the California Council on Science and Technology (CCST). In 2011, the Electric Power Research Institute performed a study to gauge human exposure to smart meters as compared to the FCC PEL. The report found that most smart meters only transmit RF signals 1% of the time or less. At this rate, and at a distance of 1 foot from the meter, RF exposure would be at a rate of 0.14% of the FCC PEL.[73] An indirect potential for harm to health by smart meters is that they enable energy companies to disconnect consumers remotely, typically in response to difficulties with payment. This can cause health problems to vulnerable people in financial difficulty; in addition to denial of heat, lighting, and use of appliances, there are people who depend on power to use medical equipment essential for life. While there may be legal protections in place to protect the vulnerable, many people in the UK were disconnected in violation of the rules.[74] Safety Issues surrounding smart meters causing fires have been reported, particularly involving the manufacturer Sensus. In 2012. PECO Energy Company replaced the Sensus meters it had deployed in the Philadelphia, US region after reports that a number of the units had overheated and caused fires. In July 2014, SaskPower, the province-run utility company of the Canadian province of Saskatchewan, halted its roll-out of Sensus meters after similar, isolated incidents were discovered. Shortly afterward, Portland General Electric announced that it would replace 70,000 smart meters that had been deployed in the state of Oregon after similar reports. The company noted that it had been aware of the issues since at least 2013, and they were limited to specific models it had installed between 2010 and 2012.[75] On July 30, 2014, after a total of eight recent fire incidents involving the meters, SaskPower was ordered by the Government of Saskatchewan to immediately end its smart meter program, and remove the 105,000 smart meters it had installed.[76] Privacy concerns One technical reason for privacy concerns is that these meters send detailed information about how much electricity is being used each time. More frequent reports provide more detailed information. Infrequent reports may be of little benefit for the provider, as it doesn't allow as good demand management in the response of changing needs for electricity. On the other hand, widespread reports would allow the utility company to infer behavioral patterns for the occupants of a house, such as when the members of the household are probably asleep or absent.[77] Furthermore, the fine-grained information collected by smart meters raises growing concerns of privacy invasion due to personal behavior exposure (private activity, daily routine, etc.).[20] Current trends are to increase the frequency of reports. A solution that benefits both provider and user privacy would be to adapt the interval dynamically.[78] Another solution involves energy storage installed at the household used to reshape the energy consumption profile.[79][80] In British Columbia the electric utility is government-owned and as such must comply with privacy laws that prevent the sale of data collected by smart meters; many parts of the world are serviced by private companies that are able to sell their data.[81] In Australia debt collectors can make use of the data to know when people are at home.[82] Used as evidence in a court case in Austin, Texas, police agencies secretly collected smart meter power usage data from thousands of residences to determine which used more power than "typical" to identify marijuana growing operations.[83] Smart meter power data usage patterns can reveal much more than how much power is being used. Research has demonstrated that smart meters sampling power levels at two-second intervals can reliably identify when different electrical devices are in use.[84][85][86][87][88][89][90][91] Ross Anderson wrote about privacy concerns "It is not necessary for my meter to tell the power company, let alone the government, how much I used in every half-hour period last month"; that meters can provide "targeting information for burglars"; that detailed energy usage history can help energy companies to sell users exploitative contracts; and that there may be "a temptation for policymakers to use smart metering data to target any needed power cuts."[92] Opt-out options Reviews of smart meter programs, moratoriums, delays, and "opt-out" programs are some responses to the concerns of customers and government officials. In response to residents who did not want a smart meter, in June 2012 a utility in Hawaii changed its smart meter program to "opt out".[93] The utility said that once the smart grid installation project is nearing completion, KIUC may convert the deferral policy to an opt-out policy or program and may charge a fee to those members to cover the costs of servicing the traditional meters. Any fee would require approval from the Hawaii Public Utilities Commission. After receiving numerous complaints about health, hacking, and privacy concerns with the wireless digital devices, the Public Utility Commission of the US state of Maine voted to allow customers to opt-out of the meter change at the cost of $12 a month.[94] In Connecticut, another US state to consider smart metering, regulators declined a request by the state's largest utility, Connecticut Light & Power, to install 1.2 million of the devices, arguing that the potential savings in electric bills do not justify the cost. CL&P already offers its customers time-based rates. The state's Attorney General George Jepsen was quoted as saying the proposal would cause customers to spend upwards of $500 million on meters and get few benefits in return, a claim that Connecticut Light & Power disputed.[95] Abuse of dynamic pricing Smart meters allow dynamic pricing; it has been pointed out that, while this allows prices to be reduced at times of low demand, it can also be used to increase prices at peak times if all consumers have smart meters.[96] Additionally smart meters allow energy suppliers to switch customers to expensive prepay tariffs instantly in case of difficulties paying. In the UK during a period of very high energy prices from 2022, companies were remotely switching smart meters from a credit tariff to an expensive prepay tariff which disconnects supplies unless credit has been purchased. While regulations do not permit this without appropriate precautions to help those in financial difficulties and to protect the vulnerable, the rules were often flouted.[74] (Prepaid tariffs could also be levied without smart meters, but this required a dedicated prepay meter to be installed.) In 2022, 3.2 million people were left without power at some point after running out of prepay credit.[97] Limited benefits There are questions about whether electricity is or should be primarily a "when you need it" service where the inconvenience/cost-benefit ratio of time-shifting of loads is poor. In the Chicago area, Commonwealth Edison ran a test installing smart meters on 8,000 randomly selected households together with variable rates and rebates to encourage cutting back during peak usage.[98] In Crain's Chicago Business article "Smart grid test underwhelms. In the pilot, few power down to save money.", it was reported that fewer than 9% exhibited any amount of peak usage reduction and that the overall amount of reduction was "statistically insignificant".[98] This was from a report by the Electric Power Research Institute, a utility industry think tank who conducted the study and prepared the report. Susan Satter, senior assistant Illinois attorney general for public utilities said "It's devastating to their plan......The report shows zero statistically different result compared to business as usual." [98] By 2016, the 7 million smart meters in Texas had not persuaded many people to check their energy data as the process was too complicated.[99] A report from a parliamentary group in the UK suggests people who have smart meters installed are expected to save an average of £11 annually on their energy bills, much less than originally hoped.[100] The 2016 cost-benefit analysis was updated in 2019 and estimated a similar average saving.[101] The Australian Victorian Auditor-General found in 2015 that 'Victoria's electricity consumers will have paid an estimated $2.239 billion for metering services, including the rollout and connection of smart meters. In contrast, while a few benefits have accrued to consumers, benefits realisation is behind schedule and most benefits are yet to be realised'[102] Erratic demand Smart meters can allow real-time pricing, and in theory this could help smooth power consumption as consumers adjust their demand in response to price changes. However, modelling by researchers at the University of Bremen suggests that in certain circumstances, "power demand fluctuations are not dampened but amplified instead."[103] In the media In 2013, Take Back Your Power, an independent Canadian documentary directed by Josh del Sol was released describing "dirty electricity" and the aforementioned issues with smart meters.[104] The film explores the various contexts of the health, legal, and economic concerns. It features narration from the mayor of Peterborough, Ontario, Daryl Bennett, as well as American researcher De-Kun Li, journalist Blake Levitt,[105] and Dr. Sam Milham. It won a Leo Award for best feature-length documentary and the Annual Humanitarian Award from Indie Fest the following year. UK roll-out criticism In a 2011 submission to the Public Accounts Committee, Ross Anderson wrote that Ofgem was "making all the classic mistakes which have been known for years to lead to public-sector IT project failures" and that the "most critical part of the project—how smart meters will talk to domestic appliances to facilitate demand response—is essentially ignored."[106] Citizens Advice said in August 2018 that 80% of people with smart meters were happy with them. Still, it had 3,000 calls in 2017 about problems. These related to first-generation smart meters losing their functionality, aggressive sales practices, and still having to send smart meter readings.[107] Ross Anderson of the Foundation for Information Policy Research has criticised the UK's program on the grounds that it is unlikely to lower energy consumption, is rushed and expensive, and does not promote metering competition. Anderson writes, "the proposed architecture ensures continued dominance of metering by energy industry incumbents whose financial interests are in selling more energy rather than less," and urged ministers "to kill the project and instead promote competition in domestic energy metering, as the Germans do – and as the UK already has in industrial metering. Every consumer should have the right to appoint the meter operator of their choice."[108] The high number of SMETS1 meters installed has been criticized by Peter Earl, head of energy at the price comparison website comparethemarket.com. He said, "The Government expected there would only be a small number of the first-generation of smart meters before Smets II came in, but the reality is there are now at least five million and perhaps as many as 10 million Smets I meters."[109] UK smart meters in southern England and the Midlands use the mobile phone network to communicate, so they do not work correctly when phone coverage is weak. A solution has been proposed, but was not operational as of March 2017.[109] In March 2018 the National Audit Office (NAO), which watches over public spending, opened an investigation into the smart meter program, which had cost £11bn by then, paid for by electricity users through higher bills.[110][111] The National Audit Office published the findings of its investigation in a report titled "Rolling out smart meters" published in November 2018.[112] The report, amongst other findings, indicated that the number of smart meters installed in the UK would fall materially short of the Department for Business, Energy & Industrial Strategy (BEIS) original ambitions of all UK consumers having a smart meter installed by 2020. In September 2019, smart meter rollout in the UK was delayed for four years.[113] Ross Anderson and Alex Henney wrote that "Ed Miliband cooked the books" to make a case for smart meters appear economically viable. They say that the first three cost-benefit analyses of residential smart meters found that it would cost more than it would save, but "ministers kept on trying until they got a positive result... To achieve 'profitability' the previous government stretched the assumptions shamelessly".[114] A counter-fraud officer at Ofgem with oversight of the roll-out of the smart meter program who raised concerns with his manager about many millions of pounds being misspent was threatened in 2018 with imprisonment under section 105 of the Utilities Act 2000, prohibiting disclosure of some information relevant to the energy sector, with the intention of protecting national security.[115][116] The Employment Appeal Tribunal found that the law was in contravention of the European Convention on Human Rights.[117] Main Suppliers Top ten smart electricity meters suppliers depends on the ranking method[118] Among them Landis+Gyr Itron Xylem (formerly Sensus) Sagemcom [fr] Honeywell / Elster Kamstrup A/S [da] Wasion Holdings Limited [zh] Holley Technology Ltd Gallery Newer retrofitted U.S. domestic digital electricity meter Elster REX[119] with 900 MHz[120] mesh network topology for automatic meter reading and "EnergyAxis" time-of-use metering.[121][122][123] Each local mesh networked smart meter has a hub such as this Elster A3 Type A30, which interfaces 900MHz smart meters to the metering automation server via a landline.[124] Itron OpenWay electricity Smart meter with two-way communications for remote reading in use by DTE Energy om Wikipedia, the free encyclopedia (Redirected from Electric energy) Electrical energy is the energy transferred as electric charges move between points with different electric potential, that is, as they move across a potential difference. As electric potential is lost or gained, work is done changing the energy of some system. The amount of work in joules is given by the product of the charge that has moved, in coulombs, and the potential difference that has been crossed, in volts.[1] Electrical energy is usually sold by the kilowatt hour (1 kW·h = 3.6 MJ) which is the product of the power in kilowatts multiplied by running time in hours. Electric utilities measure energy using an electricity meter, which keeps a running total of the electrical energy delivered to a customer. Electric heating is an example of converting electrical energy into thermal energy. The simplest and most common type of electric heater uses electrical resistance to convert the energy. There are other ways to use electrical energy. Electric charges moves as a current the heater element which has a potential difference between the ends: energy is transferred from the charges to the element, increasing the element's temperature and thermal energy as the charges lose potential energy. Electricity generation Main article: Electricity generation Electricity generation is the process of generating electrical energy from other forms of energy. The fundamental principle of electricity generation was discovered during the 1820s and early

1830s by the British scientist Michael Faraday. His basic method is still used today: electric current is generated by the movement of a loop of wire, or disc of copper between the poles of a magnet.[2] For electrical utilities, it is the first step in the delivery of electricity to consumers. The other processes, electricity transmission, distribution, and electrical energy storage and recovery using pumped-storage methods are normally carried out by the electric power industry.[3] Electricity is most often generated at a power station by electromechanical generators, primarily driven by heat engines fueled by chemical combustion or nuclear fission but also by other means such as the kinetic energy of flowing water and wind. There are M-Bus or Meter-Bus is a European standard (EN 13757-2 physical and link layer, EN 13757-3 application layer) for the remote reading of water, gas or electricity meters. M-Bus is also usable for other types of consumption meters, such as heating systems or water meters. The M-Bus interface is made for communication on two wires, making it cost-effective. A radio variant of M-Bus Wireless M-Bus is also specified in EN 13757–4. The M-Bus was developed to fill the need for a system for the networking and remote reading of utility meters, for example to measure the consumption of gas or water in the home. This bus fulfills the special requirements of remotely powered or battery-driven systems, including consumer utility meters. When interrogated, the meters deliver the data they have collected to a common master, such as a hand-held computer, connected at periodic intervals to read all utility meters of a building. An alternative method of collecting data centrally is to transmit meter readings via a modem. Other applications for the M-Bus such as alarm systems, flexible illumination installations, heating control, etc. are suitable. Relation to the OSI model Since no bus system was available for the requirements of meter reading, the M-Bus was developed by Horst Ziegler of the University of Paderborn in cooperation with Texas Instruments Deutschland GmbH and Techem GmbH [de]. The concept was based on the ISO-OSI Reference Model, in order to realize an open system which could use almost any desired protocol. Since the M-Bus is not a network, and therefore does not - among other things - need a transport or session layer, the levels four to six of the OSI model are empty. Therefore, only the physical, the data link, the network and the application layer are provided with functions. OSI Model Data unit Layer Standard Host layers Data 7. Application EN1434-3 6. Presentation Empty 5. Session Empty Segment/Datagram 4. Transport Empty Media layers Packet 3. Network Optional Frame 2. Data link IEC 60870 Bit 1. Physical M-Bus Physical wire and connectors M-Bus connection is called M-Bus or HAN (Home Area Network) consumer connection. M-Bus uses two-wire telephone cable (JYStY 1x2x0.8 mm or similar, 73 ohm/km, 120 nF/km) maximum length of 350 meters when using nominal transfer speeds 300 and 9600 baud. Lowering the speed up to 1000 meter cable can be used. There is no standardized connector, but RJ11 and RJ12 Modular connectors are used by meter manufacturers.[1] The master communication uses voltage signaling, where 1 (idle state, mark) is the bus nominal 36 volts, 0 (space) drops the voltage to 24 volts. As bus voltage can vary with length and load, the signal is specified as 1 for bus voltage drop less than 5.5V, 0 for drop higher than 8.2 volts. Slaves communicate by current consumption, where 1 (idle state, mark) is less than 1.5 milliamperes, 0 (space) raises current to 11-20 mA. The signal is specified as the at least 11 mA current increase. The slaves are connected via diode bridge and can use either polarity of the wires. To protect the bus against shortcircuited slaves, a 430 ohm is connected in series at each slave (or, two 215 ohm resistors, one for each wire). A M-bus load unit is 1.5 mA. Most slaves use at most this, some can need two units (3 mA). Masters can provide type-dependent number of load units, and usually visually indicate overload. Data link protocol The data link protocol is described by IEC 870-5, or its updated version, IEC 60870-5. The data are sent in serial form, at speed between 300 and 9600 bit/s (some variants may operate up to 19200 or 38400 bit/s), using one start bit, one stop bit, and even parity (8e1). The least significant bit is sent first. When sending packets ("telegrams"), there is no pause between stop and subsequent start bit. Suggested speeds are 300, 2400, 9600, and with newer hardware 38400 bit/s, while 2400 bit/s is most common. Devices with different baudrates can coexist on the same bus. Some devices use autobauding[clarification needed]. There are four kinds of packets: single character - 0xE5 - acknowledgement short frame, 5 bytes - 0x10, C-field, A-field, checksum, 0x16 - sending simple commands control frame, 9 bytes - 0x68, 0x03, 0x03, 0x68, C-field, A-field, CI-field, checksum, 0x16 oThe control frame is a long frame with no payload. long frame, 9+ bytes - 0x68, length, length, 0x68, C-field, A-field, CI-field, [0..252 payload bytes], checksum, 0x16 C-field is the control/function field. The sequence, from bit 7, is: bit 7: 0 bit 6: 1 for master-to-slave, 0 for slave reply bit 5: ofrom master: FCB, frame count bit - indicates request to repeat message when reply was not received ofrom slave: ACD, access demand - 1 when slave wishes to transmit class-1 data, priority data (class-2 data is ordinary non-priority) - the master then should request the class-1 data transfer bit 4: ofrom master: FCV, frame count valid - when 0, slave should ignore FCB ofrom slave: DFC, data flow control - when 1, slave can not accept further data bit 3,2,1,0: F3,F2,F1,F0, function code - eg. for short frame, 0 is for initialization of slave, xA is for class-1 (priority) data read, xB is for class-2 (normal) read. For long/control frame, x3 is sending data to slave, x8 is data reply from slave. A-field is the address field. It is a 8-bit number: 0x00 - unset address, assigned at manufacture time, some meters fixed at this 0x01..0xFA - slave addresses 0xFB, 0xFC - reserved 0xFD - "broadcast" for secondary addressing, addressing done on network layer instead of on data link layer 0xFE - test broadcast, all slaves reply (collisions will happen, use for testing with a single slave; slave replies with its own address in A-field), also possible to use when there is only one slave on the bus 0xFF - broadcast, no reply from slaves CI-field is the control information field. Defined at application layer.[2] Length field in control/long frame is sent twice. Both bytes have to be equal. Minimum value is 0x03, as C-field, A-field and CI-field are mandatory parts of the payload. Slaves respond only to correctly formed packets that match their address. Any fault is indicated by lack of response. Absence of response is defined as no response for 330 bit periods (35 ms for 9600 bit/s, 1.1 s for 300 bit/s) plus 50 ms.[3] Numerical values are usually sent in BCD format.[4] Electric energy consumption is energy consumption in the form of electrical energy.[2] About a fifth of global energy is consumed as electricity: for residential, industrial, commercial, transportation and other purposes.[2] The global electricity consumption in 2022 was 24,398 terawatt-hour (TWh), almost exactly three times the amount of consumption in 1981 (8,132 TWh).[3][failed verification] China, the United States, and India accounted for more than half of the global share of electricity consumption. Japan and Russia followed with nearly twice the consumption of the remaining industrialized countries.[3] Overview Electric energy is most often measured either in joules (J), or in watt hours (W·h).[4] 1 W·s = 1 J 1 W·h = 3,600 W·s = 3,600 J 1 kWh = 3,600 kWs = 1,000 Wh = 3.6 million W·s = 3.6 million J Electric and electronic devices consume electric energy to generate desired output (light, heat, motion, etc.). During operation, some part of the energy is lost depending on the electrical efficiency.[5] Electricity has been generated in power stations since 1882.[6] The invention of the steam turbine in 1884 to drive the electric generator led to an increase in worldwide electricity consumption.[7] In 2022, the total worldwide electricity production was nearly 29,000 TWh.[8] Total primary energy is converted into numerous forms, including, but not limited to, electricity, heat and motion.[9] Some primary energy is lost during the conversion to electricity, as seen in the United States, where a little more than 60% was lost in 2022.[9] Electricity accounted for more than 20% of worldwide final energy consumption in 2022, with oil being less than 40%, coal being less than 9%, natural gas being less than 15%, biofuels and waste less than 10%, and other sources (such as heat, solar electricity, wind electricity and geothermal) being more than 5%.[10] The total final electricity consumption in 2022 was split unevenly between the following sectors: industry (42.2%), residential (26.8%), commercial and public services (21.1%), transport (1.8%), and other (8.1%; i.e., agriculture and fishing).[10] In 1981, the final electricity consumption continued to decrease in the industrial sector and increase in the residential, commercial and public services sectors.[10] A sensitivity analysis on an adaptive neuro-fuzzy network model for electric demand estimation shows that employment is the most critical factor influencing electrical consumption.[11] The study used six parameters as input data, employment, GDP, dwelling, population, heating degree day and cooling degree day, with electricity demand as output variable.[11] World electricity consumption See also: List of countries by electricity consumption The table lists 45 electricity-consuming countries, which used about 22,000 TWh. These countries comprise about 90% of the final consumption of 190+ countries. The final consumption to generate this electricity is provided for every country. The data is from 2022.[8][12] In 2022, OECD's final electricity consumption was over 10,000 TWh.[3] In that year, the industrial sector consumed about 42.2% of the electricity, with the residential sector consuming nearly 26.8%, the commercial and public services sectors consuming about 21.1%, the transport sector consuming nearly 1.8%, and the other sectors (such as agriculture and fishing) consuming nearly 8.1%.[10] In recent decades, the consumption in the residential and commercial and public services sectors has grown, while the industry consumption has declined.[3] More recently, the transport sector has witnessed an increase in consumption with the growth in the electric vehicle market.[3] Electricity consumption of selected countries (OECD, 2022)[8][12] Rank Country Final consumption (TWh) Population (millions) Per capita consumption (MWh) — WORLD 24,398 7,960 3.07 1 China 7,214 1,443 5 2 United States 4,272 336 12.71 3 India 1,403 1,401 1 4 Japan 1,132 126 8.98 5 Russia 934 146 6.4 6 Canada 595 38.1 15.62 7 South Korea 553 51.2 10.8 8 Brazil 550 215 2.56 9 Germany 539 82.2 6.55 10 France 463 67.7 6.84 11 Saudi Arabia 317 36 8.81 12 United Kingdom 312 68.4 4.56 13 Indonesia 308 276 1.17 14 Italy 300 60 5 15 Mexico 296 127 2.33 16 Iran 280 83.3 3.36 17 Turkey 264 84 3.14 18 Taiwan 257 23.8[13] 10.8 19 Spain 246 46.8 5.26 20 South Africa 233 60 3.88 21 Australia 225 26 8.65 22 Vietnam 220 100 2.2 23 Thailand 203 70 2.9 24 Malaysia 170 33.2 5.12 25 Egypt 168 105 1.6 26 Poland 156 37.5 4.17 27 Ukraine 154 43.2 3.56 28 Sweden 147 10.2 14.4 29 Argentina 138 46 3 30 United Arab Emirates 136 10.2 13.33 31 Norway

128 5.5 23.27 32 Pakistan 124 226 0.55 33 Netherlands 120 17.5 6.86 34 Belgium 98 11.8 8.33 35 Finland 90 5.6 16.03 36 Chile 84 19.2 4.38 37 Kazakhstan 75 18.7 4 38 Austria 73 9.1 8.02 39 Venezuela 72 28.1 2.56 40 Algeria 66 44 1.5 41 Switzerland 62 9.3 6.67 42 Israel 59 9.4 6.27 43 New Zealand 43 5 8.6 44 Denmark 35 5.8 6.02 45 Ireland 28 5.5 5.1 Consumption per capita The final consumption divided by the number of inhabitants provides a country's consumption per capita. In Western Europe, this is between 4 and 8 MWh/year.[8] (1 MWh = 1,000 kWh) In Scandinavia, the United States, Canada, Taiwan, South Korea, Australia, Japan and the United Kingdom, the per capita consumption is higher; however, in developing countries, it is much lower.[8] The world's average was about 3 MWh/year in 2022.[8] Very low consumption levels, such as those in Philippines, not included in the table, indicate that many inhabitants are not connected to the electricity grid, and that is the reason why some of the world's most populous countries, including Nigeria and Bangladesh, do not appear in the table.[12] Electricity generation and GDP The table lists 30 countries, which represent about 76% of the world population, 84% of the world GDP, and 85% of the world electricity generation.[8][12][14][15] Productivity per electricity generation (concept similar to energy intensity) can be measured by dividing GDP over the electricity generated. The data is from 2019. [8][12][14][15] Electricity generation (2019) and GDP (PPP) (2019) Country Population, millions rank* GDP (PPP), billions (USD) rank* GDP (PPP) per capita rank* Electricity generation (GWh/yr) rank* GDP (PPP) / kWh* China 1,407 1 $14,280 2 $10,149 15 7,503,428 1 $1.9 India 1,366 2 $2,871 6 $2,102 26 1,603,675 3 $1.8 USA 328 3 $21,433 1 $65,345 1 4,411,159 2 $4.9 Indonesia 270.6 4 $1,119 16 $4,135 20 278,942 17 $4.0 Brazil 211 6 $1,878 9 $8,900 18 626,328 7 $3.0 Pakistan 216.6 5 $279 26 $1,288 28 138,626 24 $2.0 Bangladesh 163 8 $302 25 $1,853 27 89,672 27 $3.4 Nigeria 201 7 $448 22 $2,229 25 33,552[16] 28 $13.4 Russia 144 9 $1,687 11 $11,715 14 1,118,143 4 $1.5 Japan 126 11 $5,149 3 $40,865 7 1,030,286 5 $5.0 Mexico 127.6 10 $1,269 15 $9,945 16 322,584 13 $3.9 Philippines 108 13 $377 23 $3,491 21 106,041 26 $3.6 Vietnam 96.5 15 $262 27 $2,715 24 227,461 21 $1.2 Ethiopia 112 12 $96 29 $857 29 14,553[17] 29 $6.6 Egypt 100.4 14 $303 24 $3,018 23 200,563 22 $1.5 Germany 83 18 $3,888 4 $46,843 4 609,406 8 $6.4 Turkey 83.5 17 $761 19 $9,114 17 303,898 15 $2.5 DR Congo 86.8 16 $50 30 $576 30 9,990[18] 30 $5.0 Iran 83 19 $258 28 $3,108 22 318,696 14 $0.8 Thailand 69.6 20 $544 21 $7,816 19 186,503 23 $2.9 France 67.3 21 $2,729 7 $40,550 8 562,842 10 $4.8 UK 66.8 22 $2,879 5 $43,099 6 324,761 12 $8.9 Italy 59.7 23 $2,009 8 $33,652 9 293,853 16 $6.8 South Korea 51.7 24 $1,651 12 $31,934 10 585,301 9 $2.8 Spain 47.1 25 $1,393 13 $29,575 11 267,501 19 $5.2 Canada 37.6 26 $1,742 10 $46,330 5 648,676 6 $2.7 Saudi Arabia 34.3 27 $793 18 $23,120 13 343,661 11 $2.3 Taiwan 23.6[13] 28 $605[19] 20 $25,636 12 274,059 18 $2.2 Australia 25.4 29 $1,392 14 $54,803 2 265,901 20 $5.2 Netherlands 17.3 30 $910 17 $52,601 3 121,062 25 $7.5 World 7,683 — $87,555 — $11,395 — 27,044,191 — $3.5 Population data is from the World Bank[12] GDP data is from the World Bank[14] Electricity data is from BP Global[15] rank* of Population, GDP, and Electricity generation are rankings within this list GDP (PPP) / kWh is the amount of GDP (PPP) (USD) produced per kilowatt-hour Electricity consumption by sector The table below lists the 15 countries with the highest final electricity consumption, which comprised more than 70% of the global consumption in 2022.[8] Electricity final consumption by sector (2022) Country/ Geographical region Total (TWh) Industry Transport Commercial /Public services Residential Agriculture /Forestry Other China 7,214 59.9% 2.4% 7.3% 16.4% 2.2% 11.8% United States 4,272 19.9% 0.6% 35.2% 37.4% 2.1% 4.8% India 1,403 37.7% 11.2% 7.8% 21.7% 15.9% 5.7% Japan 1,132 37% 1.8% 33.7% 27.1% 0.3% 0.1% Russia 934 44.8% 11.1% 20.4% 21.1% 2.5% 0.1% Canada 595 35.9% 1.5% 28.1% 32.5% 2.0% 0% South Korea 553 52.3% 0.6% 31.4% 12.7% 2.5% 0.5% Brazil 550 38.3% 0.7% 27.3% 27.7% 6% 0% Germany 539 44.8% 2.3% 26.4% 25.4% 1.1% 0% France 463 26.9% 2.4% 31.5% 37% 1.9% 0.3% Saudi Arabia 317 33.7% 3.9% 28.3% 25% 4.1% 5% United Kingdom 312 18.3% 2.2% 38.2% 39.1% 2% 0.2% Italy 300 30% 5% 32% 30% 1% 2% Mexico 296 29% 4% 33% 30% 3% 1% Iran 280 24% 6% 37% 25% 5% 3% World 24,398 42.2% 1.8% 21.1% 26.8% 3.1% 5% Electricity outlook This section needs to be updated. Please help update this article to reflect recent events or newly available information. (February 2022) Looking forward, increasing energy efficiency will result in less electricity needed for a given demand in power, but demand will increase strongly on the account of:[20] Economic growth in developing countries,[20] and Electrification of transport and heating. Combustion engines are replaced by electric drive and for heating less gas and oil, but more electricity is used, if possible with heat pumps.[20] The International Energy Agency expects revisions of subsidies for fossil fuels which amounted to $550 billion in 2013, more than four times renewable energy subsidies. In this scenario,[21] almost half of the increase in 2040 of electricity consumption is covered by more than 80% growth of renewable energy. Many new nuclear plants will be constructed, mainly to replace old ones. The nuclear part of electricity generation will increase from 11 to 12%. The renewable part goes up much more, from 21 to 33%. The IEA warns that in order to restrict global

warming to 2 °C, carbon dioxide emissions[22] must not exceed 1000 gigaton (Gt) from 2014. This limit is reached in 2040 and emissions will not drop to zero ever. The World Energy Council[23] sees world electricity consumption increasing to more than 40,000 TWh/a in 2040. The fossil part of generation depends on energy policy. It can stay around 70% in the so-called "Jazz" scenario where countries rather independently "improvise" but it can also decrease to around 40% in the "Symphony" scenario if countries work "orchestrated" for more climate friendly policy. Carbon dioxide emissions, 32 Gt/a in 2012, will increase to 46 Gt/a in Jazz but decrease to 26 Gt/a in Symphony. Accordingly, until 2040 the renewable part of generation will stay at about 20% in Jazz but increase to about 45% in Symphony. An EU survey conducted on climate and energy consumption in 2022 found that 63% of people in the European Union want energy costs to be dependent on use, with the greatest consumers paying more. This is compared to 83% in China, 63% in the UK and 57% in the US.[24][25] 24% of Americans surveyed believing that people and businesses should do more to cut their own usage (compared to 20% in the UK, 19% in the EU, and 17% in China).[26][27] Nearly half of those polled in the European Union (47%) and the United Kingdom (45%) want their government to focus on the development of renewable energies. This is compared to 37% in both the United States and China when asked to list their priorities on energy.[26][28][29] The United States is on track to break electricity consumption records in 2025 and 2026, according to the U.S. Energy Information Administration's (EIA) Short-Term Energy Outlook, released in February 2025. With demand from data centers powering artificial intelligence and cryptocurrency operations, alongside rising electricity use in homes and businesses for heating and transportation, the EIA projects total power consumption will hit 4,179 billion kilowatt-hours (kWh) in 2025 and 4,239 billion kWh in 2026—both surpassing the current record of 4,082 billion kWh set in 2024. The forecasted increase can be broken down as follows: residential electricity sales will climb to 1,524 billion kWh in 2025, commercial demand to 1,458 billion kWh, and industrial usage to 1,054 billion kWh. This would mark new highs for the commercial sector, which set its current record of 1,421 billion kWh in 2024, and for residential consumers, whose last peak was 1,509 billion kWh in 2022. Meanwhile, the industrial sector—historically the largest consumer of electricity—remains just below its all-time high of 1,064 billion kWh set in 2000. As AI, cryptocurrency mining, and electrification continue to drive demand, the U.S. power grid faces mounting pressure to keep pace with this record surge in electricity consumption.[30] Topic 2 experimental company theory practical 2.1 .Overview : Keyword description Update Regarding Your Application Inbox Eaton TalentHub 11:43 AM (1 hour ago) to me Hi Fiston, Thank you for applying for the position of Area Sales Manager - Industrial Sales – 40445. We appreciate you considering a career at Eaton. After careful review, we have decided to move forward with other candidates who more closely match the current needs for this team and position. We know that messages like this are disappointing, but we really hope you continue to pursue other opportunities at Eaton. Be sure to check out Eaton.com/careers, where you can find all our open jobs and set up a job alert. Thank you for your interest in Eaton and wish you all the best! 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33335 Sep 28, 2024 No Longer Under Consideration Johannesburg, Gauteng, ZAF, 1619 Lead Design Engineer 33175 Sep 22, 2024 No Longer Under Consideration Louisville, Kentucky, USA, 40299 Field Services Engineer - UPS 32511 Sep 10, 2024 No Longer Under Consideration Johannesburg, Gauteng, ZAF, 1619 Senior Field Service Representative 31161 Sep 5, 2024 No Longer Under Consideration Nashville, Tennessee, USA, 37211 Utility Service Sales Specialist 32009 Sep 5, 2024 No Longer Under Consideration Charlotte, North Carolina, USA, 28269 Senior Field Service Representative 31188 Aug 29, 2024 No Longer Under Consideration Nashville, Tennessee, USA, 37211 Skip to main content Home My Jobs Search Jobs 0 results FT My Applications Applications Saved Jobs Showing 53 Jobs Field Service Engineer 30764 Aug 29, 2024 Job Filled - Other Candidate Selected RIYADH, Riyad, SAU, 12482 Technical Services Engineering MFG Technician 30256 Aug 25, 2024 Job Filled - Other Candidate Selected Arecibo, Puerto Rico, USA, 00612 Commercial Finance Manager 31056 Aug 18, 2024 No Longer Under Consideration Johannesburg, Gauteng, ZAF, 1619 Key Account Manager - Data Centre Accounts 31211 Aug 18, 2024 No Longer Under Consideration Johannesburg, Gauteng, ZAF, 1619 Engineering Manager - Power Electronics CoE 24619 Jun 25, 2024 No Longer Under Consideration Titchfield, GBR, PO14 4QA Field Service Engineer - UPS 26849 May 29, 2024 No Longer Under Consideration Johannesburg, Gauteng, ZAF, 1619 Power Systems Engineering Specialist (Expert) 25412 May 19, 2024 No Longer Under Consideration Milton, Ontario, CAN, L9T 5C3 Manager Engineering Product Design Connected Solutions 25058 May 19, 2024 No Longer Under Consideration Santo Domingo, DOM Field Service Engineer - UPS 26105 May 19, 2024 No Longer Under Consideration Cape Town, ZAF, 7550 Service Centre Helpdesk Coordinator 20686 Mar 6, 2024 No Longer Under Consideration Johannesburg, Gauteng, ZAF, 1619 Field Services Engineer - UPS 20228 Mar 2, 2024 No Longer Under Consideration Durban, ZAF, 4017 Field Services Engineer - UPS 19852 Feb 10, 2024 No Longer Under Consideration Cape Town, ZAF, 7550 Quality Auditor, Training program, 3rd Shift 19275 Feb 9, 2024 Processed Rumford, Rhode Island, USA, 02916 Lead Power Systems Engineer 19197 Jan 31, 2024 No Longer Under Consideration El Paso, Texas, USA, 79912 Product Manager - Electrical Working Training & Remote Services 18926 Jan 31, 2024 No Longer Under Consideration Moon Township, Pennsylvania, USA, 15108 Finance Early Talent Leadership Development Program (m/w/d) 18647 Jan 31, 2024 No Longer Under Consideration Bonn, DEU, 53115 Finance Early Talent Leadership Development Program 18817 Jan 31, 2024 No Longer Under Consideration Budapest, HUN, 1123 Site Manager South Africa - Customer Projects 12131 Dec 16, 2023 No Longer Under Consideration Johannesburg, Gauteng, ZAF, 1619 Engineering Technician - Mechanical 13241 Dec 11, 2023 No Longer Under Consideration Wilsonville, Oregon, USA, 97070-8247 Lead Engineer Power Conversion 14106 Dec 10, 2023 No Longer Under Consideration Bonn, DEU, 53115 Powered by #WhatsNextForYou Skip to main content Home My Jobs Search Jobs 0 results FT My Applications Applications Saved Jobs Showing 53 Jobs Senior Power Electronics HW Engineer 5488 Dec 10, 2023 No Longer Under Consideration Bonn, DEU, 53115 Mechanical Design Engineer - Electrical Vehicle (m/w/d) 14843 Dec 10, 2023 No Longer Under Consideration Bonn, DEU, 53115 Manager Engineering - Engineering Center (Eplan) ESS EMEA 12431 Dec 10, 2023 No Longer Under Consideration Hengelo, NLD, 7559 Senior Electrical Project Engineer 15841 Dec 5, 2023 Job Filled - Other Candidate Selected Dublin, IRL, 4 Applications Engineer 13964 Dec 5, 2023 No Longer Under Consideration Mascot, New South Wales, AUS, 2020 Project Management Engineer 10396 Dec 5, 2023 No Longer Under Consideration Selangor, MYS, 46050 Service Engineer - Power Quality 4449 Dec 3, 2023 No Longer Under Consideration Warszawa, Mazowieckie, POL, 02555 Internship: Engineering Summer - Lincoln, IL 11161 Dec 3, 2023 No Longer Under Consideration Lincoln, Illinois, USA, 62656 Senior Electrical Engineer 13779 Dec 3, 2023 No Longer Under Consideration Raleigh, North Carolina, USA, 27616 Electrical Tender Engineer 12618 Dec 3, 2023 No Longer Under Consideration New Cairo City, EGY, 11835 Project Management Leader South Africa - Customer Projects 12134 Dec 1, 2023 No Longer Under Consideration Johannesburg, Gauteng, ZAF, 1619 Project Manager South Africa - Customer Projects 12130 Dec 1, 2023 No Longer Under Consideration Johannesburg, Gauteng, ZAF, 1619 Field Service Engineer - UPS 15094 Dec 1, 2023 No Longer Under Consideration Durban, ZAF, 4017 Training Transcript 4. 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Course code- ETN_ATLTR_A25 Course Name - Assessing Talent (LeaderX Talent Review Webinars) For EMEA Start Date: 4/28/2025 10:00:00 AM CEST End Date: 4/28/2025 11:00:00 AM CEST Facility and Location: Location: Virtual Instructor Led Training Facility: (VILT) Completion notification and survey for Surge Solutions Inbox eatonuniversityalerts@eaton.com Sat, Feb 22, 12:30 PM (22 hours ago) to me Dear tshingombe tshitadi, Congratulations on the successful completion of: Activity Name: Surge Solutions Completion Date: 2/22/2025 5:28:37 AM EST Important: To help us improve this course, please complete this short survey (optional). We look forward to serving your future development needs. Thank you, Eaton University Registration confirmation for Arc Flash Hazards Assessment and Protection Device Coordination Webinar Inbox eatonuniversityalerts@eaton.com Sat, Feb 22, 12:25 PM (22 hours ago) to me Powered by EatonUniversity Registration Confirmation Notification Dear tshingombe tshitadi, You have been successfully registered for the below activity. Course code- EDUCYMEAFHA Course Name - Arc Flash Hazards Assessment and Protection Device Coordination Webinar User Notes and login details: Please do not reply to this system generated email. For any questions or assistance, open a service request with Eaton University. To open a service request, open JOE> click on Employee Center > Search "Eaton University" and login your request. (ensure to have active JOE and OKTA). When you have completed this activity, you will receive a completion email that includes a link to complete a survey. We greatly appreciate any feedback you can provide to help us improve the course. Thanks and Regards, EatonUniversity Registration confirmation for Power press Training Module 1 - PPE & Housekeeping Inbox eatonuniversityalerts@eaton.com Sat, Feb 22, 12:20 PM (22 hours ago) to me Powered by EatonUniversity * Registration Confirmation Notification * Dear tshingombe tshitadi, You have been successfully registered for the below activity. Course code- ETN_PPTM1 Course Name - Power press Training Module 1 - PPE & Housekeeping Instructions to access 1. Open or login to JOE Homepage 2. Select “Eaton University Classes & Registration” from the “My Applications” section. 3. Once the Eaton University Classes & Registration homepage opens, scroll down to the “To Do” section to locate the course. 4. Please click on start button to launch the course. Important To ensure successful completion of an eLearning course:

•Access Eaton University from an Eaton location, or if you are logging in remotely, use a high-speed internet connection. •Use IE11 in compatibility mode and disable any pop-up blockers. •Carefully follow course exit instructions. User Notes: When you have completed this activity, you will receive a completion email that includes a link to complete a survey. We greatly appreciate any feedback you can provide to help us improve the course. Thanks and Regards, EatonUniversity Please do not reply to this system generated Registration confirmation for Power press Training Module 1 - PPE & Housekeeping Inbox eatonuniversityalerts@eaton.com Sat, Feb 22, 12:20 PM (22 hours ago) to me Powered by EatonUniversity * Registration Confirmation Notification * Dear tshingombe tshitadi, You have been successfully registered for the below activity. Course code- ETN_PPTM1 Course Name - Power press Training Module 1 - PPE & Housekeeping Instructions to access 1. Open or login to JOE Homepage 2. Select “Eaton University Classes & Registration” from the “My Applications” section. 3. Once the Eaton University Classes & Registration homepage opens, scroll down to the “To Do” section to locate the course. 4. Please click on start button to launch the course. Important To ensure successful completion of an eLearning course: •Access Eaton University from an Eaton location, or if you are logging in remotely, use a high-speed internet connection. •Use IE11 in compatibility mode and disable any pop-up blockers. •Carefully follow course exit instructions. User Notes: When you have completed this activity, you will receive a completion email that includes a link to complete a survey. We greatly appreciate any feedback you can provide to help us improve the course. Completion notification and survey for Functional Skills Workshop: Human Resources [eLearning] Inbox eatonuniversityalerts@eaton.com Fri, Feb 21, 12:35 PM (2 days ago) to me Powered by EatonUniversity Activity Completion Notification Dear tshingombe tshitadi, Congratulations on the successful completion of: Activity Code: ETNFRFSWHR_EL Activity Name: Functional Skills Workshop: Human Resources [eLearning] Completion Date: 2/21/2025 5:30:26 AM EST Important: To help us improve this course, please complete this short survey (optional). Wishing to share the accomplishments with your friends, colleagues, and family? If yes, 1. Click here to download the certificate of completion in PDF format. Note: An active JOE (refresh JOE if it has been open for a while) session must be opened to access the download link. 2. Login to your social media platforms (Viva Engage (Yammer), LinkedIn, Twitter, Instagram, Facebook) 3. 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To open a service request, open JOE> click on HR Services Catalog (Employee Center) > Search "Eaton University" and login your request. (ensure to have active JOE and OKTA). Back-up power, UPS, surge & IT power distribution Clutches and brakes Conduit, cable and wire management Cylinders Differentials and traction control Electrical circuit protection Electric vehicles and EV charging Energy storage systems Engine solutions Filtration solutions Fuel systems, emissions and components Golf grips Hose, tubing, fittings & connectors Industrial controls, drives, automation & sensors Lighting & controls Low-voltage power distribution & control systems Medium voltage power distribution & control systems Motors & generators Process safety, automation, test & measurement Pumps Safety, security and emergency communications Server racks, enclosures & airflow management Steering systems Support systems Transmissions Utility & grid solutions Valves Vehicle controls, automation & power management Wiring devices & connectivity Build a data center that fits your business needs Whether your infrastructure is a single network closet or hyperscale, our data center solutions can help you power a more efficient, sustainable and secure data center. Explore the path that best fits your operational needs. Applications Network closet Server room Data center white space Facility infrastructure Data center types Small business Medium to larger enterprise Multi-tenant and colocation Hyperscale Design, build and operate more sustainable data centers Realize your decarbonization goals and increase efficiency with solutions and services that enable you to implement, manage and monitor power systems across your data center operations. Our EnergyAware UPS backup power and Brightlayer Data Centers software suite allow you to integrate renewables and make more effective energy decisions with data. Reduce risk with safety and security built in Keep your data, equipment and people safe with predictive security solutions backed by our industry-leading secure-by-design approach, internationally-recognized cybersecurity standards and compliance best practices. From arc flash protection to UL/IEC cybersecurity accreditation, safety and security is built into the foundation of everything we make. Scale easier and get to market faster Realize the value of your investment sooner with accelerated, data-driven design and project management services, easy implementation, pre-tested solutions and expert support. Lower costs, increase revenue and ensure always-on reliability Reduce total cost of ownership and open new revenue streams with flexible, reliable power solutions that support the bi-directional flow of energy and enable you to sell power back to the grid. All while maintaining constant uptime. Knowledge center Turn information into insights. Access our Knowledge center and explore success stories, white papers and more to take your data center into the future. Success story Building data centers to exceed big expectations } Success story Building data centers to exceed big expectations Data center Visualize our solutions in our 3D environment } Data center Visualize our solutions in our 3D environment An explosion 4x hotter than the sun The mere drop of a tool or accidental contact with electrical systems can set off an arc flash and instantly generate an energy explosion releasing temperatures in excess of 36,000°F. That's four times hotter than the sun. Why arc flashes occur An arc flash is the explosive energy released when an electrical fault, for instance a short circuit, causes an arc. The dangers associated with an arc flash event include heat, flying debris, sound, UV radiation and more. 2 3 5 7 6 4 1 Power intensive environments are especially vulnerable In heavy power, continuous operation industries, arc flash poses a very real threat. Environments operating with 125 kVA or larger transformers call for special safety measures. Protecting personnel and equipment is everyone's responsibility. 8 Employees require education Electrical workers must be trained and should understand the risks of arc flash safety. This includes reading and understanding arc flash labels and wearing the proper personal protective equipment (PPE) to perform energized work. Codes and standards are always changing and it is imperative that your organization be in compliance. Arc flash labels provide advance warning Arc flash labels indicate two key pieces of information: The expected incident energy (measured in calories per cm2)—at a working distance of 18 inches or 24 inches—which drives the proper PPE required for protection. And the distance a worker without PPE must work to avoid a non-curable burn (typically measured in feet). Avoiding electrical disasters Time and distance are the most controllable variables reducing the risk of arc flash issues. Reducing the time that an event persists by tripping a breaker or blowing a fuse significantly reduces the arc flash incident energy. Increasing distance to the arc flash by remote operation, or with closed doors or protective barriers, protects workers in case an event occurs. Better equipment can help Installing the right equipment can help mitigate arc flash hazards. Specially designed low voltage motor control centers (MCCs) and switchgear can reduce the probability of electrical shock and arc flash energy during maintenance. As powerful as an 8-stick dynamite blast A 10,000A arc on a 480-volt circuit can have the explosive force of eight (8) sticks of dynamite. Another example of the energy in an arc flash: copper expands at 67,000 times its volume during an arc flash event—a small, pea-sized piece of copper would expand to fill the volume of a railroad car! 9 10 Good safety optimizes operational efficiency A sound safety policy incorporating arc flash safety solutions will protect your people and equipment, minimizing risk and increasing uptime. Human error is often to blame The most common cause of electrical accidents is human error. And the majority of those mistakes occur during routine maintenance of power system equipment or troubleshooting controls. Follow the Charge » to consider when designing your data center 10 THINGS ABOUT ARC FLASH SAFETYEach year, Eaton is performing discharge tests for over 300 000 batteries in Finland, where the EMEA UPS factory is located, to guarantee the safety and the functionality of the complete battery system. Eaton has a performing battery approval process, that leads to utilizing only the premium batteries on the market. In addition, regular audits are performed in all the facilities of the approved battery suppliers of Eaton Battery replacement service Batteries are the core element of any critical power protection system, hence they are assuring the backup time delivery. Most frequent cause of unplanned outages is premature end of life of few battery blocks. Handling batteries without proper training can lead to disastrous results of full UPS system investment 30-80% + - Continous quality monitoring Eaton is utilizing millions of batteries per year for UPS applications globally. Battery quality indeed plays the most critical role in battery selection criteria. >300 000 BATTERIES>1 000 000 Batteries utilized globally TESTED FOR EATON 3PH UPS IN EMEA PER YEAR As identical as possible battery performance between each battery blocks in the same string is crucial for the battery lifetime and battery string performance. In the graphs there are real test results from the same discharge test for 20 blocks of lower quality and 20 blocks of high quality batteries. With lower quality batteries there is much higher dispersion in the graphs than with high quality batteries. Eaton EMEA 3ph UPS service Good quality battery example Low quality battery example End of discharge Time Voltage Time Voltage End of discharge Changes to the products, to the information contained in this document, and to prices are reserved; so are errors and omissions. Only order confirmations and technical documentation by Eaton is binding. Photos and pictures also do not warrant a specific layout or functionality. Their use in whatever form is subject to prior approval by Eaton. The same applies to Trademarks (especially Eaton, Moeller, and Cutler-Hammer). The Terms and Conditions of Eaton apply, as referenced on Eaton Internet pages and Eaton order confirmations.Follow us on social media to get the latest product and support information.Eaton EMEA Headquarters Route de la Longeraie 7 1110 Morges, Switzerland Eaton.com © 2022 Eaton All Rights Reserved Publication No. SA161013EN June 2022Eaton is a registered trademark. All other trademarks are property of their respective owners. Safety ensured With over 50 years of experience in qualifying batteries for UPS applications, Eaton is replacing more than 200 000 blocks every year in EMEA. Eaton field service engineers and authorized partners are trained to perform the battery replacement according to the required safety procedures. In addition, Eaton's trained personnel is able to set and operate UPS and battery according to the site specific requirements, like environmental temperature and humidity, and Eaton UPS features like ABM, ESS and VMMS. This is crucial for safety and optimal UPS system performance. As an active steward of the environment, Eaton guarantees an efficient disposal of the end-of-life batteries. To benefit from battery replacement and other features, Eaton offers Service Level Agreements for maintaining the condition of your UPS to ensure its continuous performance while allowing you to accurately plan your budget. For more information about UPS services please visit https://www.eaton.com/gb/en-gb/services.html >200 000 BLOCKS REPLACED PER YEAR Years of expertise with UPS batteries 50+ >4000 A can be delivered from a battery cabinet ABM A correct set-up of the charging method promotes battery life Relevance A-Z Z-A Filters News and insights (3) Product (26) Resources (289) Multi-mode (6) Online (7) 13-19 kVA (2) 161-400 kVA (4) 20-40 kVA (5) 401-1200 kVA (3) 41-80 kVA (4) Data centre (6) Marine (2) Network closet (1) Server room (2) End of row (3) Facility level (3) Horizontal (2) Mounted with UPS (1) Tower (7) Basic (2) Configurable (1) Managed (1) Metered input (1) Switched (1) Single phase (2) Three phase (7) Articles (1) Brochures (48) Catalogues (33) Infographics and listicles (2) Presentations (1) Application notes (2) Certification reports (18) Drawings (45) Product notifications (1) Installation instructions (25) Eaton 93PM G2 UPS https://www.eaton.com/za/en-gb/catalog/backup-power-ups-surge-it-power-distribution/eaton-93pm-generation-2-ups.html Models Resources Power Xpert 9395P UPS https://www.eaton.com/za/en-gb/catalog/backup-power-ups-surge-it-power-distribution/power-xpert-9395P.html Models Resources Eaton 93PM UPS 30-500 kVA https://www.eaton.com/za/en-gb/catalog/backup-power-ups-surge-it-power-distribution/eaton-93pm-ups-emea.html Models Resources Eaton 93PS Marine UPS https://www.eaton.com/za/en-gb/catalog/backup-power-ups-surge-it-power-distribution/eaton-93ps-marine.html Models Resources Uninterruptible power supply (UPS) FAQs 09/04/2019 https://www.eaton.com/za/en-gb/products/backup-power-ups-surge-it-power-distribution/backup-power-ups/uninterruptible-power-supply-faq.html Eaton 93E UPS https://www.eaton.com/za/en-gb/catalog/backup-power-ups-surge-it-power-distribution/eaton93e-ups-emea.html Models Resources Eaton 9PHD Marine UPS https://www.eaton.com/za/en-gb/catalog/backup-power-ups-surge-it-power-distribution/eaton-9phd-marine-ups-emea.html Models Resources UPS buying guide | Power infrastructure for edge computing environments https://www.eaton.com/za/en-gb/products/backup-power-ups-surge-it-power-distribution/backup-power-ups/ups-buying-guide-power-infrastructure-for-compute-edge.html 9390 UPS Electrical equipment life extension and modernisation services (ELEM) https://www.eaton.com/za/en-gb/services/modernization-services/9390-ups-equipment-life-extension-and-modernization-services--el.html 93PM Gen2 UPS | Toy Force I Data Centre Solutions https://www.eaton.com/za/en-gb/company/partnering-with-eaton/become-an-eaton-partner/toy-force/jaws/data-centre-solutions/small-medium-data-centers/eaton-93pm-generation-2-ups.html UPS buying guide https://www.eaton.com/za/en-gb/markets/data-centers/it-channel/work-from-anywhere/ups-buying-guide.html 6 tips for keeping your UPS battery back-up in top shape https://www.eaton.com/za/en-gb/products/backup-power-ups-surge-it-power-distribution/backup-power-ups/6-tips-for-keeping-your-ups-battery-backup-in-top-shape.html Lithium-ion UPS FAQ https://www.eaton.com/za/en-gb/products/backup-power-ups-surge-it-power-distribution/backup-power-ups/lithium-ion-batteries-/lithium-ion-ups-faq.html The Fundamentals | Critical Power | Buildings | Eaton https://www.eaton.com/za/en-gb/markets/buildings/how-we-drive-building-efficiency-and-safety/CriticalPowerinCommercialBuildings/fundamentals-uninterruptable-power-supply-critical-power.html Achieving generator-UPS harmony 23/07/2018 https://www.eaton.com/za/en-gb/products/backup-power-ups-surge-it-power-distribution/backup-power-ups/six-considerations-to-achieving-generator-ups-harmony.html Eaton 9395X UPS https://www.eaton.com/za/en-gb/catalog/backup-power-ups-surge-it-power-distribution/eaton-9395x-ups.html Technical Resources Choosing the optimal UPS

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6000 3:1/8000 3:1/11000 3:1/EBM 240V - Installation and user manual (application/pdf 9MB) https://www.eaton.com/content/dam/eaton/products/backup-power-ups-surge-it-power-distribution/backup-power-ups/eaton-9px-ups/user-guides/Eaton%25209PX%2520UPS%2520-%25206000%25203.1-8000%25203.1-11000%25203.1-EBM%2520240V%2520-%2520Installation%2520and%2520user%2520manual.pdf /content/dam/eaton/products/backup-power-ups-surge-it-power-distribution/backup-power-ups/5P-Gen2-UPS---EMEA/eaton-5p-gen2-ups-emea-resources/eaton-5pgen2-declaration-origin-en-us.pdf Eaton UPS Declaration of Origin (application/pdf 282KB) https://www.eaton.com/content/dam/eaton/products/backup-power-ups-surge-it-power-distribution/backup-power-ups/5P-Gen2-UPS---EMEA/eaton-5p-gen2-ups-emea-resources/eaton-5pgen2-declaration-origin-en-us.pdf /content/dam/eaton/products/backup-power-ups-surge-it-power-distribution/backup-power-ups/power-xpert-9395/power-xpert-9395p-ups-500-kva-technical-specification-en.pdf Power Xpert 9395P UPS 500-600 kVA Technical Specification (application/pdf 198KB) https://www.eaton.com/content/dam/eaton/products/backup-power-ups-surge-it-power-distribution/backup-power-ups/power-xpert-9395/power-xpert-9395p-ups-500-kva-technical-specification-en.pdf /content/dam/eaton/products/backup-power-ups-surge-it-power-distribution/crouse-hinds/instruction-sheets/crouse-hinds-mtl-fs32-xe-operating-instructions.pdf Crouse-Hinds series MTL FS32-XE instruction sheet (application/pdf 363KB) https://www.eaton.com/content/dam/eaton/products/backup-power-ups-surge-it-power-distribution/crouse-hinds/instruction-sheets/crouse-hinds-mtl-fs32-xe-operating-instructions.pdf /content/dam/eaton/products/backup-power-ups-surge-it-power-distribution/backup-power-ups/5P-Gen2-UPS---EMEA/eaton-5p-gen2-ups-emea-resources/eaton-5pgen2-tower-user-manual-en-us.pdf Eaton 5P Gen2 Tower UPS Advance User Guide (application/pdf 1MB) https://www.eaton.com/content/dam/eaton/products/backup-power-ups-surge-it-power-distribution/backup-power-ups/5P-Gen2-UPS---EMEA/eaton-5p-gen2-ups-emea-resources/eaton-5pgen2-tower-user-manual-en-us.pdf /content/dam/eaton/support/apac-support-assets/anz/eaton-single-phase-ups-catalogue-fy24-en-gb-anz.pdf Eaton A/NZ Single Phase UPS Catalogue FY2024 (application/pdf 1MB) https://www.eaton.com/content/dam/eaton/support/apac-support-assets/anz/eaton-single-phase-ups-catalogue-fy24-en-gb-anz.pdf /content/dam/eaton/products/backup-power-ups-surge-it-power-distribution/power-distribution-for-it-equipment/eaton-basic-rack-pdu/ePDU_Brochure_2012_IEC_version_low_pdf.381.pdf ePDU Brochure 2012 IEC version low pdf (application/pdf 724KB) https://www.eaton.com/content/dam/eaton/products/backup-power-ups-surge-it-power-distribution/power-distribution-for-it-equipment/eaton-basic-rack-pdu/ePDU_Brochure_2012_IEC_version_low_pdf.381.pdf /content/dam/eaton/products/backup-power-ups-surge-it-power-distribution/power-distribution-for-it-equipment/eaton-rackpdug4-emea/eaton-rack-pdu-g4-resources---emea/eaton-dpq-rackpdug4-outline-drawing-9001-22351-EVMIF332X-en-us.pdf Eaton Rack PDU G4 EVMIF332X technical drawing (application/pdf 3MB) https://www.eaton.com/content/dam/eaton/products/backup-power-ups-surge-it-power-distribution/power-distribution-for-it-equipment/eaton-rackpdug4-emea/eaton-rack-pdu-g4-resources---emea/eaton-dpq-rackpdug4-outline-drawing-9001-22351-EVMIF332X-en-us.pdf /content/dam/eaton/products/backup-power-ups-surge-it-power-distribution/backup-power-ups/eaton_5e_ups/Eaton%205E%20UPS%20-%20Installation%20and%20user%20manual.pdf Eaton 5E UPS - 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Review. Complete. Order. Plan your service according to your maintenance needs and budget Basic: professional routine maintenance for your UPS Standard (+): essential services to minimize failure rate and its impact ("+" supported by Cyber Secured Monitoring) Advanced (+): your choice to optimize maintenance investment ("+" supported by Cyber Secured Monitoring) Premium: integral solution to maximize your power security supported by Cyber Secured Monitoring Choose what should be included in your contract: Emergency response (8/5 or 24/7) Yes No Travel and labour costs Yes No All spare parts expenses Yes No Cyber Secured Monitoring - including 24/7 monitoring, remote diagnostic, periodical health reports Yes No UPS type * kVA * UPS Serial no. Flexible energy systems will power the future The transition to a more sustainable, low-carbon future is accelerating. This energy transition is driven by the progressive replacement of carbon-based fuels with renewables, clean air regulation and the direct and indirect electrification of more applications. Today, energy flows through the grid in more directions and through more devices than ever before, and although that decentralisation creates more complexities and challenges, it also creates new potential. Everything as a Grid is our approach to reinventing the way power is distributed, stored and consumed. Our Everything as a Grid approach is shaping a future where homeowners and businesses can reduce the cost and environmental impact of energy. Flexible, intelligent power creates new opportunities for everyone. Energy transition: Everything as a Grid Our Everything as a Grid approach reinvents how power is distributed, stored and consumed worldwide. Because the world's energy needs are shifting, but what matters isn't. Eaton.com/EnergyTransition Watch the full story The transition to renewable power Global renewable adoption is on the rise; electricity demand is expected to reach 38,700 terawatt-hours by 2050 – with renewables providing 50% of that energy.1 The highly distributed nature of renewable energy is upending the traditional power delivery model. Electricity no longer flows in one direction from the utility that generates it to those who consume it. The new energy ecosystem comprises an intricate network of "prosumers" – consumers and businesses who produce their own energy locally, use what's needed and in many cases, are looking to export excess power back to the grid. Furthermore, the electrification of transport, building systems and industrial processes will drive considerable increases in demand for electrical power over the coming decades. Data centers, offices, factories and similar sites can participate in the transition via battery and thermal energy storage systems and grid-interactive uninterruptible power systems. This will give rise to vast bi-directional electricity flows requiring a network with the flexibility to cope with higher volatility and demand. 57 % Increase in global electricity demand by 2050 13X Growth in energy storage installed base by 2030 4X Growth of electricity required for data and computing by 2030 Planning for the shift to more electrical power The electrification of more areas of the economy, including transport, building systems and industry will drive a substantial increase in power demand by 2050. It is technically feasible to meet this extra demand with electricity generated from low or zero carbon sources. However, this will require concerted government support through policy and regulation as well as research and development to reduce the cost of new green energy sources like clean hydrogen. Decarbonisation: cleaner power Businesses and consumers are participating in cleaner power initiatives. Active corporate sourcing of renewable electricity reached 465 terawatt-hours (TWh), with production for self-consumption reaching 165TWh.2 On the consumer side, electric vehicle (EV) charging technology prices continue to fall, while charging point accessibility continues to rise. By facilitating the trading of self-generated clean electricity to reduce energy costs, we're enabling energy users, both consumers and businesses, to participate in demand response programmes where the utility can turn demand and/or on-site generation up or down in response to signals for real-time grid balancing needs. Democratisation: less reliance on the grid More homes, businesses and communities are becoming self-sufficient power producers that rely less on the utility grid. They generate, store and consume their own energy via renewable solar arrays, wind turbines, microgrids and battery storage. And they create a bi-directional flow that is changing the way power is managed and reducing the impact of sudden outages caused by rolling blackouts, cyberattacks and extreme weather events. These prosumers may also sell excess energy back to the grid and take advantage of demand response programmes to help reduce utility bills. Digitalisation: connectivity behind powerful decisions Digital innovation can be used to make smarter business or personal energy management decisions. It’s the transformation of the data from appliances, equipment or processes into actionable insights that help consumers and businesses drive new efficiencies, maximise uptime and manage their energy footprint. Through technologies that support bi-directional power generation, storage and energy management, we’re playing a critical role in helping meet demand growth and balance grid volatility. We are reimagining and rebuilding the electrical power value chain. Need help with the shift to more electrical power? Contact us Embracing the new power paradigm Homes, offices, stadiums, factories and data centres can now generate and store more of their own power to optimise energy costs, lower their carbon footprint and in some cases, reduce reliance on the grid. This is Everything as a Grid. Traditional electrical power infrastructures must be upgraded, with software and services optimising every process, to realise new energy benefits. We enable a systems approach to infrastructure integration and the technologies that help transform power generation and distribution for homes, buildings and utilities. Buildings as a grid Unlock the energy transition for your building See how the energy transition can help you seize the opportunity to improve the performance and expand functional use of your building infrastructure. Eaton introduces its Buildings as a Grid approach to energy transition Eaton introduces its Buildings as a Grid approach to help customers accelerate decarbonization, boost resilience, reduce energy costs and create new revenue streams. Responding to the high demand for low carbon Renewable and battery market shares continue to rise and play a larger role in the global power supply, even in the wake of the COVID-19 pandemic. The steady increase of competitiveness in renewables, along with their modularity, rapid scalability and job creation potential, make them highly attractive as countries and communities evaluate economic stimulus options.3 The challenge lies in balancing variable renewable power and storage options against the always-there, always-on power that users demand. By helping utilities, building managers and homeowners adopt renewable power and storage strategies, we’re helping to make clean energy available when and where it’s needed. Energy storage Capture renewable energy whenever it’s available and use it on demand. You’ll see immediate gains in reliability, realise greater independence from the utility grid and avoid dips in grid power supply due to brownouts, cyberattacks and weather-related events. This transformational technology revolutionises power for all, with energy storage available for the home, commercial and industrial buildings and even large-scale implementations for utilities. EnergyAware UPS Our EnergyAware technology helps applications like data centres to support energy providers by balancing sustainable power generation and consumption. The technology optimises power usage during peak demand hours and helps facilities earn additional revenues from currently deployed assets while maintaining complete control of deployed uninterruptible power systems and batteries. Electric vehicles Changing energy demands will affect infrastructure investments – and understanding that impact will be critical in enabling a resilient systems approach that seamlessly and flexibly integrates different assets and EV infrastructure. Power systems, EV manufacturers and charging infrastructure providers can then drive a deeper understanding of energy usage to maximise energy efficiency and lower operational costs to consumers. Microgrids Built to help isolate power from the main grid, microgrids balance multiple sources of on-site generation and demand to make energy available when it is needed. Grid modernisation Discover how utilities can adopt grid modernisation technologies to build resilient, efficient and secure power networks. Find out more about Eaton’s global sustainability commitments, including carbon neutrality by 2030 Find out more Adapting to fast-changing regulations Regulators are starting to make important changes to incentivise services like demand response to reduce costs, encourage and integrate the uptake of clean energy and increase customer participation. However, we have far to go if we are to replicate best practices and further encourage innovation. This includes financial mechanisms that reward utilities and distribution companies for contracting with distributed energy providers in place of capital investments – a departure from traditional regulation in which the addition of new capital assets is the main source of profit. Through market data analysis and expert insights, we help companies and countries prepare for and embrace the regulatory changes needed to assure a reliable power mix. Ensuring cybersecurity throughout the transition Only 48% of utility executives feel they are prepared to handle the challenges of a cyberattack interruption.4 As utilities address the challenges of improving power reliability and efficiency, they must also contend with the near-constant barrage of security threats. We proactively address cyber threats via a system-wide defensive approach and an unwavering focus on the dangers malware, spyware and ransomware present across the globe. Our team members meet and exceed competencies recognised by international standards organisations like UL, IEC, ISA and others through rigorous, in-depth technical training programmes. Our "secure-by-design" philosophy, processes and secure development lifecycle are integrated into product development and guide our labs, procurement and design teams as the foundation of innovation. And our understanding of and influence in changing global standards help guide safer, more efficient energy infrastructures. Powering the energy transition The technologies that convert wind and sunlight to renewable energy have matured, allowing for more flexible power possibilities. The growth of renewables, localised electricity production and bi-directional energy helps more homes, businesses and communities produce their own clean, dependable energy for less reliance on the utility grid. Count on Eaton for the technologies and digital intelligence needed for you to join this energy transition. Through our Everything as a Grid approach, infrastructures can be re-vamped to manage and optimise renewable integration, so you can realise more efficient, sustainable power that costs less. MTL4500/MTL5500 range Analogue Input Modules with passive input for 4-wire separately powered transmitters MTL4541A, MTL4541AS, MTL5541A, MTL5541AS, MTL4544A, MTL4544AS, MTL5544A, MTL5544AS April 2024 SM4541A/AS, 5541A/AS, 4544A/AS, 5544A/AS rev 2 Safety manual MTL intrinsic safety solutions FUNCTIONAL SAFETY MANAGEMENT These products are for use as elements within a Safety System conforming to the requirements of IEC 61508:2010 and enable a Safety Integrity Level of up to SIL 2 to be achieved for the instrument loop in a simplex architecture. Eaton Electric Ltd, Luton is a certified Functional Safety Management company meeting the requirements of IEC61508:2010 Part 1, Clause 6. * * Subject to special conditions for detection of out-of-range signal currents. Refer to content of this manual for details. SIL IEC 61508:2010 2 2SM4541A/AS, 5541A/AS, 4544A/AS, 5544A/AS rev 2 This manual supports the application of the products in functional-safety related loops. It must be used in conjunction with other supporting documents to achieve correct installation, commissioning and operation. Specifically, the data sheet, instruction manual and applicable certificates for the particular product should be consulted, all of which are available on the MTL web site. In the interest of further technical developments, Eaton reserve the right to make design changes. Contents 1 Introduction 3 1.1 Application and function 3 1.2 Variant description 3 1.3 Product build revisions covered by this manual 4 2 System configuration 5 2.1 Associated system components 6 3 Selection of product and implications 6 4 Assessment of functional safety 6 4.1 Hardware Safety Integrity 6 4.2 Systematic Safety Integrity 7 4.3 SIL Capability 7 4.4 Example of use in a safety function 7 4.5 EMC 8 4.6 Environmental 8 5 Installation 8 6 Maintenance 9 7 Appendices 9 7.1 Appendix A: Summary of applicable standards 9 7.2 Appendix B: Proof Test Procedure, MTLx541A/AS, MTLx544A/AS Modules 10 - 12 Analogue Input Modules with passive input for 4-wire transmitters Hardware Fault Tolerance (HFT) † Module type 0, 1 MTL4541A, MTL4541AS, MTL5541A, MTL5541AS, MTL4544A, MTL4544AS, MTL5544A, MTL5544AS † These modules have an inherent fault tolerance of 0. SIL IEC 61508:2010 2 3SM4541A/AS, 5541A/AS, 4544A/AS, 5544A/AS rev 2 1 INTRODUCTION 1.1 Application and function The Analogue Input module types MTLx541A/MTLx541AS (single channel) and MTLx544A/MTLx544AS (dual channel) are intrinsic safety isolators that interface with process measurement transmitters located in a hazardous area of a process plant. They are also designed and assessed according to IEC 61508 for use in safety instrumented systems up to SIL 2. The MTLx541A provides an input for a separately-powered 4/20mA transmitter located in a hazardous area, and repeats the transmitter current into a load in the safe area. The MTLx544A supports two identical channels for use with two separate transmitters. The MTLx541AS and MTLx544AS versions act as a current sink for the safe area connection rather than driving the current into the load. All the modules allow bi–directional transmission of HART communication signals superimposed on the 4/20mA loop current, so that the transmitter can be interrogated either from the operator station or by a hand- held communicator (HHC). There are no configuration switches or operator controls to be set on the modules. These modules are members of the MTL4500 and MTL5500 range of products. 1.2 Variant Description Functionally the MTL4500 and MTL5500 range of modules are the same but differ in the following way: - the MTL4500 modules are designed for backplane mounted applications - the MTL5500 modules are designed for DIN-rail mounting. In both models the hazardous area field-wiring connections (terminals 1,2, and optionally 4,5) are made through the removable blue connectors, but the safe area and power connections for the MTL454xA/MTL454xAS modules are made through the connector on the base, while the MTL554xA/ MTL554xAS modules use the removable grey connectors on the top and side of the module. Note that the safe-area connection terminal numbers differ between the backplane and the DIN-rail mounting models. The analogue input models covered by this manual are: Module type Number of channels Safe area connection MTL4541A and 5541A 1 Current source MTL4541AS and 5541AS 1 Current sink MTL4544A and 5544A 2 Current source MTL4544AS and 5544AS 2 Current sink Note: To avoid repetition, further use of MTLx54xA and MTLx54xAS in this document can be understood to include both DIN-rail and backplane models. Individual model numbers will be used only where there is a need to distinguish between them. All the module types described in this manual have the same connectivity for the field signals, supporting 4-wire process transmitters or currents sourced in the hazardous area. The connection of the repeated current signals into the input measurement channels for the safety logic system follows the arrangement shown in the following diagram. When the input channels of the Safety Instrumented System (SIS) are providing power for the loop, the 'S' variants of the isolator modules are used to 'sink' the measuring current. In the other cases the isolator modules 'source' the measuring current that flows into a load resistor inside the input card of the Safety Instrumented System. 4SM4541A/AS, 5541A/AS, 4544A/AS, 5544A/AS rev 2 2+ 1- Pwr 0V 24V Safety Instrumented System (SIS) Logic Solver with 'Passive' input MTLx541A/ MTLx544A (Safe area current source) B A 2+ 1- Pwr 0V 24V Safety Instrumented System (SIS) Logic Solver with 2-wire input A B Current limiter Output terminal MTL4541A, MTL4541AS MTL5541A, MTL5541AS A 8 11 B 9 12 4-wire Transmitter or current source Pwr Field wiring MTLx541AS/MTLx544AS (Safe area current sink) Figure 1.1 – Input and output connections 1.3 Product build revisions covered by this manual The information provided in this manual is valid for the product build revisions listed in the following table: Model Type Product build revision covered by this manual MTL4541A Up to and including 08 MTL4541AS Up to and including 08 MTL5541A Up to and including 08 MTL5541AS Up to and including 08 MTL4544A Up to and including 08 MTL4544AS Up to and including 08 MTL5544A Up to and including 08 MTL5544AS Up to and including 08 The product build revision is identified by the field 'CC' in the module Product Identification Number that appears at the bottom left-hand corner of the side label: The CC field immediately precedes the 7-digit Serial Number field, DDDDDDD. Example: 5SM4541A/AS, 5541A/ AS, 4544A/AS, 5544A/AS rev 2 2 System configuration An MTLx54x module may be used in single-channel (1oo1) safety functions up to SIL 2. The worked example in this manual is for a SIL 2 application. The figure below shows the system configuration and specifies detailed interfaces to the safety-related and non safety-related system components. It does not aim to show all details of the internal module structure, but is intended to support understanding for the application. Figure 2 – System Configuration The MTLx54xA/ MTLx54xAS modules are designed to receive an active 4-20mA signal from separately powered process transmitters in the hazardous area and to repeat the current flowing in the field loop to the safe-area load. The shaded area indicates the safety-related system connection, while the power supply con- nections are not safety-related. The term 'Logic Solver' has been used to denote the safety system performing the monitoring function of the process loop variable. Note: When using the MTLx544A/MTLx544AS dual-channel modules, it is not appropriate for both channels to be used in the same loop, or the same safety function, as this creates concerns regarding common-cause failures. Consideration must also be given to the effect of common-cause failures when both loops of a dual- channel module are used for different safety functions. Hazardous area Safe area Logic Solver (Safety related) Logic Solver (Safety related) Power supply (Not safety related) MTL5544A/MTL5544AS (2-channel version) shown. MTL5541A/MTL5541AS (single-channel version) omits Ch 2. 20 - 35V dc 6SM4541A/AS, 5541A/AS, 4544A/AS, 5544A/AS rev 2 2.1 Associated System Components There are many parallels between the loop components that must be assessed for intrinsic safety as well as functional safety. In both situations the contribution of each part is considered in relation to the whole. The MTLx54xA/MTLx54xAS modules are components in the signal path between safety-related process trans- mitters and safety-related control systems. The transmitter or other field device must be suitable for the process and have been assessed and independently verified for use in functional safety applications. The field instrument and Analogue input card of the Logic Solver shall have a normal operating range of 4-20mA but be capable of working over an extended range of 3 to 22mA for under- and over-range. The Logic Solver shall have the ability to detect and annunciate input currents higher than the threshold of 21mA and lower than the threshold of 3.6mA to determine out-of-range conditions. Note that the transmission of HART data is not considered as part of the safety function and is excluded from this analysis. However, for HART data communication to take place, the input impedance of the receiving equip- ment must be at least 240R. 3 Selection of product and implications The safe area output signal from the MTLx541A/AS and MTLx544A/AS modules is within the operating range of 4-20mA under normal conditions. If the field wiring to the transmitter or connection between the isolator and logic solver is open-circuit then the loop current will fall to less than 3.6mA and close to zero. If the field wiring connection between the transmitter and isolator is short-circuited, the loop current will also fall to below 3.6mA. For module types MTLx541A and MTLx544A that source the 4-20mA signal in the safe area circuit, then the current seen by the logic solver will fall to less than 3.6mA and close to zero if the connection between the isolator and logic solver is shorted. For module types MTLx541AS and MTLx544AS that sink the 4-20mA signal in the safe area circuit, then the current seen by the logic solver will rise to a value greater than 21mA if the connection between the isolator and logic solver is shorted. In both cases, the fault condition must be detected by the logic solver in Functional Safety applications. This should also include the detection of power supply failures which cause the output of the isolator to fall to zero mA. 4 Assessment of Functional Safety 4.1 Hardware Safety Integrity The hardware assessment shows that MTLx541A/MTLx541AS and MTLx544A/MTLx544AS modules: • have a hardware fault tolerance (HFT) of 0 • are classified as Type A devices ("non-complex" component with well-defined failure modes) • have no internal diagnostic elements The failure rates of these modules at an ambient temperature of 45°C are as follows: Failure mode Failure rate (FIT)* MTL4541A MTL5541A MTL4541AS MTL5541AS MTL4544A MTL5544A MTL4544AS MTL5544AS Output current >21mA (upscale) 3 3 3 14 Output current 2% in error 42 42 49 49 Output current correct within ±2% 73 73 80 81 *(FITs means failures per 109 hours or failures per thousand million hours) • Reliability data for this analysis is taken from IEC TR 62380:2004 Reliability Data Handbook. • Failure mode distributions are taken principally from IEC 62061:2005 Safety of Machinery. • Stated failure rates for dual-channel modules apply to a single channel. It is assumed that the module is powered from a nominal 24V dc supply and operating at a maximum ambient temperature of 45°C. 7SM4541A/AS, 5541A/AS, 4544A/AS, 5544A/AS rev 2 4.2 Systematic Safety Integrity The MTLx54x modules have a systematic safety integrity measure of SC 2. This has been established using compliance Route 1S, as described in IEC 61508-2: 2010, section 7.4.2.2 c. 4.3 SIL Capability Considering both the hardware safety integrity and the systematic capability, this allows the modules to be used in safety functions up to SIL 2 in a simplex architecture (HFT=0), provided SFF ≥60% is the case for the application. The hardware safety integrity assessment has been conducted according to compliance Route 1H, as described in IEC 61508-2:2010, section 7.4.4. (See example below). Note: • Independent of hardware architecture and systematic capability considerations, the hardware probability of failure for the entire safety function needs to be calculated for the application to ensure the required PFH (for a high or continuous demand safety function) or PFDAVG (for a low demand safety function) for the SIL is met. 4.4 Example of use in a safety function In this example, the application context is assumed to be: • the safety function is to repeat current within ±2% • the logic solver will diagnose currents above 21mA and below 3.6mA as faults and take appropriate action The failure modes shown above can then be defined as: Failure mode Category Output current >21mA (upscale) Dangerous detected, dd Output current 2% in error Dangerous undetected, du Output current correct within ±2% No effect, ne* The failure rates of the MTL4541A and MTL5541A for these categories are then (FITs): Model sd su dd du ne* MTL4541A or MTL5541A 0 0 227 42 73 In this example, the safe failure fraction (SFF) is 84.4%. * ne is not used in the calculation of SFF. Defining the "output current correct within ±2%" failure mode as ne represents a conservative approach to the calculation of SFF. Interpreting this failure mode as su (safe, undetected) may also be considered and yields an SFF value of 87.7%. Accordingly, the SFF of all module types described in this manual, when used in the same application, are as follows: Model sd su dd du ne SFF MTL4541A, MTL5541A, MTL4541AS, MTL5541AS 0 0 227 42 73 84.4% MTL4544A, MTL5544A 0 0 267 49 80 84.5% MTL5544AS, MTL5544AS 0 0 267 49 81 84.5% 8SM4541A/AS, 5541A/AS, 4544A/AS, 5544A/AS rev 2 4.5 EMC The MTL4500 and MTL5500 modules are designed for operation in normal industrial electromagnetic environ-ment but, to support good practice, modules should be mounted without being subjected to undue conducted or radiated interference, see Appendix A for applicable standards and levels. 4.6 Environmental The MTL4500 and MTL5500 modules operate over the temperature range from -20°C to +60°C, and at up to 95% non-condensing relative humidity. The modules are intended to be mounted in a normal industrial environment without excessive vibration, as specified for the MTL4500 & MTL5500 product ranges. See Appendix A for applicable standards and levels. Continued reliable operation will be assured if the exposure to temperature and vibration are within the values given in the specification. 5 Installation There are two particular aspects of safety that must be considered when installing the MTL4500 or MTL5500 modules and these are: • Functional safety • Intrinsic safety Reference must be made to the relevant sections within the instruction manual for MTL4500 range (INM4500) or MTL5500 range (INM5500) which contain basic guides for the installation of the interface equipment to meet the requirements of intrinsic safety. In many countries there are specific codes of practice, together with industry guidelines, which must also be adhered to. Provided that these installation requirements are followed then there are no additional factors to meet the needs of applying the products for functional safety use. To guard against the effects of dust and water the modules should be mounted in an enclosure providing at least IP54 protection degree, or the location of mounting should provide equivalent protection such as inside an equipment cabinet. In applications using MTL4500 range, where the environment has a high humidity, the mounting backplanes should be specified to include conformal coating. 9SM4541A/AS, 5541A/AS, 4544A/AS, 5544A/AS rev 2 6 Maintenance To follow the guidelines pertaining to operation and maintenance of intrinsically safe equipment in a hazardous area, yearly periodic audits of the installation are required by the various codes of practice. In addition, proof- testing of the loop operation to conform with functional safety requirements should be carried out at the intervals determined by safety case assessment. Proof testing must be carried out according to the application requirements, but it is recommended that this be carried out at least once every three years. Refer to Appendix B for the proof testing procedure of the MTLx541A/AS and MTLx544A/AS modules. Note that there may also be specific requirements laid down in the E/E/PE operational maintenance procedure for the complete installation. If an MTLx541A/AS and MTLx544A/AS module is found to be faulty during commissioning or during the normal lifetime of the product, then such failures should be reported to the local MTL office. When appropriate, a Cus- tomer Incident Report (CIR) will be notified by Eaton to enable the return of the unit to the factory for analysis. If the unit is within the warranty period then a replacement unit will be sent. Consideration should be given to the service lifetime for a device of this type, which is in the region of ten years. Operating an MTLx541A/AS and MTLx544A/AS module for longer than this period could invalidate the functional safety analysis, meaning that the overall safety function no longer meets its target SIL. If high failure rates of the MTL modules are detected, indicating that they have entered the ‘end of life phase’ of their service life, then they should be replaced promptly. 7 Appendices 7.1 Appendix A: Summary of applicable standards This annex lists all standards referred to in the previous sections of this document: IEC 61508:2010 Functional safety of electrical/electronic/programmable electronic safety-related systems. Parts 1 and 2 as relevant EN 61131-2:2003 Programmable controllers – Part 2: Equipment requirement and tests (EMC requirements) EN 61326-1:2013 Electrical equipment for measurement, control and laboratory use – EMC requirements. (Criterion A) IEC 61326-3-1:2017 Electrical equipment for measurement, control and laboratory use – EMC requirements – Part 3-1: Immunity requirements for equipment performing or intended to perform safety related functions (functional safety) – General industrial applications. (Criterion FS) NE21:2007 Electromagnetic Compatibility of Industrial Process and Laboratory Control Equipment. (Criterion A) Lloyds Register Type Approval System: 2015, Test Specification Number 1. Specifically vibration: 1.0mm displacement @ 5 to 13.2Hz and EN 60068-2-27 Environmental testing. Test Ea and guidance. Shock. (Criterion FS) 10SM4541A/AS, 5541A/AS, 4544A/AS, 5544A/AS rev 2 7.2 Appendix B: Proof Test Procedure, MTLx541A/AS, MTLx544A/AS Modules Confirmation, through testing, that a safety function will operate as designed, is a necessary periodic activity to ensure that the probability of failure upon demand (PFDavg) is maintained. In some applications, the user may prefer to conduct a proof test on the overall safety instrumented function without dismantling or disconnecting the individual instrumentation components, in order to avoid disturbing the integrity of the installation. However, where it is deemed desirable to perform proof testing on the MTL modules individually, the following procedure may be used. Proof tests of the other components of the loop must then be conducted in accordance with their manufacturers’ instructions, to maintain the integrity of the overall safety function. Alternative proof tests may be devised and applied, provided they give a similar level of test coverage that is appropriate to the safety function. The tests described here - see Figure 7.1 - compare the output current of the MTL isolator with the input current (A1) over the required range of operation, and measure the “error current” i.e. the difference between the two - as indicated on A2. The tests should be employed per channel, as appropriate. Figure 7.1 - Basic test arrangement Ammeter A2 must be capable of measuring currents of either polarity. If it is not an auto-ranging instrument, set it to a high range before switch on, and then adjust sensitivity to obtain the required reading. Proof Test Procedure Test sequence: 1. System - Normal operation test 2. Input /Output characteristic functional safety test 3. System - Normal operation test Modules types MTL4541A, MTL4544A, MTL5541A, MTL5544A Modules types MTL4541AS, MTL4544AS, MTL5541AS, MTL5544AS 11SM4541A/AS, 5541A/AS, 4544A/AS, 5544A/AS rev 2 1 System - Normal operation test Make sure that the module to be tested is operating normally in the target system, without errors and in an energised mode. If the module is in a faulty or de-energised loop, restore normal fault-free and energised operation before testing. 2 Input/Output characteristic functional safety test Observe normal anti-static precautions when handling equipment during device testing. Remove the unit from the target system and connect it as shown in Figure 7.2. This figure shows the arrangement for the MTLx541A/ AS single-channel modules; for equivalent connections for the MTLx544A/AS dual-channel modules, refer to the relevant product data sheets. Note that it is acceptable to leave the unit in the target system but only after ensuring that the all the hazardous area input and safe area output terminals have been disconnected from the system and are available for test. Alternatively, for the backplane-mounted MTL4500 range modules, a separate backplane can be used to provide access to the power and output connections. Note that the combination of the 24V power supply and variable resistor RV1 in the hazardous area connection can be provided by a suitable industrial current simulator, which is likely to be more readily available. Also, the 250R resistor does not need to be a precision type; any value in the range 200-300R is acceptable would suffice, such as a standard value of 240R. Where a second power supply is introduced for testing the MTLx541AS or MTLx544AS module variants, note that both power supplies must be floating and not share a common 0V connection. During testing, a 24V nominal system power supply in the range 20.0 to 35.0V should be connected between terminals 13 and 14 (+ve to terminal 14). Figure 7.2 - Connections for testing the MTL5541A/AS and MTL4541A/AS modules 1 2 3 4 5 6 Ch1 i/p Ch2 i/p Ch2 o/p Ch1 o/p MTL5541A 13(–) 14(+) 7 8 9 10 11 12 V VS Power supply + MTL5501-SR 13(-) 14(+) V S +– +– +– +– + – +– V + Ch1 i/p Ch2 i/p Insert 250R and 24V supply for MTLx54xS modules, otherwise use direct link to o/p(+) 14 13 12 11 1 0 9 8 7 MTL4541A 1 2 3 4 5 6 Ch1 i/p Ch2 i/p Ch2 o/p Ch1 o/p + – + – + – + – + – A 1 A1 250RRV 1 + 250R 24V dc 24V dc – – + – + – A1 A 1 250RRV 1 + 250R 24V dc 24V dc – – 12SM4541A/AS, 5541A/AS, 4544A/AS, 5544A/AS rev 2 Channel 1 Channel 2 Measurements Make the following measurements. It is recommended to record the results in a table such as that shown on the next page. 1. Adjust resistor RV1 to vary the loop current (measured by Ammeter A1) through the range 4 to 20mA. (Tests 1 - 5 in table) 2. The measured current imbalance (measured by Ammeter A2) over this range should not exceed ±50µA. 3. Adjust RV1 to vary the current (A1) to 3.5mA and then 21.5mA (tests 6 & 7 in table). 4. The measured current imbalance (A2) at these currents should not exceed ±200µA. 5. Record the supply voltage Vs. If appropriate, repeat these measurements for Channel 2. 3 System - Normal operation test Disconnect the test setup from the unit and reconnect the original system configuration. Make sure that the tested unit operates normally in the target system, as before, without errors and in energised mode. Date: ______/ ______/__________ Supply voltage Vs: ______________V dc Module type: _________________ Serial No: ______________________________ Test # Description Actual Target 1 Current imbalance (A2) at loop current (A1) = 4mA <±50µA 2 Current imbalance (A2) at loop current (A1) = 8mA <±50µA 3 Current imbalance (A2) at loop current (A1) = 12mA <±50µA 4 Current imbalance (A2) at loop current (A1) = 16mA <±50µA 5 Current imbalance (A2) at loop current (A1) = 20mA <±50µA 6 Current imbalance (A2) at loop current (A1) = 3.5mA <±200µA 7 Current imbalance (A2) at loop current (A1) = 21.5mA <±200µA Test Step# Description Actual Target 1 Current imbalance (A2) at loop current (A1) = 4mA <±50µA 2 Current imbalance (A2) at loop current (A1) = 8mA <±50µA 3 Current imbalance (A2) at loop current (A1) = 12mA <±50µA 4 Current imbalance (A2) at loop current (A1) = 16mA <±50µA 5 Current imbalance (A2) at loop current (A1) = 20mA <±50µA 6 Current imbalance (A2) at loop current (A1) = 3.5mA <±200µA 7 Current imbalance (A2) at loop current (A1) = 21.5mA 21mA (upscale) 3 3 3 14 Output current 2% in error 42 42 49 49 Output current correct within ±2% 73 73 80 81 *(FITs means failures per 109 hours or failures per thousand million hours) • Reliability data for this analysis is taken from IEC TR 62380:2004 Reliability Data Handbook. • Failure mode distributions are taken principally from IEC 62061:2005 Safety of Machinery. • Stated failure rates for dual-channel modules apply to a single channel. It is assumed that the module is powered from a nominal 24V dc supply and operating at a maximum ambient temperature of 45°C. 7SM4541A/AS, 5541A/AS, 4544A/AS, 5544A/AS rev 2 4.2 Systematic Safety Integrity The MTLx54x modules have a systematic safety integrity measure of SC 2. This has been established using compliance Route 1S, as described in IEC 61508-2: 2010, section 7.4.2.2 c. 4.3 SIL Capability Considering both the hardware safety integrity and the systematic capability, this allows the modules to be used in safety functions up to SIL 2 in a simplex architecture (HFT=0), provided SFF ≥60% is the case for the application. The hardware safety integrity assessment has been conducted according to compliance Route 1H, as described in IEC 61508-2:2010, section 7.4.4. (See example below). Note: • Independent of hardware architecture and systematic capability considerations, the hardware probability of failure for the entire safety function needs to be calculated for the application to ensure the required PFH (for a high or continuous demand safety function) or PFDAVG (for a low demand safety function) for the SIL is met. 4.4 Example of use in a safety function In this example, the application context is assumed to be: • the safety function is to repeat current within ±2% • the logic solver will diagnose currents above 21mA and below 3.6mA as faults and take appropriate action The failure modes shown above can then be defined as: Failure mode Category Output current >21mA (upscale) Dangerous detected, dd Output current 2% in error Dangerous undetected, du Output current correct within ±2% No effect, ne* The failure rates of the MTL4541A and MTL5541A for these categories are then (FITs): Model sd su dd du ne* MTL4541A or MTL5541A 0 0 227 42 73 In this example, the safe failure fraction (SFF) is 84.4%. * ne is not used in the calculation of SFF. Defining the “output current correct within ±2%” failure mode as ne represents a conservative approach to the calculation of SFF. Interpreting this failure mode as su (safe, undetected) may also be considered and yields an SFF value of 87.7%. Accordingly, the SFF of all module types described in this manual, when used in the same application, are as follows: Model sd su dd du ne SFF MTL4541A, MTL5541A, MTL4541AS, MTL5541AS 0 0 227 42 73 84.4% MTL4544A, MTL5544A 0 0 267 49 80 84.5% MTL5544AS, MTL5544AS 0 0 267 49 81 84.5% 8SM4541A/AS, 5541A/AS, 4544A/AS, 5544A/AS rev 2 4.5 EMC The MTL4500 and MTL5500 modules are designed for operation in normal industrial electromagnetic environ- ment but, to support good practice, modules should be mounted without being subjected to undue conducted or radiated interference, see Appendix A for applicable standards and levels. 4.6 Environmental The MTL4500 and MTL5500 modules operate over the temperature range from -20°C to +60°C, and at up to 95% non-condensing relative humidity. The modules are intended to be mounted in a normal industrial environment without excessive vibration, as specified for the MTL4500 & MTL5500 product ranges. See Appendix A for applicable standards and levels. Continued reliable operation will be assured if the exposure to temperature and vibration are within the values given in the specification. 5 Installation There are two particular aspects of safety that must be considered when installing the MTL4500 or MTL5500 modules and these are: • Functional safety • Intrinsic safety Reference must be made to the relevant sections within the instruction manual for MTL4500 range (INM4500) or MTL5500 range (INM5500) which contain basic guides for the installation of the interface equipment to meet the requirements of intrinsic safety. In many countries there are specific codes of practice, together with industry guidelines, which must also be adhered to. Provided that these installation requirements are followed then there are no additional factors to meet the needs of applying the products for functional safety use. To guard against the effects of dust and water the modules should be mounted in an enclosure providing at least IP54 protection degree, or the location of mounting should provide equivalent protection such as inside an equipment cabinet. In applications using MTL4500 range, where the environment has a high humidity, the mounting backplanes should be specified to include conformal coating. 9SM4541A/AS, 5541A/AS, 4544A/AS, 5544A/AS rev 2 6 Maintenance To follow the guidelines pertaining to operation and maintenance of intrinsically safe equipment in a hazardous area, yearly periodic audits of the installation are required by the various codes of practice. In addition, proof- testing of the loop operation to conform with functional safety requirements should be carried out at the intervals determined by safety case assessment. Proof testing must be carried out according to the application requirements, but it is recommended that this be carried out at least once every three years. Refer to Appendix B for the proof testing procedure of the MTLx541A/AS and MTLx544A/AS modules. Note that there may also be specific requirements laid down in the E/E/PE operational maintenance procedure for the complete installation. If an MTLx541A/AS and MTLx544A/AS module is found to be faulty during commissioning or during the normal lifetime of the product, then such failures should be reported to the local MTL office. When appropriate, a Cus- tomer Incident Report (CIR) will be notified by Eaton to enable the return of the unit to the factory for analysis. If the unit is within the warranty period then a replacement unit will be sent. Consideration should be given to the service lifetime for a device of this type, which is in the region of ten years. Operating an MTLx541A/AS and MTLx544A/AS module for longer than this period could invalidate the functional safety analysis, meaning that the overall safety function no longer meets its target SIL. If high failure rates of the MTL modules are detected, indicating that they have entered the ‘end of life phase’ of their service life, then they should be replaced promptly. 7 Appendices 7.1 Appendix A: Summary of applicable standards This annex lists all standards referred to in the previous sections of this document: IEC 61508:2010 Functional safety of electrical/electronic/programmable electronic safety-related systems. Parts 1 and 2 as relevant EN 61131-2:2003 Programmable controllers – Part 2: Equipment requirement and tests (EMC requirements) EN 61326-1:2013 Electrical equipment for measurement, control and laboratory use – EMC requirements. (Criterion A) IEC 61326-3-1:2017 Electrical equipment for measurement, control and laboratory use – EMC requirements – Part 3-1: Immunity requirements for equipment performing or intended to perform safety related functions (functional safety) – General industrial applications. (Criterion FS) NE21:2007 Electromagnetic Compatibility of Industrial Process and Laboratory Control Equipment. (Criterion A) Lloyds Register Type Approval System: 2015, Test Specification Number 1. Specifically vibration: 1.0mm displacement @ 5 to 13.2Hz and EN 60068-2-27 Environmental testing. Test Ea and guidance. Shock. (Criterion FS) 10SM4541A/AS, 5541A/AS, 4544A/AS, 5544A/AS rev 2 7.2 Appendix B: Proof Test Procedure, MTLx541A/AS, MTLx544A/AS Modules Confirmation, through testing, that a safety function will operate as designed, is a necessary periodic activity to ensure that the probability of failure upon demand (PFDavg) is maintained. In some applications, the user may prefer to conduct a proof test on the overall safety instrumented function without dismantling or disconnecting the individual instrumentation components, in order to avoid disturbing the integrity of the installation. However, where it is deemed desirable to perform proof testing on the MTL modules individually, the following procedure may be used. Proof tests of the other components of the loop must then be conducted in accordance with their manufacturers' instructions, to maintain the integrity of the overall safety function. Alternative proof tests may be devised and applied, provided they give a similar level of test coverage that is appropriate to the safety function. The tests described here - see Figure 7.1 - compare the output current of the MTL isolator with the input current (A1) over the required range of operation, and measure the "error current" i.e. the difference between the two - as indicated on A2. The tests should be employed per channel, as appropriate. Figure 7.1 - Basic test arrangement Ammeter A2 must be capable of measuring currents of either polarity. If it is not an auto-ranging instrument, set it to a high range before switch on, and then adjust sensitivity to obtain the required reading. Proof Test Procedure Test sequence: 1. System - Normal operation test 2. Input /Output characteristic functional safety test 3. System - Normal operation test Modules types MTL4541A, MTL4544A, MTL5541A, MTL5544A Modules types MTL4541AS, MTL4544AS, MTL5541AS, MTL5544AS 11SM4541A/AS, 5541A/AS, 4544A/AS, 5544A/AS rev 2 1 System - Normal operation test Make sure that the module to be tested is operating normally in the target system, without errors and in an energised mode. If the module is in a faulty or de-energised loop, restore normal fault-free and energised operation before testing. 2 Input/Output characteristic functional safety test Observe normal anti-static precautions when handling equipment during device testing. Remove the unit from the target system and connect it as shown in Figure 7.2. This figure shows the arrangement for the MTLx541A/ AS single-channel modules; for equivalent connections for the MTLx544A/AS dual-channel modules, refer to the relevant product data sheets. Note that it is acceptable to leave the unit in the target system but only after ensuring that the all the hazardous area input and safe area output terminals have been disconnected from the system and are available for test. Alternatively, for the backplane-mounted MTL4500 range modules, a separate backplane can be used to provide access to the power and output connections. Note that the combination of the 24V power supply and variable resistor RV1 in the hazardous area connection can be provided by a suitable industrial current simulator, which is likely to be more readily available. Also, the 250R resistor does not need to be a precision type; any value in the range 200-300R is acceptable would suffice, such as a standard value of 240R. Where a second power supply is introduced for testing the MTLx541AS or MTLx544AS module variants, note that both power supplies must be floating and not share a common 0V connection. During testing, a 24V nominal system power supply in the range 20.0 to 35.0V should be connected between terminals 13 and 14 (+ve to terminal 14). Figure 7.2 - Connections for testing the MTL5541A/AS and MTL4541A/AS modules 1 2 3 4 5 6 Ch1 i/p Ch2 i/p Ch2 o/p Ch1 o/p MTL5541A 13(–) 14(+) 7 8 9 10 11 12 V VS Power supply + MTL5501-SR 13(-) 14(+) V S +– +– +– +– + – +– V + Ch1 i/p Ch2 i/p Insert 250R and 24V supply for MTLx54xS modules, otherwise use direct link to o/p(+) 14 13 12 11 1 0 9 8 7 MTL4541A 1 2 3 4 5 6 Ch1 i/p Ch2 i/p Ch2 o/p Ch1 o/p + – + – + – + – + – A 1 A1 250RRV 1 + 250R 24V dc 24V dc – – + – + – A1 A 1 250RRV 1 + 250R 24V dc 24V dc – – 12SM4541A/AS, 5541A/AS, 4544A/AS, 5544A/AS rev 2 Channel 1 Channel 2 Measurements Make the following measurements. It is recommended to record the results in a table such as that shown on the next page. 1. Adjust resistor RV1 to vary the loop current (measured by Ammeter A1) through the range 4 to 20mA. (Tests 1 - 5 in table) 2. The measured current imbalance (measured by Ammeter A2) over this range should not exceed ±50μA. 3. Adjust RV1 to vary the current (A1) to 3.5mA and then 21.5mA (tests 6 & 7 in table). 4. The measured current imbalance (A2) at these currents should not exceed ±200μA. 5. Record the supply voltage Vs. If appropriate, repeat these measurements for Channel 2. 3 System - Normal operation test Disconnect the test setup from the unit and reconnect the original system configuration. Make sure that the tested unit operates normally in the target system, as before, without errors and in energised mode. Date: ______/ ______/__________ Supply voltage Vs: ______________V dc Module type: _________________ Serial No: ______________________________ Test # Description Actual Target 1 Current imbalance (A2) at loop current (A1) = 4mA <±50μA 2 Current imbalance (A2) at loop current (A1) = 8mA <±50μA 3 Current imbalance (A2) at loop current (A1) = 12mA <±50μA 4 Current imbalance (A2) at loop current (A1) = 16mA <±50μA 5 Current imbalance (A2) at loop current (A1) = 20mA <±50μA 6 Current imbalance (A2) at loop current (A1) = 3.5mA <±200μA 7 Current imbalance (A2) at loop current (A1) = 21.5mA <±200μA Test Step# Description Actual Target 1 Current imbalance (A2) at loop current (A1) = 4mA <±50μA 2 Current imbalance (A2) at loop current (A1) = 8mA <±50μA 3 Current imbalance (A2) at loop current (A1) = 12mA <±50μA 4 Current imbalance (A2) at loop current (A1) = 16mA <±50μA 5 Current imbalance (A2) at loop current (A1) = 20mA <±50μA 6 Current imbalance (A2) at loop current (A1) = 3.5mA <±200μA 7 Current imbalance (A2) at loop current (A1) = 21.5mA 17V @ 20mA) is at least 1.5V greater than the total voltage developed across the transmitter and associated field wiring at 20mA. The Analogue Input module must not itself be part of a Safety Instrumented Function. Its non-hazardous 4-20mA output signal may be part of the basic process control system, but must not be used as part of the Safety Instrumented System. Note that HART communications are not supported on the 4-20mA signal. Note: • The MTL5314 is capable of operating in conjunction with MTL Analogue Input modules (such as MTL5541) that provide power for the hazardous area current loop, where the MTL5314 is connected in series with the process transmitter. This configuration also provides a means of transferring the loop current to the non-hazardous area in addition to the trip alarms, and is shown in other MTL documentation such as the MTL5314 product data sheet. However, this configuration is different to that described in 2.1 above, and has not been assessed for Functional Safety applications. SM5314 rev 1 rev 2 DRAFT - 2401207 4 ASSESSMENT OF FUNCTIONAL SAFETY 4.1 Hardware Safety Integrity The hardware safety integrity stated in this manual is drawn from a Failure Modes, Effects and Diagnostic Analysis (FMEDA) for the MTL5314 Trip Amplifier, conducted on behalf of Eaton-MTL by Exida (Exida report no. MTL 05/05-26 R007, version V1, revision R1). Minor amendments have been made in this manual where appropriate, to ensure that the calculation of Safe Failure Fraction (SFF) is in compliance with IEC 61508-2: 2010. The hardware assessment shows that MTL5314 module: • has a hardware fault tolerance (HFT) of 0 • is classified as a Type A device ("non-complex" component with well-defined failure modes) • has no internal diagnostic elements The failure rates derived by the FMEDA for the MTL5314 are stated as FITs (failures per 109 hours, or failures per thousand million hours) in the table below: Model sd su dd du ne* SFF MTL5314, Low Trip 0 156 0 50 165 75.7% MTL5314, High Trip 0 151 0 56 165 72.9% The Safe Failure Fraction (SFF) shown in the table is calculated as (dd + sd + su) / (du + dd + sd + su), and stated as a percentage. For both trip modes, the calculated SFF is between 60 and 90%, and therefore meets the requirements for SIL 2 according to Table 2 of IEC 61508-2: 2010, for a hardware fault tolerance of 0. * Note that "No-effect" failures (ne) are not used in the calculation of SFF. No-effect failures are defined in IEC 61508-4: 2010 as failures of elements (or components) that are part of the safety function but have no effect on the safety function. 4.2 Assumptions The following assumptions have been made during this analysis: • The fail safe state is defined as the alarm relay in the MTL5314 being de-energised. • Only one trip output is used in the Safety Instrumented Function. • A single failure will fail the entire product. • Failure rates are constant; wear-out mechanisms are not considered. • Propagation of failures is not relevant. • All components that are not part of the safety function and cannot influence the safety function are excluded. • The stress levels are typical for an industrial environment and can be compared to the Ground Fixed classification of MIL-HDBK-217F. This is similar to Class C (sheltered location) as defined in IEC 60654-1, with temperature and humidity levels within those stated in the product data sheet and Section 4.6 of this manual, and an average long-term temperature of 40oC. • The module is powered from a nominal 24V dc supply. • Power supply failure rates are not considered. SM45314 rev 1 DRAFT - 2401208 4.3 Systematic Safety Integrity The MTL5314 module has a systematic safety integrity measure of SC 2. This has been established using compliance Route 1S, as described in IEC 61508-2: 2010, section 7.4.2.2 c. 4.4 SIL Capability Considering both the hardware safety integrity and the systematic capability, this allows the module to be used in safety functions up to SIL 2 in a simplex architecture (HFT=0). The hardware safety integrity assessment has been conducted according to compliance Route 1H, as described in IEC 61508-2: 2010, section 7.4.4. Note: • Independent of hardware architecture and systematic capability considerations, the hardware probability of failure for the entire safety function needs to be calculated for the application to ensure the required PFH (for a high or continuous demand safety function) or PFDavg (for a low demand safety function) for the SIL is met. 4.5 EMC The MTL5314 module is designed for operation in normal industrial electromagnetic environment but, to support good practice, the module should be mounted without being subjected to undue conducted or radiated interference. See Appendix A for applicable standards and levels. 4.6 Environmental The MTL5314 module is designed for operation over the temperature range from -20°C to +60°C, and at up to 95% non-condensing relative humidity. The module is intended to be mounted in a normal industrial environment without excessive vibration, as specified for the MTL5500 product range. See Appendix A for applicable standards and levels. Continued reliable operation will be assured if the exposure to temperature and vibration are within the values given in the specification. 5 INSTALLATION There are two aspects of safety that must be considered when installing the MTL5314 module. These are: • Functional safety • Intrinsic safety To comply with intrinsic safety requirements, reference should be made to the relevant sections in the instruction manual INM5500, which is available to download from the Eaton-MTL website. In many countries there are also specific codes of practice and industry guidelines, which must also be adhered to. Provided that these installation requirements are followed then there are no additional environmental factors to meet the needs of applying the products for functional safety use. To guard against the effects of dust and water the modules should be mounted in an enclosure providing at least IP54 protection degree, or the mounting location should provide equivalent protection such as inside an equipment cabinet. SM5314 rev 1 rev 2 DRAFT - 2401209 6 MAINTENANCE To follow the guidelines relating to operation and maintenance of intrinsically safe equipment in a hazardous area, yearly periodic audits of the installation are required by the various codes of practice. In addition, proof- testing of the loop operation to conform with functional safety requirements should be carried out at the intervals determined by safety case assessment. Proof testing must be carried out according to the application requirements, but it is recommended that this be performed at least once every three years. Refer to Appendix B for the proof testing procedure for the MTL5314 module. Note that there may also be specific requirements laid down in the E/E/PE operational maintenance procedure for the complete installation. If an MTL5314 module is found to be faulty during commissioning or during the normal lifetime of the product, then such failures should be reported to the local Eaton-MTL office. Where appropriate, a Customer Incident Report (CIR) will be notified by Eaton to enable the unit to be returned to the factory for analysis. If the unit is within the warranty period and the failure is due to defective components or manufacture, then a replacement unit will be sent. Consideration should be given to the service lifetime for a device of this type, which is in the region of ten years. Operating an MTL5314 module for longer than this period could invalidate the functional safety analysis, meaning that the overall safety function no longer meets its target SIL. If high failure rates of the module are detected in service, indicating that they have entered the 'end of life phase' of their service life, then they should be replaced promptly. SM45314 rev 1 DRAFT - 24012010 7 APPENDICES 7.1 Appendix A: Summary of applicable standards This annex lists all standards referred to in the previous sections of this document: IEC 61508: 2010 Functional safety of electrical/electronic/programmable electronic safety-related systems. Parts 1 and 2 as relevant EN 61131-2: 2003 Programmable controllers – Part 2: Equipment requirement and tests (EMC requirements) EN 61326-1: 2013 Electrical equipment for measurement, control and laboratory use – EMC requirements. (Criterion A) IEC 61326-3-1: 2017 Electrical equipment for measurement, control and laboratory use – EMC requirements – Part 3-1: Immunity requirements for equipment performing or intended to perform safety related functions (functional safety) – General industrial applications. (Criterion FS) NE21:2007 Electromagnetic Compatibility of Industrial Process and Laboratory Control Equipment. (Criterion A) Lloyds Register Type Approval System: 2002, Test Specification Number 1. (specifically vibration: 1.0mm displacement @ 5 to 13.2Hz and 0.7G acceleration @13.2Hz to 100Hz per IEC60068-2-6, test Fc) EN 60068-2-27 Environmental testing. Test Ea and guidance. Shock. (Criterion FS) Note that other standards are referenced in Exida report no. MTL 05/05-26 R007, version V1, revision R1, which was used for the derivation of failure rates used in this manual. SM5314 rev 1 rev 2 DRAFT - 24012011 7.2 Appendix B : Proof Test Procedure, MTL5314 Module Confirmation, through testing, that a safety function will operate as designed, is a necessary periodic activity to ensure that the probability of failure upon demand (PFDavg) is maintained. In some applications, the user may prefer to conduct a proof test on the overall safety instrumented function without dismantling or disconnecting the individual instrumentation components, in order to avoid disturbing the integrity of the installation. However, where it is deemed desirable to perform proof testing on the MTL modules individually, the following procedure may be used. Proof tests of the other components of the loop must then be conducted in accordance with their manufacturers' instructions, to maintain the integrity of the overall safety function. Alternative proof tests may be devised and applied, provided they give a similar level of test coverage that is appropriate to the safety function. Observe normal anti-static precautions when handling equipment during device testing. Remove the MTL5314 from the target system and observe the following test sequence: 1. Select a variable current source or sink, according to which is most representative of the actual field device in the Safety Instrumented Function. A current sink is representative of typical 2 or 3-wire field transmitters, whereas a current source is representative of the 4-20mA output from 4-wire transmitters. The current source or sink should have a traceable calibration history. 2. Set the current source or sink to 12.0mA, and connect it to the appropriate input terminals on the MTL5314 module as shown in Figure 7.2. 3. Adjust the trip potentiometers on the top of the MTL5314 module for Alarms A and B in turn, until the associated LEDs just extinguish. 4. Set the current source or sink to 11.5mA 5. Using the switches on top of the module, set both Alarms to 'Low Alarm'. 6. Confirm that the LEDs and alarm relays comply with the status shown in 'Low Alarm' column of the table below. A multi-meter set to a low ohms range can be used to check that the relays are open or closed. 7. Set both Alarms to 'High Alarm', and confirm that the LEDs and alarm relays comply with the status shown in the 'High Alarm' column of the table. 8. Set the current source or sink to 12.5mA and repeat steps 5 to 7. Current High Alarm Low Alarm LEDs Alarm A LEDs Alarm A Terminals 11 - 12 Terminals 10 - 11 Terminals 11 - 12 Terminals 10 - 11 Alarm B Alarm B Terminals 8 - 9 Terminals 7 - 8 Terminals 8 - 9 Terminals 7 - 8 11.5mA on closed open off open closed 12.5mA off open closed on closed open continued SM45314 rev 1 DRAFT - 24012012 Figure 7.2 - Connections for testing MTL5314 module Source or sink 6 5 4 3 2 1 7 8 9 10 11 12 13 14 Trip B Trip A Vs Vs 20 to 35V dc SM5314 rev 1 rev 2 DRAFT - 24012013 THIS PAGE IS LEFT INTENTIONALLY BLANK SM45314 rev 1 DRAFT - 24012014 THIS PAGE IS LEFT INTENTIONALLY BLANK SM5314 rev 1 rev 2 DRAFT - 24012015 THIS PAGE IS LEFT INTENTIONALLY BLANK DRAFT - 20 November 2014 EUROPE (EMEA): +44 (0)1582 723633 mtlenquiry@eaton.com THE AMERICAS: +1 800 835 7075 mtl-us-info@eaton.com ASIA-PACIFIC: +65 6 645 9888 sales.mtlsing@eaton.com The given data is only intended as a product description and should not be regarded as a legal warranty of properties or guarantee. In the interest of further technical developments, we reserve the right to make design changes. Eaton Electric Limited, Great Marlings, Butterfield, Luton Beds, LU2 8DL, UK. Tel: + 44 (0)1582 723633 Fax: + 44 (0)1582 422283 E-mail: mtlenquiry@eaton.com www.mtl-inst.com © 2020 Eaton All Rights Reserved Publication No. SM5314 rev 1 240120 January 2020 DRAFT - 240120 The safety you rely on. See the complete MTL product portfolio at www.mtl-inst.com For more information: If further assistance is required, please contact an authorised MTL Distributor, Sales Office, or Customer Service Department Connect with Eaton, MTL: AUSTRALIA Eaton Electrical (Australia) Pty Ltd, 10 Kent Road, Mascot, New South Wales, 2020, Australia Tel: +61 1300 308 374 Fax: +61 1300 308 463 E-mail: mtlsalesanz@eaton.com BeNeLux MTL Instruments BV Ambacht 6, 5301 KW Zaltbommel The Netherlands Tel: +31 (0)418 570290 Fax: +31 (0)418 541044 E-mail: mtl.benelux@eaton.com CHINA Cooper Electric (Shanghai) Co. 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Suite 200, Houston TX 77086, USA Tel: +1 281-571-8065 Fax: +1 281-571-8069 E-mail: mtl-us-info@eaton.com www.eaton.eu Application Note 11/2017 AP040017EN PowerXL™ DE1 Variable Speed Starters Motor Data – Motor Protection – V/f curves – Slip Compensation Level 2 1 – Fundamental – No previous experience necessary 2 – Basic – Basic knowledge recommended 3 – Advanced – Reasonable knowledge required 4 – Expert – Good experience recommended 2017-11-09 AP040017EN DE1 Motor Data – Motor Protection – V/f Curves – Slip Compensation Page 2 Contents Disclaimer

.... 4 General .... 5 Motor data .... 5 Motor Nom Voltage (P-07) .... 6 Motor Nom Current (P-08) .... 6 Motor Nom Frequency (P-09) .... 6 Motor Nom Speed (P-10) (Switching from Hz to rpm, Slip compensation) .... 7 Motor protection.. 8 SwitchRemanentStorage (P-33) .... 9 V/f curve .... 9 f-max

(P-01) .... 9 Energy Optimizer (P-06) .... 10 Motor Nom Voltage (P-07) .... 10 Motor Nom Frequency (P-09) .... 10 V-Boost (P-11) 10
Examples.. 11
Example 1: Linear V/f curve 11
Example 2: Linear V/f curve with voltage boost 11
Example 3: Energy Optimization (automatic modification of the V/f curve) 12
Example 4: 87 Hz – Curve 12
2017-11-09 AP040017EN DE1 Motor Data – Motor Protection – V/f Curves – Slip Compensation Page 3 Danger! - Dangerous electrical voltage! · Disconnect the power supply of the device. · Ensure that devices cannot be accidentally restarted. · Verify isolation from the supply. · Cover or enclose any adjacent live components. · Follow the engineering instructions (AWA/IL) for the device concerned. · Only suitably qualified personnel in accordance with EN 50110-1/-2 (VDE 0105 Part 100) may work on this device/ system. · Before installation and before touching the device ensure that you are free of electrostatic charge. · The functional earth (FE, PES) must be connected to the protective earth (PE) or the potential equalization. The system installer is responsible for implementing this connection. · Connecting cables and signal lines should be installed so that inductive or capacitive interference does not impair the automatic control functions. · Suitable safety hardware and software measures should be implemented for the I/O interface so that an open circuit on the signal side does not result in undefined states. · Deviations of the mains voltage from the rated value must not exceed the tolerance limits given in the specification, otherwise this may cause malfunction and/or dangerous operation. · Emergency stop devices complying with IEC/EN 60204-1 must be effective in all operating modes. Unlatch- ing of the emergency-stop devices must not cause a restart. · Devices that are designed for mounting in housings or control cabinets must only be operated and con- trolled after they have been properly installed and with the housing closed. · Wherever faults may cause injury or material damage, external measures must be implemented to ensure a safe operating state in the event of a fault or malfunction (e.g. by means of separate limit switches, me- chanical interlocks etc.). · Variable speed starters may have hot surfaces during and immediately after operation. · Removal of the required covers, improper installation or incorrect operation of motor or variable speed starter may destroy the device and may lead to serious injury or damage. · The applicable national safety regulations and accident prevention recommendations must be applied to all work carried on live variable speed starters. · The electrical installation must be carried out in accordance with the relevant electrical regulations (e. g. with regard to cable cross sections, fuses, PE). · Transport, installation, commissioning and maintenance work must be carried out only by qualified per- sonnel (IEC 60364, HD 384 and national occupational safety regulations). · Installations containing variable speed starters must be provided with additional monitoring and protective devices in accordance with the applicable safety regulations. Modifications to the variable speed starters using the operating software are permitted. · All covers and doors must be kept closed during operation. · To reduce the hazards for people or equipment, the user must include in the machine design measures that restrict the consequences of a malfunction or failure of the variable speed starter (increased motor speed or sudden standstill of motor). These measures include: • Other independent devices for monitoring safety related variables (speed, travel, end positions etc.). • Electrical or non-electrical system-wide measures (electrical or mechanical interlocks). • Never touch live parts or cable connections of the variable speed starter after it has been discon- nected from the power supply. Due to the charge in the capacitors, these parts may still be alive after disconnection. Consider appropriate warning signs. 2017-11-09 AP040017EN DE1 Motor Data – Motor Protection – V/f Curves – Slip Compensation Page 4 Disclaimer The information, recommendations, descriptions, and safety notations in this document are based on Eaton's experience and judgment and may not cover all contingencies. If further information is required, an Eaton sales office should be consulted. Sale of the product shown in this literature is subject to the terms and conditions outlined in the applicable Terms and Conditions for Sale of Eaton or other contractual agreement between Eaton and the purchaser. THERE ARE NO UNDERSTAND- INGS, AGREEMENTS, WARRANTIES, EXPRESSED OR IMPLIED, INCLUDING WARRANTIES OF FITNESS FOR A PARTICULAR PURPOSE OR MERCHANTABILITY, OTHER THAN THOSE SPECIFICALLY SET OUT IN ANY EXISTING CONTRACT BETWEEN THE PARTIES. ANY SUCH CONTRACT STATES THE ENTIRE OBLI- GATION OF EATON. THE CONTENTS OF THIS DOCUMENT SHALL NOT BECOME PART OF OR MODIFY ANY CONTRACT BETWEEN THE PARTIES. As far as

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By default they are configured, that motors of the respective power class can be supplied without changing the settings. Many standard cases can be covered. There are some applications, which require an adaptation by changing parameters. In this Application Note the following aspects are covered: · Adaptation to the connected motor · Slip compensation · Motor protection · Setting the V/f curve · Energy optimization Motor data Condition for a proper operation is the right connection (star / delta) of the motor to the output ter- minals of the device. The rated voltage of the motor windings is decisive. Device Output Voltage Motor Connection DE1-12… 3 x 230 V 230 / 400 V Delta DE1-34… 3 x 400 V 230 / 400 V 400 / 660 V Star Delta DE1-34… 3 x 400 V 230 / 400 V Delta Special case: 87 Hz-curve (see Example 4 below) An adaptation to the connected motor can be done with the following parameters: · P-07 Motor Nom Voltage · P-08 Motor Nom Current · P-09 Motor Nom Frequency · P-10 Motor Nom Speed The respective values can be taken from the name plate of the motor or from the data sheet of the motor manufacturer. They are used for the setting of the motor protection and define the V/f curve. 2017-11-09 AP040017EN DE1 Motor Data – Motor Protection – V/f Curves – Slip Compensation Page 6 Motor Nom Voltage (P-07) Motor rated voltage (name plate) taking the connection (star / delta) into account. This value defines the max. output voltage of the Variable Speed Starter. Is the output frequency higher than the rated frequency of the motor (P-09), the output voltage remains on the value set with P-07. See also chap- ter "V/f curve" below. Devices of the series DE1 have a voltage compensation. That means, that the output voltage is kept constant, even with fluctuation of the mains voltage. In case P-07 = 0 , the voltage compensation is disabled. In this case the maximum output voltage of the device is equal to the mains voltage at the input terminals. In exceptional cases, a different setting of P-07 is necessary. See chapter "87 Hz curve" PNU Parameter Name Range Default 211.0 P-07 Motor Nom Voltage 0 / 50 V … Ue Ue Ue = Rated voltage of the device, e.g. 230 V or 400 V, depending on device type Motor Nom Current (P-08) Rated current of the motor. By default, parameter P-08 „Motor Nom Current" is set to the rated cur- rent Ie of the Variable Speed Starter. P-08 is also used to set the thermal protection for the motor. See also chapter "Motor Protection". In case the rated current of the motor is different to the one of the Variable Speed Starter, P-08 has to be set accordingly to provide a thermal motor protection. It must be pointed out, that this current value is set, which is assigned to the type of connection of the motor. In the example above it is 3,2 A at 230 V (Delta) respectively 1,9 A at 400 V (Star). PNU Parameter Name Range Default 210.0 P-08 Motor Nom Current 0.1 · Ie … Ie Ie Ie = Rated current of the device Motor Nom Frequency (P-09) Rated frequency of the motor. By default this parameter is set to the mains frequency (50 Hz in Eu- rope, 60 Hz in USA) and doesn't need to be changed in the majority of cases. In case, motors with rated frequencies different from the mains frequency (e.g. 200 Hz for fast rotat- ing motors) or if the 87 Hz curve is used, P-09 has to be set accordingly. PNU Parameter Name Range Default 216.0 P-09 Motor Nom Frequency 20 … 300 Hz 50 Hz resp. 60 Hz 2017-11-09 AP040017EN DE1 Motor Data – Motor Protection – V/f Curves – Slip Compensation Page 7 Motor Nom Speed (P-10) (Switching from Hz to rpm, Slip compensation) P-10 = 0: Setting / display of the output frequency in Hz P-10 > 0: all speed related parameters (P-01, P-02, P-20…P-23) are set and displayed in rpm. Fur- thermore the slip compensation is activated, which ensures, that the motor speed is kept constant even with changing loads. In case the value of P-10 corresponds to a synchronous speed (e.g. 3000 rpm for a 2 pole motor at 50 Hz), the speed is set and displayed in rpm, but the slip compensation is not activated. With slip compensation Without slip compensation The slip is the difference between a synchronous speed because of a rotating field and the actual speed of the motor. The name plate in the example on page 5 shows a rated speed of 1410 rpm. It is a 4 pole motor with a synchronous speed of 1500 rpm. Between no load and rated load there is a slip of 90 rpm. Running the motor with a Variable Speed Starter, one wants to prevent the speed vari- ance by compensating the slip. With slip compensation: at load increase j voltage and frequency are increased accordingly k. The speed n1 remains constant. At load decrease voltage and frequency are reduced. Without slip compensation: with load j the speed drops from n1 to n2 k, when unloading the speed increases again. PNU Parameter Name Range Default 217.0 P-10 Motor Nom Speed 0 / 200 … 18000 rpm

0 rpm 2017-11-09 AP040017EN DE1 Motor Data – Motor Protection – V/f Curves – Slip Compensation Page 8 Motor protection The Variable Speed Starters of the series DE1 own an internal motor protection function, which trips the drive after a certain time in case of overload. The display shows the fault message “I.t-trP“. The overload is related to the rated current of the motor, set with P-08. In case the output current of the device exceeds the value set with P-08 „Motor Nom Current“, this status is displayed on the keypad. 7-Segment LED display: dots a…f are flashing OLED display: text „O-L“ is displayed It has to be considered that, similar to a thermal overload relay, the current is used to estimate the temperature inside the motor. This kind of “indirect temperature measurement” is sufficient in many cases, but doesn’t reflect the real temperature conditions inside the motor. In case of Variable speed it has to be taken into account, that the cooling of the motor is done by an impeller, which is mount- ed on the motor’s shaft. Therefore the cooling is reduced at lower speeds. Experience shows that this is not critical between approx. 40 % and 100 % speed, but below 40 % it can lead to problems, if the application requires full torque also in this range (= full amount of losses). In pump and fan applica- tions where the torque is square with the speed, this effect is uncritical. In case of steady operation with nearly rated load below 40 % rated speed it is recommended to use motors with temperature sensors (thermistors or thermo contacts), which provide information about the real motor temperature. Thermistors as well as temperature contacts can be directly connected to DE1 devices. Example thermistor Example temperature contact Parameter P-15 has to be set in a way, that the function „External Fault“ (EXTFLT) is assigned to ter- minal 3 (DI3). During proper operation, a High-Signal is applied to terminal 3. In case of fault the temperature contact must open respectively the resistance of the thermistor has to increase. DE1 trips at a resistance of > 3.6 kΩ, Reset can be performed at values 100 % of the current set in P-08 for a certain time. · Check if the value of P-08 is equal to the motor rated current · Check motor connection (star / delta) · Flashing dots on the display indicate an operation with overload (> P- 08). Increase ramp time or decrease load in this case. · Check the load mechanically to ensure it is free and no jams, blockages or other mechanical faults exist. „Fault Code“ 5 x flash 2 s OFF O-t Heatsink overtemperature. The drive is too hot. · Check the ambient temperature around the drive is within the speci- fied range (maximum 50 °C / 60 °C, partly with derating) · Ensure sufficient cooling air is free to circulate around the drive (dis- tance to other devices above and below the variable speed starter). · Improve cooling of the control cabinet, when necessary. · The cooling slots may not be closed e.g. by pollution or by devices which are mounted too close „Fault Code“ 6 x flash 2 s OFF Internal fault in power section " Please refer to your next Eaton sales office. „Fault Code“ 7 x flash 2 s OFF SC-trp Loss of the serial communication · Check, if the connection to drives and other devices in the network is correct · Each participant in the network must have its own unique address. Two devices with the same address are not allowed. „Fault Code“ 8 x flash 2 s OFF P-dEf Default parameters have been loaded „Fault Code“ 9 x flash 2 s OFF Distorsion of the d.c. voltage „Fault Code“ 10 x flash 2 s OFF 4-20 F Analog input current out of range · Check settings of P-16 for AI1 · In case of 4-20mA: Check reference signal on wire break 2017-11-13 AP040029EN DE1 Starting, Stopping and Operation Page 19 Message Possible causes and remedy „Fault Code“ 11 x flash 2 s OFF U-t Undertemperature. This message is displayed, when the ambient temperature is below – 10 °C. To start the drive, the temperature must be above this value. „Fault Code“ 12 x flash 2 s OFF Th-flt Thermistor on the heatsink is faulty. Please refer to your next Eaton sales of- fice. „Fault Code“ 13 x flash 2 s OFF dAtA-F Fault in the internal memory. Parameters are not saved and default settings are reloaded. Try to save the (again modified) parameters again. If the message still appears: Please refer to your next Eaton sales office. 2017-11-13 AP040029EN DE1 Starting, Stopping and Operation Page 20 5 Stopping There are multiple possibilities to stop a variable speed drive: Possible with DE1? Accessories required Switch off, drive coasts to standstill YES None Ramp down to standstill YES None Ramp down to standstill with overvoltage control YES None Dynamic braking with brake resistor No - DC braking YES None Feedback energy to the mains NO - Mechanical brake (Variant DE11 only) YES None. Control with DE11 5.1 Ramping down or coasting? Parameter P-05 „Stop Mode“ determines, if the motor coasts or if it ramps down when the enable signal (FWD, REV, STOP) is removed. 5.1.1 Stop Mode (P-05) Coast to stop (P-05 = 0): When the enable signal is removed, the output of the inverter is disabled and the motor coasts to stop. Ramp to stop (P-05 = 1): When the enable signal is removed, the motor ramps to standstill with the ramp set with P-04. ATTENTION: In a drive system the energy always flows from the subsystem with the higher frequency to the one with lower frequency. If the output frequency of the variable speed starter is reduced too fast (deceleration ramp too short) and the motor still turns at a higher speed than the one corre- sponding to the output frequency of the inverter because of its inertia, the motor becomes a genera- tor and feeds back energy into the d.c. link. This leads to an increase of the d.c. link voltage and pos- sibly to a trip with the message O.Volt (Overvoltage). To prevent this, variable speed starters have the function

“Overvoltage control”, which is enabled by default. More details see chapter 4.2.1. PNU Parameter Name Range Default 620.1 P-05 Stop Mode 0: coast to stop 1: ramp to stop 0 2017-11-13 AP040029EN DE1 Starting, Stopping and Operation Page 21 5.2 DC braking to standstill A DC current is injected into the motor, which generates a braking torque. The rotating energy of the machine is converted into heat, dissipated by the motor. This means that a DC braking must not be performed quite often, not to overload the motor. A DC braking cannot be used for a speed reduction e.g. from 1000 rpm to 800 rpm, but to a braking to standstill only. The DC braking is also used to stop rotating motors (e.g. fans, which turn because of the chimney effect inside a wind tunnel) before they start. This is to prevent overcurrent trips. See chapter 3.3 “Starting a rotating motor”. 5.2.1 DCBrake (P-25), t-DCBrake@Stop (P-26), DCBrake Voltage (P-27), f-DCBrake@Stop (P-28) Parameter P-25 „DCBrake“ determines, in which situations a DC braking is performed. In case a DC braking is required at stop, P-25 has to be set to 1 or 3. The behavior at removal of the signals FWD / REV / START depends on the stop mode (P-05). P-05 = 0 (coast to stop): The DC braking starts, once the signal FWD / REV / START is removed. P-05 = 1 (ramp to stop) At removal of FWD / REV / START the motor decelerates with the ramp set with “t-dec” (P-04). Once the frequency set with “f-DCBrake@Stop” (P-28) is reached, the DC braking starts. The strength and the duration depend on the settings of P-26 “t-DCBrake@Stop” and P-27 “DCBrake Voltage” (in percent of the motor rated voltage P-07). With P-25 = 3 it has to be noted, that the brak- ing time before a start is the same as after a stop. During a DC braking the LED „Fault code“ on the front of the variable speed starter lights yellow. 2017-11-13 AP040029EN DE1 Starting, Stopping and Operation Page 22 PNU Parameter Name Range Default 2221.0 P-25 DCBrake 0: OFF 1: ON at Stop 2: ON before Start 3: ON before Start and at Stop 0 2222.1 P-26 t-DCBrake@Stop 0.0…10 s 0.0 s 2220.0 P-27 DCBrake Voltage 0.0…100 % 0.0 % 2223.0 P-28 f-DCBrake@Stop 0 … P-01 (f-max) 0.0 Hz 2017-11-13 AP040029EN DE1 Starting, Stopping and Operation Page 23 5.3 Control of a mechanical brake HINT: The information is exclusively valid for the variant DE11! When a mechanical brake is used it should be activated at a certain speed. The relay contact be- tween the terminals 13 and 14 have the possibility to generate a speed dependent signal. The threshold is adjustable. It can be configured, if the relay contact closes above or below the threshold. Die Funktion des Ausgangs ist entsprechend zu konfigurieren. Kind of signal Terminals Function Threshold Normally open contact 13 / 14 P-51 „RO1 Function“ P-52 „RO1 Upper Limit“ 5.3.1 RO1 Funktion (P-51), RO1 obere Grenze (P-52) PNU Parameter Name Wertebereich Werk 451.0 P-51 RO1 Function 0: Drive running 1: Drive healthy 2: Motor at target speed 3: Drive tripped 4: Speed > RO1 Upper Limit (P-19) 5: Motor current > RO1 Upper Limit (P-19) 6: Speed < RO1 Upper Limit (P-19) 7: Motor current 0: all speed related parameters (P-01, P-02, P-20 … P-23) are set and displayed in rpm. PNU Parameter Name Range Default 217.0 P-10 Motor Nom Speed 0 / 200 … 30000 rpm 0 rpm 2017-11-10 AP040042EN DE1 Set Point Setting Page 6 1.2 Upper and lower speed limit The speed range of the connected motor is determined by the parameters “f-min” (P-02) and “f- max” (P-01). The reference is linear between these two values. Please note, that the value of P-01 cannot be exceeded, respectively the value of P-02 cannot be undercut. This is true for both senses of rotation. Frequency respectively speed = P-02 + (set pointactual / set pointmax) · (P-01 – P-02) Example 1: P-10 = 0 (setting / display in Hz) P-01 = 50 Hz P-02 = 0.0 Hz Set point via analog input: 0 … 10 V Set point actually set: 5 V Frequency = 0 Hz + (5 V / 10 V) · (50 Hz – 0 Hz) = 0 Hz + 0.5 · 50 Hz = 25 Hz Example 2: P-10 = 1470 rpm (setting / display in rpm) P-01 = 1470 rpm P-02 = 300 rpm Set point via analog input: 0 … 10 V Set point actually set: 5 V Speed = 300 rpm + (5 V / 10 V) · (1470 rpm – 300 rpm) = 300 rpm + 0.5 · 1170 rpm = 885 rpm PNU Parameter Name Range Default 20.1 P-01 f-max P-02 … 5 · P-09 (300 Hz max) 50.0 Hz 20.0 P-02 f-min 0.0 Hz … P-01 0.0 Hz Note: · With values of P-10 > 0 the setting is done in rpm instead of Hz. · The value, which can be set with P-01 „f-max“, is limited to five times „Motor Nom Frequen- cy“ (P-09) with a maximum of 300 Hz. 1.3 Behavior during change over between reference sources During a change over between two reference sources, e.g. from an analog signal to a fixed frequency, the new reference is approached with the actual ramp. The ramp times are determined by “t-acc” (P- 03) for acceleration and “t-dec” (P-04) for deceleration. 2017-11-10 AP040042EN DE1 Set Point Setting Page 7 1.4 Skip frequencies to avoid resonances In some applications an operation of the motor in a certain frequency band leads to mechanical res- onances, which can end up in a destruction of machine parts. The devices of the series PowerXLTM DE1… have the possibility to skip this frequency band for steady operation to avoid this effect. Fading out frequencies is possible with all kind of reference sig- nals, not depending on where they come from, e.g. analog input, fixed frequency, digital reference … , whatever is selected. The band width is determined by P-42 “f-SkipBand1”, while the center point is defined by P-43 “f-Skip1”. The diagram on the left hand side shows the behavior. Setting P-26 to zero, deactivates the function. REF = Reference Example: A motor runs up to 50 Hz. In the range between

15 Hz and 25 Hz mechanical resonances can occur. Therefore the motor may not run inside this range steadily. Band width: P-42 = 25 Hz – 15 Hz = 10 Hz Center point: P-43 = 15 Hz + 25 Hz 2 = 20 Hz How it works: The reference is below the disabled range. " Drive runs with the set frequency. " Increase of refer- ence into the disabled range " Motor accelerates and remains at the lower limit (in this example: 15 Hz). " Increase of reference above the disabled range " Motor accelerates with the ramp, set with P-03 “t-acc” to the new speed. " Motor operates above the disabled range according to the refer- ence. " Reduction of reference into the disabled area " Motor decelerates and remains at the up- per limit (in this example: 25 Hz). " Reduction of reference below the disabled area " Motor decel- erates with the ramp, set with P-04 “t- dec” to the new speed. PNU Parameter Name Range Default 22.0 P-42 f-SkipBand1 0…P-01 0 Hz1) 21.0 P-43 f-Skip1 0…P-01 0Hz1) 1) The default setting of P-10 “Motor Nom Speed” = 0. In this case the values for P-42 and P-43 are given in Hz. When P-10 is different from „0“, P-42 and P-43 have to be set in min-1. 2017-11-10 AP040042EN DE1 Set Point Setting Page 8 2 Analog reference Variable speed starters of the series DE1 have one analog input: · Analog input AI1 terminal 4 The configuration of the inputs and outputs is described inside the Application Note „I/O Configura- tion“ (AP040036EN). Beside the setting of the signal format (voltage or current), a scaling factor can be used to adopt the speed to the input signal. 2.1 Selecting the sense of rotation The analog value at terminal 4 determines the amount of speed. The control commands FWD and REV select clockwise or counter clockwise sense of rotation. If a change of sense is required, the actual command (e.g. FWD) has to be removed first, before applying the other one (e.g. REV). Applying FWD and REV simultaneously leads to a coasting of the motor. 2.2 Format of the analog value The speed reference signal can be a voltage signal as well as a current one. It is invertible with Pa- rameter P-18 in a way that a minimum signal leads to the maximum speed and vice versa. Format P-18 counter clockwise rotation clockwise rotation f-min f-max f-min f-max 0 … 10 V (U 0-10) 0 0 V + REV 10 V + REV 0 V + FWD 10 V + FWD 1 10 V + REV 0 V + REV 10 V + FWD 0 V + FWD 0 … 20 mA (A 0-20) 0 0 mA + REV 20 mA + REV 0 mA + FWD 20 mA + FWD 1 20 mA + REV 0 mA + REV 20 mA + FWD 0 mA + FWD 4 … 20 mA (t 4-20) 0 4 mA + REV 20 mA + REV 4 mA + FWD 20 mA + FWD 1 20 mA + REV 4 mA + REV 20 mA + FWD 4 mA + FWD 4 … 20 mA (r 4-20) 0 4 mA + REV 20 mA + REV 4 mA + FWD 20 mA + FWD 1 20 mA + REV 4 mA + REV 20 mA + FWD 4 mA + FWD Note: In case a terminal configuration without the commands FWD and REV is selected with P-15, the sense of rotation is set with the commands START and DIR. · Clockwise rotation " START · Counter clockwise rotation " START + DIR 2017-11-10 AP040042EN DE1 Set Point Setting Page 9 3 Fixed frequencies Fixed frequencies are references, which are set once, e.g. during commissioning and which can be selected by a digital command when required. The devices of the series DE1 have up to 4 fixed fre- quencies f-Fix1 … f-Fix4, which can be selected independently. 3.1 Setting the frequency value The setting of the fixed frequencies is done with P-20 up to P-23. Each value can be between zero and the maximum frequency „f-max“ (P-01). It has to be noted, that the minimum frequency “f-min” (P-02) will not be undercut, even when the fixed frequency is set to a lower value than P-02. Example: P-02 (f-min) = 10 Hz P-20 (f-Fix1) = 5 Hz When f-Fix1 is selected, the drive runs with 10 Hz! PNU Parameter Name Range Default 5.1 P-20 f-Fix1 0 … f-max (P-01) 20.0 Hz 5.2 P-21 f-Fix2 0 … f-max (P-01) 30.0 Hz 5.3 P-22 f-Fix3 0 … f-max (P-01) 40.0 Hz 5.4 P-23 f-Fix4 0 … f-max (P-01) 50.0 Hz 3.2 Selecting the sense of rotation When using a fixed frequency the sense of rotation is determined by the commands FWD (clockwise) and REV (counter clockwise) respectively DIR. 3.3 Selecting the fixed frequency The fixed frequencies can be activated via commands at the control terminals or via a field bus. The selection is binary coded " for 4 fixed frequencies 2 Bits (FF20 and FF21) are required. The predefined terminal configurations selected with P-15 enable access to the fixed frequencies. 3.3.1 Selection with predefined terminal configurations (P-15) 2017-11-10 AP040042EN DE1 Set Point Setting Page 10 Inside the Application Note „I/O Configuration” (AP040036EN) the configuration of the control ter- minals is described. The following commands are important for the selection of fixed frequencies: Abbreviation Function FF1 Selection between the analog speed reference at analog input AI1 (ter- minal 6) and the fixed frequency 1 (f-Fix1), set with P-20. Low = analog reference, High = f-Fix1. FF20 / FF21 Selection of the digital frequencies f-Fix1 … f-Fix4 with digital commands FF20 FF21 f-Fix1 (P-20) L L f-Fix2 (P-21) H L f- Fix3 (P-22) L H f-Fix4 (P-23) H H 3.3.2 Use of fixed frequencies in device functions In certain situations, fixed frequencies are selected by a device function. Please take care, that there is no collision because of user specific settings. Fixed frequency Function f-Fix1 When P-16 = 4 (analog inputs with a signal 4 … 20 mA) the drive ramps to f-Fix1, in case of wire break in the reference circuit. 2017-11-10 AP040042EN DE1 Set Point Setting Page 11 4 Digital reference The speed reference of the variable speed starters DE1 can also be given via digital commands. The command UP (faster) increases the content of the reference counter, while DOWN (slower) reduces it. The use of a digital reference has the advantage, that the

reference can be set from different loca- tions by paralleling push buttons, which is required in cases of large machines. The setting occurs between the minimum speed / frequency (f-min, P-02) and the maximum fre- quency / speed (f-max, P-01) with the actual ramp. The setting can be done with the keypad as well as via terminals. Example: · When an enabled drive gets the "UP" command, the motor accelerates according to the ac- tual ramp according to "t-acc" (P-03) · When the „UP" command is removed, the speed remains constant. Applying "UP" again leads to a further acceleration. The maximum frequency / speed is defined with "f-max" (P- 01). · Consequently, applying „DOWN" leads to a speed reduction. · When starting, the drive ramps to the speed determined by P-24 without an "UP" command. 2017-11-10 AP040042EN DE1 Set Point Setting Page 12 4.1 Configuration 4.1.1 Terminals / Keypad With the settings P-15 = 4, 5 or 6 UP and DOWN commands via terminals are possible. In case a key- pad DEX-KEY-LED is used, the reference value can be modified by using the arrow keys in addition. With P-12 = 1 or 2 the variable speed starter can be started and stopped with the keys on the key- pad. The behavior depends on the setting of P-24 "Digital Reference Reset Mode" (see 4.1.2) 4.1.2 Reference at start and at changeover between speed sources When starting a drive with a digital reference and when changing over from another speed source, e.g. a fixed frequency, to a digital reference the reference value to be ramped to is determined by the setting of P-24 "Digital Reference Reset Mode": · P-24 = 0 or 2 o Minimum speed o Example 1: Behavior at start § Drive runs with digital reference " switch OFF " restart " drive ramps to the minimum speed, set with P-02 „f-min". 2017-11-10 AP040042EN DE1 Set Point Setting Page 13 o Example 2: Behavior at changeover between speed sources § Drive runs with digital reference " Changeover to another speed source by applying a signal to the terminal " drive ramps to the speed required by the other speed source " Select "Digital reference" by removing the signal from the terminal " drive remains at the speed of the other speed source. The speed can now be changed with the keys on the keypad or with the signals UP and DOWN at the control terminals. · P-24 = 1 or 3 o Start with the latest speed before switching OFF or changing over to another speed source, set with the keypad or with the commands UP and DOWN at the terminals. This also applies to cases where another speed source was active at the time of switching OFF, but which is not selected at restart. o Example 1: The digital reference was set with the keypad to 1000 rpm. The speed source was changed from "Digital reference" to „Fixed Frequency 1" by means of a command at the control terminals. The drive is switched OFF when "Fixed Frequen- cy1" is active. § Select „Digital reference" at the terminals " drive ramps to the 1000 rpm set with the keypad § „Fixed Frequency 1" was selected at the terminal when restarting " Drive ramps to Fixed Frequency 1 § Changeover to "Digital reference" with the signal at the terminals " drive ramps to 1000 rpm o Example 2: Switching OFF when the drive runs with another speed source than the digital reference § Selection of the other speed source is still active at restart " drive ramps to the speed of the other speed source. § Selection of the other speed source is not active at restart " drive ramps to the latest digital reference. P-24 „Digital Reference Reset Mode" also determines, how the drive can be started when P-12 = 1 or 2: · P-24 = 0…1 o Starting of the drive by pushing the green START button on the keypad. § To start, an additional signal at the terminals is necessary (START / FWD / REV) · P-24 = 2…3 o The start of the drive is carried out via the terminals (see also 4.1.1). A start with the button on the keypad is not possible. o Note: With P-12 = 2 it is still possible to reverse the drive by pushing the green but- ton on the keypad. 2017-11-10 AP040042EN DE1 Set Point Setting Page 14 PNU Parameter Name Range Default 620.3 P-24 Digital Reference Reset Mode 0 / 1: START via keypad 0: Minimum speed (P-02) 1: Previous speed from Keypad / terminals (UP/DOWN) 2 / 3: START via terminals 2: Minimum speed (P-02) 3: Previous speed from Keypad / terminals (UP/DOWN) 1 4.2 Bedienung 4.2.1 Starting / Stopping Drives, which operate with a digital reference, can be started via terminals as well as via keypad. The possibilities depend on the setting of the parameters P-12 "Local ProcessData Source", P-15 "DI Con- fig Select" and P-24 "Digital Reference Reset Mode". Note: It can also be selected, that a signal from the terminal as well as one from the keypad must be ap- plied to start the drive. In this case the signal at the terminal must be present before the button on the keypad is pushed. P-12 P-24 P-15 Starting via terminal only Starting via keypad only Starting via terminal AND keypad P-12 = 0 P-24 = 0…3 P-15 = 4 / 5 / 6 YES NO NO P-12 = 1 / 2 P-24 = 0 / 1 P-15 = 0 … 9 NO NO YES P-24 = 2 / 3 P-15 = 0 … 9 YES* NO NO *In this case the keypad cannot be used to start the drive, but with P1-12 = 2 the green button can still be used to reverse it (see 4.2.3) 4.2.2 Increase / reduce speed When using a digital reference the speed is changed via the commands UP and DOWN. For the dura- tion of the commands the speed is increased respectively reduced. The commands are given via the keypad or via terminals. The behavior of the drive is depending on keypad or terminal adjustment. While a command via ter- minals modifies the speed with the actual ramp directly, an adjustment with the keypad has a slope and works more smoothly. This results in a delay of about 1.5 s for every actuation. With the setting of P-12 = 1 or 2 a speed adjustment via keypad is always possible, an adjustment via terminals only with the settings P-12 = 1 or 2 AND P-15 = 4 / 5 / 6. 2017-11-10 AP040042EN DE1 Set Point Setting Page 15 Note: · Simultaneous use of UP and DOWN (both via terminals or both via keypad) reduces the speed. · The terminal command dominates the one from the keypad. This also means: DOWN via keypad and UP via terminal " the speed increases. · A speed adjustment via keypad is also possible in cases where starting and stopping via key- pad is disabled. 4.2.3 Change sense of rotation The sense of rotation at start with a digital reference is basically determined by the terminal com- mands. With P12 = 2 one has the possibility to reverse the motor by pressing the green Start button on the keypad. Behavior at start: see column "Sense of rotation at START" in the table below. P-12 P-24 P-15 Sense of rotation via terminal Sense of rotation via keypad Sense of rotation at START P-12 = 0 P-24 = 0 … 3 P-15 = 4 / 5 NO NO No change of sense of rotation possible P-15 = 6 YES Sense of rotation as selected via terminals P-12 = 1 P-24 = 0 … 3 P-15 = 3 / 4 / 5 / 7 NO NO No change of sense of rotation possible P-15 = 8 / 9 YES (DIR) Sense of rotation as selected via terminals P-24 = 2 / 3 P-15 = 0 / 1 / 2 / 6 YES (FWD / REV) P-12 = 2 P-24 = 0 … 3 P-15 = 3 / 4 / 5 / 7 NO YES (INV) Sense of rotation as selected via termi- nals, taking into ac- count a possible in- version at the time of stopping the drive (Start button on the keypad). P-15 = 8 / 9 YES (DIR) P-24 = 2 / 3 P-15 = 0 / 1 / 2 / 6 YES (FWD / REV) Note: · P-15 = 0 / 1 / 2 / 6: o Applying the FWD and REV commands simultaneously leads to a coasting of the motor o In applications with reversion, the Stop Mode should be set in a way, that the ramp is active (P1-5 = 1). If this is not the case a changeover between the com- mands FWD and REV is detected as stop command and the drive behaves ac- cording the setting with P-05. After this, it restarts into the opposite direction. Starting a motor, which is still turning can lead to an overcurrent trip. · P-12 = 2 o A possible inversion with the Start button on the keypad is stored at stop. The drive restarts with the same sense of rotation he had before stopping. Please note, that in this case the sense of rotation at restart cannot be clearly defined by the terminal commands.. www.eaton.eu Application Note 11/2017 AP040036EN PowerXL™ DE1 Variable Speed Starter I/O Configuration Level 2 1 – Fundamental – No previous experience necessary 2 – Basic – Basic knowledge recommended 3 – Advanced – Reasonable knowledge required 4 – Expert – Good experience recommended 2017-11-13 AP040036EN DE1 I/O Configuration Page 2 Contents 1 General ....5 2 Hardware..6 2.1 Designation of the control terminals and technical data...6 2.2 Wiring examples ....6 2.2.1 Example 1: Application motor starter ....6 2.2.2 Example 2: Application with variable speed..7 2.2.3 Example 3: Control voltage from an external voltage source ....7 2.2.4 Example 4: external reference value ....8 2.2.5 Example 5: control by a PLC ....8 2.3 Relay output..9 3 Configuration .... 10 3.1 Inputs .... 10 3.1.1 Terminal configuration.. 10 3.1.2 Displaying input signals .... 15 3.1.3 Configuration of digital input DI3.. 16 3.1.4 Configuration of analog input AI1 .... 16 3.2 Relay output.. 17 3.2.1 Selecting the function of RO1 (DE11 only) .... 18 2017-11-13 AP040036EN DE1 I/O Configuration Page 3 Danger! - Dangerous electrical voltage! • Disconnect the power supply of the device. • Ensure that devices cannot be accidentally restarted. • Verify isolation from the supply. • Cover or enclose any adjacent live components. • Follow the engineering instructions (AWA/IL) for the device concerned. • Only suitably qualified personnel in accordance with EN 50110-1/-2 (VDE 0105 Part 100) may work on this device/ system. • Before installation and before touching the device ensure that you are free of electrostatic charge. • The functional earth (FE, PES) must be connected to the protective earth (PE) or the potential equalization. The system installer is responsible for implementing this connection. • Connecting cables and signal lines should be installed so that inductive or capacitive interference does not impair the automatic control functions. • Suitable safety hardware and software measures should be implemented for the I/O interface so that an open circuit on the signal side does not result in undefined states. • Deviations of the mains voltage from the rated value must not exceed the toleranc e limits give n in the specification, otherwise this may cause malfunction and/or dangerous operation. • Emergency stop devices complying with IEC/EN 60204-1 must be effective in all operating modes. Unlatch- ing of the emergency-stop devices must not cause a restart. • Devices that are designed for mounting in housings or control cabinets must only be oper ated and c on- trolled after they have been properly installed and with the housing closed. • Wherever faults may cause injury or material damage, external measures must be implemented to ensure a safe operating state in the event of a fault or malfunction (e.g. by means of separate limit switches, me - chanical interlocks etc.). • Variable speed starters may have hot surfaces during and immediately after operation. • Removal of the required covers, improper installation or incorrect operation of motor or var iable spe ed starter may destroy the device and may lead to serious injury or damage. • The applicable national safety regulations and accident prevention recommendations must be applied to all work carried on live variable speed starters. • The electrical installation must be carried out in accordance with the relevant electrical regulations (e . g. with regard to cable cross sections, fuses, PE). • Transport, installation, commissioning and maintenance work must be carried out only by qualified per - sonnel (IEC 60364, HD 384 and national occupational safety regulations). • Installations containing variable speed starters must be provided with additional monitoring and protective devices in accordance with the applicable safety regulations. Modifications to the variable speed star te rs using the operating software are permitted. • All covers and doors must be kept closed during operation. • To reduce the hazards for people or equipment, the user must include in the machine design me asure s that restrict the consequences of a malfunction or failure of the variable speed starter (incre ased motor speed or sudden standstill of motor). These measures include: • Other independent devices for monitoring safety related variables (speed, travel, e nd positions etc.). • Electrical or non-electrical system-wide measures (electrical or mechanical interlocks). • Never touch live parts or cable connections of the variable speed starter after it has been disc on- nected from the power supply. Due to the charge in the capacitors, these parts may still be alive after disconnection. Consider appropriate warning signs. 2017-11-13 AP040036EN DE1 I/O Configuration Page 4 Disclaimer The information, recommendations, descriptions, and safety notations in this document are based on Eaton’s experience and judgment and may not cover all contingencies. If further information is required, an Eaton sales office should be consulted. Sale of the product shown in this literature is subject to the terms and conditions outlined in the applicable Terms and Conditions for Sale of Eaton or other contractual agreement between Eaton and the pur- chaser. THERE ARE NO UNDERSTANDINGS, AGREEMENTS, WARRANTIES, EXPRESSED OR IM- PLIED, INCLUDING WARRANTIES OF FITNESS FOR A PARTICULAR PURPOSE OR MERCHANTA- BILITY, OTHER THAN THOSE SPECIFICALLY SET OUT IN ANY EXISTING CONTRACT BETWEEN THE PARTIES. ANY SUCH CONTRACT STATES THE ENTIRE OBLIGATION OF EATON. THE CON- TENTS OF THIS DOCUMENT SHALL NOT BECOME PART OF OR MODIFY ANY CONTRACT BE- TWEEN THE PARTIES. 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Not only internal variables like ramp times or speed are changed, but also different functions can be assigned to the terminals. This possibility is universal inside the DE1 series and does not depend on the power rating. This Application Note describes • the existing input and output terminals • the technical data • the assignment of functions to terminals • the configuration of the I/Os Wiring diagram of a variable speed starter DE1 with default settings 2017-11-13 AP040036EN DE1 I/O Configuration Page 6 2 Hardware All signals at the input terminal have the same signal common (0 V). Terminal 4 can be used as digital input as well as analog input. The respective function depends on the configuration (see chapter 3ff). 2.1 Designation of the control terminals and technical data Designation Function Default 0 V Signal common for all inputs (terminals. 1 … 4) - + 10 V Control voltage and reference voltage 20 mA max. Signal common: 0 V - 1 (DI1) Digital input 1 HIGH: 9 … 30 V 10 V: 1,15 mA / 24 V: 3 mA FWD 2 (DI2) Digital input 2 HIGH: 9 … 30 V 10 V: 1,15 mA / 24 V: 3 mA REV 3 (DI3) Digital input 3 HIGH: 9 … 30 V 10 V: 0,12 mA / 24 V: 0,3 mA FF1 4 (AI1 / DI4) Analog input 1 or digital input 4 analog: 0 … 10 V; 0,12 mA 0/4 … 20 mA, RB = 500 Ω digital: HIGH: 9 … 30 V 10 V: 0,12 mA / 24 V: 0,3 mA REF (analog, 0 … 10 V) 13 Relay RO1 (NO) 250 V, 6 A AC / 30 V, 5 A DC RUN, device enabled14 2.2 Wiring examples The control terminals of the devices DE1 are fixed. On the variant DE11, the terminal block for the control signals is pluggable. To apply control signals to the terminals, the internal 10 V as well as ex- ternal voltages, e.g. 24 V from a PLC, can be used. 2.2.1 Example 1: Application motor starter 2017-11-13 AP040036EN DE1 I/O Configuration Page 7 2.2.2 Example 2: Application with variable speed 2.2.3 Example 3: Control voltage from an external voltage source 2017-11-13 AP040036EN DE1 I/O Configuration Page 8 2.2.4 Example 4: external reference value 2.2.5 Example 5: control by a PLC 2017-11-13 AP040036EN DE1 I/O Configuration Page 9 2.3 Relay output Depending on the kind of load, we recommend the use of protection circuitry for the relay outputs. 2017-11-13 AP040036EN DE1 I/O Configuration Page 10 3 Configuration The table gives an overview, how to determine the function of the single I/Os. Designation Selection / setting of Function Format (signal range) Scaling (Gain) Inversion Hysteresis Offset 0 V fixed - - - - - +10 V fixed - - - - - 1 (DI1) P-12 / P-15 - - - - - 2 (DI2) - - - - - 3 (DI3) - - P-19 - - 4 (AI1 / DI4) P-16 P-17 P-18 - P-44 DE1: 13 fixed - - - - - DE1: 14 - DE11: 13 P-51 - - - P-52 / P-53 / P-54 - DE11: 14 3.1 Inputs The function of the inputs can be configured in different ways: • using the default settings. • configuration with the configuration module DXE-EXT-SET. The numbers at the selector switch correspond to the settings of P-15 in terminal mode (P-12 = 0) • via the optional keypad DX-KEY-LED • via the parameter software DrivesConnect The available terminal combinations depend on the selection of the “Local ProcessData Source” (P- 12). Default: P-15 = 0, P-12 = 0. 3.1.1 Terminal configuration PNU Parameter Name Range Default 423.0 P-15 DI Config Select 0 … 9 0 2017-11-13 AP040036EN DE1 I/O Configuration Page 11 2017-11-13 AP040036EN DE1 I/O Configuration Page 12 2017-11-13 AP040036EN DE1 I/O Configuration Page 13 2017-11-13 AP040036EN DE1 I/O Configuration Page 14 For the terminal functions the following abbreviations are used: Abbreviation Function DIR Used for the selection of the sense of rotation in connection with the START command. Low = cw (FWD) High = ccw (REV) ATTENTION: in case of a wire break the drive reverses in case REV is selected! Alternative: use configuration with FWD/REV. DOWN “Reduce speed” command, when a digital reference is selected. Used in combination with the command UP. In case UP and DOWN are ap- plied simultaneously. The motor reduces its speed for the duration of the simultaneous signals with the deceleration ramp set with “t-dec” (P-04). ENA Enable variable frequency drive. To start the drive an additional start signal (START, FWD, REV) is necessary. When removing ENA, the mo- tor coasts to stop. ENAINV In case ENAINV is used instead of ENA, the sense of rotation is invert- ed, compared to the one determined by a keypad or a fieldbus. Example: ENA + FWD = FWD, ENAINV + FWD = REV ENAREF Enable signal for the speed reference. This signal is necessary to oper- ate the variable speed starter in addition to START respectively FWD/REV. At disconnection of ENAREF the variable speed starter ramps to stand still, but the variable speed starter will not be disa- bled. EXTFLT External fault. Enables the inclusion of an external signal into the fault messages of the variable speed starter. P-19 = 0: During operation a High signal must be applied to the termi- nal. A Low signal leads to a trip with the message “E-trip”. P-19 = 1: During operation a Low signal must be applied to the termi- nal. A High signal leads to a trip with the message “E-trip”. FF1 Selection between the analog speed reference at analog input AI1 (terminal 4) and the fixed frequency 1 (f-Fix1), set with P-20. Low = analog reference, High = f-Fix1 FF20 / FF21 Selection of the fixed frequency with digital commands. The fixed frequencies f-Fix1 … f-Fix4 are defined with P-20 … P-23. FF20 FF21 f-Fix1 (P-20) L L f-Fix2 (P-21) H L f-Fix3 (P-22) L H f-Fix4 (P-23) H H FWD START with a clockwise rotating field (FWD = Forward). When applying a High signal to the respective terminal, the motor accelerates with the predefined ramp. Removing the signal leads to a stop. The stop behavior depends on the setting of P-05 “Stop Mode”. At standstill the variable speed starter is disabled. In applications with two direc- tions, counter clockwise rotation is selected with REV. FWD and REV are logically connected (XOR). Applying both signals at the same time leads to a trip of the variable speed starter. 2017-11-13 AP040036EN DE1 I/O Configuration Page 15 Abbreviation Function REF Analog input AI1 (terminal 4) is used as speed reference input. P-16: Format (voltage input / current input …) P-17: Scaling P-18: Inversion REV START with a counter clockwise rotating field (REV = Reverse). When applying a High signal to the respective terminal, the motor acceler- ates with the predefined ramp. Removing the signal leads to a stop. The stop behavior depends on the setting of P-05 “Stop Mode”. At standstill the variable speed starter is disabled. In applications with two directions, clockwise rotation is selected with FWD. FWD and REV are logically connected (XOR). Applying both signals at the same time leads to a trip of the variable speed starter. START Starts and stops the motor. When applying a High signal to the re- spective terminal, the motor accelerates with the predefined ramp. Removing the signal leads to a stop. The stop behavior depends on the setting of P-05 “Stop Mode”. At standstill the variable speed start- er is disabled. In applications with two directions, the sense of rota- tion is selected with DIR or INV.In applications with Smartwire DT this signal is necessary in addition to the start command coming via bus. UP “Increase speed” command, when a digital reference is selected. Used in combination with the command DOWN. In case UP and DOWN are applied simultaneously. The motor reduces its speed for the duration of the simultaneous signals with the deceleration ramp set with “t- dec” (P-04). 3.1.2 Displaying input signals The status of the inputs can be displayed by selecting the respective parameters. PNU Parameter Name Range Default 560.0 P00-01 Analog input1 0.0 … 100 % input signal - 550.0 … 550.3 P00-04 DI1 Status 0 / 1 - The value, displayed with P00-01, takes also a potential scaling factor (P-17) into account. Example: P00-01 = Signal at AI1 [%] · P-17 The display on the keypad can be used to see the status of the digital inputs DI1 … DI4. It starts with DI1 on the left hand side of the display. 0 = Low signal, 1 = High signal at the respective input termi- nal. Voltages between 9 and 30 V are identified as High signal. If an input is configured as analog input, its status is displayed in P00-04 with 0 with voltage levels up to 9 V, above this with 1. 2017-11-13 AP040036EN DE1 I/O Configuration Page 16 3.1.3 Configuration of digital input DI3 Digital input 3 (Terminal 3) can be used to include an external signal into the fault messages. Parame- ter P-19 (DI3 Logic) determines, if a HIGH or a LOW signal is necessary at terminal 3 to indicate a proper status. PNU Parameter Name Range Default 650.2 P-19 DI3 Logic 0 " HIGH = OK, LOW = fault 1 " LOW = OK, HIGH = fault 0 DI3 can be configured in a way, that a thermistor can be used to protect the connected motor. In this case P-19 must be set to 0. Parameter P-15 has to be set in a way, that the function „External Fault“ (EXTFLT) is assigned to terminal 3 (DI3). During proper opera- tion, a High-Signal is applied to terminal 3. In case of fault the tem- perature contact must open respectively the resistance of the ther- mistor has to increase. DE1 trips at a resistance of > 3.6 kΩ, Reset can be performed at values “RO1 Upper Limit” , output will be logic 0 if value “RO1 Upper Limit” , output will be logic 1 if value RO1 Upper Limit (P-52) 5: Motor current > RO1 Upper Limit (P-52) 6: Speed < RO1 Upper Limit (P-52) 7: Motor current 3.6 kΩ, Reset can be performed at values “RO1 Upper Limit” , output will be logic 0 if value “RO1 Upper Limit” , output will be logic 1 if value RO1 Upper Limit (P-52) 5: Motor current > RO1 Upper Limit (P-52) 6: Speed < RO1 Upper Limit (P-52) 7: Motor current < RO1 Upper Limit (P-52) 8: DE1 not enabled 9: Speed not at speed reference value 0 452.0 P-52 RO1 Upper Limit 0.0 … 200.0 % 100.0 % 454.0 P-53 RO1 Hysteresis 0.0 … 100.0 % 0.0 % 457.0 P-54 RO1 Switch-On Delay 0.0 … 250.0 s 0.0 s Application Note 07/2022 AP040184EN PowerXL DG1 – Firmware Update Level 3 1 – Fundamental – No previous experience necessary 2 – Basic – Basic knowledge recommended 3 – Advanced – Reasonable knowledge required 4 – Expert – Good experience recommended 2 Application Note Firmware Update DG1 07/2022 AP040184EN Eaton.com All proprietary names and product designations are brand names or trademarks registered to the relevant title holders. 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DANGEROUS ELECTRICAL VOLTAGE! • Disconnect the power supply of the device. • Ensure that devices cannot be accidentally restarted. • Verify isolation from the supply. • Ground and short-circuit. • Cover or enclose any adjacent live components. • Follow the engineering instructions (AWA/IL) for the device concerned. • Only suitably qualified personnel in accordance with EN 50110-1/-2 (VDE 0105 Part 100) may work on this device/system. • Before installation and before touching the device ensure that you are free of electrostatic charge. • The functional earth (FE, PES) must be connected to the protective earth (PE) or the potential equalization. The system installer is responsible for implementing this connection. • Connecting cables and signal lines should be installed so that inductive or capacitive interference does not impair the automatic control functions. • Suitable safety hardware and software measures should be implemented for the I/O interface so that an open circuit on the signal side does not result in undefined states. • Deviations of the mains voltage from the rated value must not exceed the tolerance limits given in the specification, otherwise this may cause malfunction and/or dangerous operation. • Emergency stop devices complying with IEC/EN 60204-1 must be effective in all operating modes. Unlatching of the emergency-stop devices must not cause a restart. • Devices that are designed for mounting in housings or control cabinets must only be operated and controlled after they have been properly installed and with the housing closed. • Wherever faults may cause injury or material damage, external measures must be implemented to ensure a safe operating state in the event of a fault or malfunction (e.g. by means of separate limit switches, mechanical interlocks etc.). • The used device may have hot surfaces during and immediately after operation. • Removal of the required covers, improper installation or incorrect operation of motor or device may destroy the device and may lead to serious injury or damage. • The applicable national safety regulations and accident prevention recommendations must be applied to all work carried on live device. • The electrical installation must be carried out in accordance with the relevant electrical regulations (e. g. with regard to cable cross sections, fuses, PE). • Transport, installation, commissioning and maintenance work must be carried out only by qualified personnel (IEC 60364, HD 384 and national occupational safety regulations). • Installations containing device must be provided with additional monitoring and protective devices in accordance with the applicable safety regulations. 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Application Note Firmware Update DG1 07/2022 AP040184EN Eaton.com 5 Content General .... 6 Connecting the Drive to a PC.. 6 Apply main voltage .... 6 Firmware Upgrade.. 7 Resetting to default settings .... 11 Firmware Upgrade for optional cards .... 12 6 Application Note Firmware Update DG1 07/2022 AP040184EN Eaton.com General The device software of the DG1 can be updated to a newer version or downgraded to an old one. Both is done via the so-called firmware update tool. Connecting the Drive to a PC 1. Remove the front cover. 2. Connect the programming cable to terminals 25 and 26. Abbildung 1: Connecting the programming cable Apply main voltage Start the drive by applying the main voltage. Depending on frame size: 230V AC à single phase: L1(L)/L3(N) 400V AC à three phase: L1/ L2/L3 Application Note Firmware Update DG1 07/2022 AP040184EN Eaton.com 7 Firmware Upgrade 1. First download the desired firmware package from the Eaton website and unzip the file. Abbildung 2: Firmware package 2. Open the Firmware Upgrade Tool. Abbildung 3: Firmware Upgrade Tool 3. Select the previously downloaded firmware package from your directory by clicking "Browse". Abbildung 4: Power Xpert inControl Software 4. Select the file “DG1_C0033“. Abbildung 5: DG1_C0033 5. Check the cable connection and the COM port in the Windows Device Manager. 8 Application Note Firmware Update DG1 07/2022 AP040184EN Eaton.com Abbildung 6: Device Manager 6. Enter "1" for "Slave Address" and select the COM port. Abbildung 7: Settings 7. Establish the connection via "Connect". Abbildung 8: Establish connection 8. After the firmware has been detected, a dialog for confirming the firmware package is displayed. The tool automatically sets check marks once the version differences have been detected. Abbildung 9: Update process 9. Choose „Block 0“ for german and „Block 1“ for english. Application Note

Firmware Update DG1 07/2022 AP040184EN Eaton.com 9 Abbildung 10: Update process 10. Confirm the selection with „Program". Abbildung 11: Confirming 11. Verify that the update has been completed correctly. ("Programming Success - Verification OK"). If "Verification OK" appears, select "Disconnect". If "Failed" appears, repeat the update process or contact After Sales Service. 10 Application Note Firmware Update DG1 07/2022 AP040184EN Eaton.com Abbildung 12: Update completed Application Note Firmware Update DG1 07/2022 AP040184EN Eaton.com 11 Resetting to default settings Reset all parameter to the factory settings by proceeding as follows: Parameters à Basic Settings à System à Parameter Sets (P21.1.3) Then select "Reload defaults". Abbildung 13: Parameter reset Now the firmware update is completed. You can disconnect the programming cable, remove the power connector and reattach the front cover. 12 Application Note Firmware Update DG1 07/2022 AP040184EN Eaton.com Firmware Upgrade for optional cards 1. Connect the optional module to one of the expansion slots. Abbildung 14: Installating expansions 2. Follow the steps 2.1 to 4.8. 3. Confirm the selection with „Program". Abbildung 15: Confirming the selection 4. Check the update version of the board. If "Code is same" appears, no update needs to be performed here. Application Note Firmware Update DG1 07/2022 AP040184EN Eaton.com 13 Abbildung 16: Check the version 5. Click „Disconnect" to disconnect the communication again. If the drive now remains in "Loader Mode", a connection should be established again via "Connect" and then disconnected again via "Disconnect". If the drive is still in "Booth Loader Mode" and the "Startup Wizard" does not appear, please contact After Sales Service. 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For more information, visit Eaton.com Eaton addresses worldwide: Eaton.com/contacts www.eaton.eu Application Note 04/2017 AP040168EN PowerXL™ DG1 Variable Frequency Drives Load balancing in multi motor applications Level 1 1 – Fundamental – No previous experience necessary 2 – Basic – Basic knowledge recommended 3 – Advanced – Reasonable knowledge required 4 – Expert – Good experience recommended 2017-04-25 AP040168EN DG1 Load balancing in multi motor applications Page 2 Contents 1 General .... 5 2 Load balancing via slip .... 6 3 Load balancing via drooping... 7 3.1 Application example .... 8 4 Adjustable load balancing via torque control .... 9 2017-04-25 AP040168EN DG1 Load balancing in multi motor applications Page 3 Danger! - Dangerous electrical voltage! · Disconnect the power supply of the device. · Ensure that devices cannot be accidentally restarted. · Verify isolation from the supply. · Cover or enclose any adjacent live components. · Follow the engineering instructions (AWA/IL) for the device concerned. · Only suitably qualified personnel in accordance with EN 50110-1/-2 (VDE 0105 Part 100) may work on this device/system. · Before installation and before touching the device ensure that you are free of electrostatic charge. · The functional earth (FE, PES) must be connected to the protective earth (PE) or the potential equalization. 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Modifications to the frequency inverters us- ing the operating software are permitted. · All covers and doors must be kept closed during operation. To reduce the hazards for people or equipment, the user must include in the machine design measures that restrict the consequences of a malfunction or failure of the frequency inverter (increased motor speed or sud- den standstill of motor). These measures include: – Other independent devices for monitoring safety related variables (speed, travel, end positions etc.). – Electrical or non-electrical system-wide measures (electrical or mechanical interlocks). – Never touch live parts or cable connections of the frequency inverter after it has been disconnected from the power supply. Due to the charge in the capacitors, these parts may still be alive after disconnection. 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Already small differences in the mechanical structure of the drives inside the system or manufacturing tolerances can lead to an unbalanced load sharing. Beside an oversizing other measures exist to balance the load to ensure a reliable operation of the applica- tion and to prevent overload situations for single motors. Like in many other cases, multiple solutions exist, differing in complexity and costs. There is a funda- mental interest to choose the variant with the best value for money. In the end the application de- termines, which kind of solution can be chosen. This application note describes three of the possible solutions in connection with variable frequency drives and provides an indication of the right solu- tion. The following chapters describe, how the different solutions work. The table below gives an overview about the substantial features and differences. Control via slip Droop function Torque control Control mode Speed control Speed control 1 motor with speed control, the other ones with torque control Number of variable frequency drives 1 variable frequency drive per motor; con- necting multiple mo- tors in parallel to the output of one device is possible. 1 variable frequency drive per motor 1 variable frequency drive per motor Load balancing via Slip Load dependent corrective value Torque control Accuracy of balancing + ++ +++ Motors (power, manufacturer) Equal motors necessary Different motors possible Different motors possible Mechanical coupling between the motors Preferably coupled via friction; fixed mechan- ical coupling possible in some applications. Preferably coupled via friction; fixed mechan- ical coupling possible in some applications. Fixed coupling and coupling via friction possible. In case of coupling via friction a speed limitation is recommended. 2017-04-25 AP040168EN DG1 Load balancing in multi motor applications Page 6 2 Load balancing via slip The speed of a three phase induction motor depends on the load. When it is supplied with the voltage and frequency ac- cording to its name plate, an unloaded motor turns with near- ly synchronous speed, while the speed at rated load corre- sponds to the rated speed. In case of a 50 Hz mains supply and a four pole motor this means, that the unloaded motor turns with approximately 1500 rpm and at rated load e.g. with 1470 rpm. The difference between synchronous speed and the speed of the motor axis is called slip. In the example on the left the motor is loaded with torque M1 and it turns with the speed n1. The load is increased up to M2 j ¨ The speed drops down to n2 k. This behavior is utilized in a slip dependent load balancing. This simplest kind of “automatic” load sharing presumes, that the mechanics as well as the motors of all parts of the system are identical. In theory all motors have to carry the same load per definition, but tolerances, temperature dependen- cy and small mechanical differences let the loads drift apart, even when the motors were equally loaded at the point of start. But how does load balancing work? The motor with the highest load drops in speed and in this case the other one(s) have to carry more load than before. The load is now more or less balanced. There is no possibility for load adjustment and the sharing is defined by the system. Therefore it makes sense to add some margin when calculating the motor powers. The variable frequency drive DG1 has to work in the motor control mode “Freq Control” (P8.1 = 0). In case each motor has its own variable frequency drive, they must have identical parameter settings. Parameter Name Range Default P8.1 Motor Control Mode Freq Control (0) Speed Control (1) Open Loop Speed Control (5) Open Loop Torque Control (6) Freq Control (0) It is also possible to connect multiple motors in parallel to one variable frequency drive. It has to be noted, that each motor must have its own motor protection, because the total current is “known” by the variable frequency drive, but not how it is shared between the single motors. 2017-04-25 AP040168EN DG1 Load balancing in multi motor applications Page 7 3 Load balancing via drooping In case speed controlled drive systems are mechanically connected through form fit or friction, the fastest drive takes the load and pulls the other ones, which are less, or in extreme cases, not loaded. To counteract this effect, the speed reference will be corrected, depending on the load. At load in- crease, the droop function reduces the resulting speed reference (set reference – speed reduction), the motor falls back a little bit in its speed and the other motors inside the system take more load automatically. Application experience shows, that it is of advantage in many cases to have one motor inside the system, where the droop function is disabled (P8.13 “Load Drooping” = 0.00 %), while it is enabled (P8.13 “Load Drooping” different from 0.0 %) for all other motors inside the system. The set value of P8.13 is the percentage of speed by which the speed drops in case the motor is loaded with rated torque. With reduced load, the speed reduction will be reduced accordingly. In exceptional cases it can also be advantageous to enable the droop function for all motors. The variable frequency drive DG1 has to work in the motor control mode “Open Loop Speed Control” (P8.1 = 5) to achieve the best result. Parameter Name Range Default P8.1 Motor Control Mode Freq Control (0) Speed Control (1) Open Loop Speed Control (5) Open Loop Torque Control (6) Freq Control (0) P8.13 Load Drooping 0.00 % … 100.00 % 0.00 % 2017-04-25 AP040168EN DG1 Load balancing in multi motor applications Page 8 3.1 Application example Material is transported through the machine by means of two conveyor belts. Each belt is driven by its own motor. Because of the contact pressure, the two belts are connected mechanically. In case one of the two mo- tors tries to run a little bit faster than the other one, it leads to an unequal load sharing. Without an enabled droop function, motor 1 takes 80 % of its rated load, motor 2 85 %. Because of the higher load, motor 2 becomes warmer than motor 1, possibly one can also see the difference in speed on the material which is transported between the belts. Now the droop function will be enabled with P8.13. The system will change to equal load sharing iteratively. Values at the beginning (we are looking to the system at an output frequency of 40 Hz, P1.9 = 50 Hz, P8.13 = 10.00 %): Resulting speed of motor 1: 40 Hz – ((10 % · 50 Hz) · 80 %) = 36 Hz Resulting speed of motor 2: 40 Hz – ((10 % · 50 Hz) · 85 %) = 35,75 Hz Motor 2 now runs slower than motor 1 " The load of motor 1 increases " Therefore the load of motor 2 is reduced ……. . This is a repetitive process until an equal sharing of the load is achieved. Remaining differences in load can be adjusted with 8.13. 2017-04-25 AP040168EN DG1 Load balancing in multi motor applications Page 9 4 Adjustable load balancing via torque control Inside this system, one motor is speed controlled and the other one(s) torque controlled. The speed controlled motor determines the speed of the system, while the torque is the control variable for the other motors. Here it is possible to use motors of different ratings and it is also possible to set indi- vidual shares of the load. A torque control is much more complex than the principles described in chapters 2 and 3. On the other hand you have much more possibilities to adopt the control to the application, which results in a higher accuracy. Nevertheless the other principles are useful in simple applications because of their simplicity and value for money. Torque control is extensively described inside the application Note „AP040167EN Torque Control”. Please refer to this document. One important aspect must be mentioned here: A torque controlled motor always tries to bring the required torque (or tension in case of linear movements) to the load. When this is not possible, the torque is used for acceleration to the maximum possible speed. This is not critical as long as the mo- tors are connected together mechanically, e.g. when all pinions work on the same geared ring. In cases where the speeds of the motors involved are not synchronized mechanically and a slip in speed is possible, it is strongly recommended to limit the speed of the torque controlled motor. The neces- sary aspects and settings are comprehensively described in the application note AP040167EN men- tioned above. www.eaton.eu Application Note 01/2018 AP040177EN DE PowerXL™ DG1 Variable Frequency Drives Motor data and V/f curves Level 2 1 – Fundamental – No previous experience necessary 2 – Basic – Basic knowledge recommended 3 – Advanced – Reasonable knowledge required 4 – Expert – Good experience recommended 2018-01-15 AP040177EN DG1 Motor data and V/f curves Page 2 Contents 1 General .... 5 2 Motor data .... 5 2.1 Motor Nom Current .... 6 2.2 Motor Nom Speed .... 6 2.3 Motor PF .... 6 2.4 Motor Nom Voltage .... 6 2.5 Motor Nom Frequency .... 7 2.6 Motor Identification .... 7 3 Motor Control Mode .... 9 3.1 Frequency Control (V/ f).. 9 3.2 Speed Control .... 9 3.3 Open Loop Speed Control .... 10 4 V/f curve .... 11 4.1 Optimizing the V/f curve at Frequency Control and Speed Control .... 12 4.1.1 Improving the torque behavior .... 13 4.1.2 Increasing energy efficiency .... 15 4.2 87 Hz curve .... 15 2018-01-15 AP040177EN DG1 Motor data and V/f curves Page 3 Danger! - Dangerous electrical voltage! · Disconnect the power supply of the device. · Ensure that devices cannot be accidentally restarted. · Verify isolation from the supply. · Cover or enclose any adjacent live components. · Follow the engineering instructions (AWA/IL) for the device concerned. · Only suitably qualified personnel in accordance with EN 50110-1/-2 (VDE 0105 Part 100) may work on this device/system. · Before installation and before touching the device ensure that you are free of electrostatic charge. · The functional earth (FE, PES) must be connected to the protective earth (PE) or the potential equalization. The system installer is responsible for implementing this connection. · Connecting cables and signal lines should be installed so that inductive or capacitive interference does not impair the automatic control functions. · Suitable safety hardware and software measures should be implemented for the I/O interface so that an open circuit on the signal side does not result in undefined states. · Deviations of the mains voltage from the rated value must not exceed the tolerance limits given in the specification, otherwise this may cause malfunction and/or dangerous operation. · Emergency stop devices complying with IEC/EN 60204-1 must be effective in all operating modes. Unlatch- ing of the emergency-stop devices must not cause a restart. · Devices that are designed for mounting in housings or control cabinets must only be operated and con- trolled after they have been properly installed and with the housing closed. · Wherever faults may cause injury or material damage, external measures must be implemented to ensure a safe operating state in the event of a fault or malfunction (e.g. by means of separate limit switches, me- chanical interlocks etc.). · Frequency inverters may have hot surfaces during and immediately after operation. · Removal of the required covers, improper installation or incorrect operation of motor or frequency invert- er may destroy the device and may lead to serious injury or damage. · The applicable national safety regulations and accident prevention recommendations must be applied to all work carried on live frequency inverters. · The electrical installation must be carried out in accordance with the relevant electrical regulations (e. g. with regard to cable cross sections, fuses, PE). · Transport, installation, commissioning and maintenance work must be carried out only by qualified per- sonnel (IEC 60364, HD 384 and national occupational safety regulations). · Installations containing frequency inverters must be provided with additional monitoring and protective devices in accordance with the applicable safety regulations. Modifications to the frequency inverters us- ing the operating software are permitted. · All covers and doors must be kept closed during operation. To reduce the hazards for people or equipment, the user must include in the machine design measures that restrict the consequences of a malfunction or failure of the frequency inverter (increased motor speed or sud- den standstill of motor). These measures include: – Other independent devices for monitoring safety related variables (speed, travel, end positions etc.). – Electrical or non-electrical system-wide measures (electrical or mechanical interlocks). – Never touch live parts or cable connections of the frequency inverter after it has been disconnected from the power supply. Due to the charge in the capacitors, these parts may still be alive after disconnection. Consider appropriate warning signs. 2018-01-15 AP040177EN DG1 Motor data and V/f curves Page 4 Disclaimer The information, recommendations, descriptions, and safety notations in this document are based on Eaton's experience and judgment and may not cover all contingencies. If further information is required, an Eaton sales office should be consulted. Sale of the product shown in this literature is subject to the terms and conditions outlined in the applicable Terms and Conditions for Sale of Eaton or other contractual agreement between Eaton and the pur- chaser. THERE ARE NO UNDERSTANDINGS, AGREEMENTS, WARRANTIES, EXPRESSED OR IM- PLIED, INCLUDING WARRANTIES OF FITNESS FOR A PARTICULAR PURPOSE OR MERCHANTA- BILITY, OTHER THAN THOSE SPECIFICALLY SET OUT IN ANY EXISTING CONTRACT BETWEEN THE PARTIES. ANY SUCH CONTRACT STATES THE ENTIRE OBLIGATION OF EATON. THE CON- TENTS OF THIS DOCUMENT SHALL NOT BECOME PART OF OR MODIFY ANY CONTRACT BE- TWEEN THE PARTIES. As far as applicable mandatory law allows so, in no event will Eaton be responsible to the purchaser or user in contract, in tort (including negligence), strict liability, or otherwise for any special, indirect, incidental, or consequential damage or loss whatsoev- er, including but not limited to damage or loss of use of equipment, plant or power system, cost of capital, loss of power, additional expenses in the use of existing power facilities, or claims against the purchaser or user by its customers resulting from the use of the infor- mation, recommendations, and descriptions contained herein. The information contained in this manual is subject to change without notice. 2018-01-15 AP040177EN DG1 Motor data and V/f curves Page 5 1 General Devices of the series PowerXL™ DG1 are variable frequency drives for the supply of three phase in- duction motors. By default they are configured, that motors of the respective power class can be supplied without changing the settings. Many standard cases can be covered. There are some applications, which require an adaptation by changing parameters. In this Applica- tion Note the following aspects are covered: · Selection of the motor control mode · Adaptation to the connected motor · Slip compensation · Setting the V/f curve 2 Motor data Condition for a proper operation is the right connection (star / delta) of the motor to the output ter- minals of the device. The rated voltage of the motor windings is decisive. Device Output Voltage Motor Connection DG1-32… 3 x 230 V 230 / 400 V Delta DG1-34… 3 x 400 V 230 / 400 V 400 / 660 V Star Delta DG1-34… 3 x 400 V 230 / 400 V Delta Special case: 87 Hz-curve (see section 4.2) An adaptation to the connected motor can be done with the following parameters: · P1.6 Motor Nom Speed · P1.7 Motor PF · P1.8 Motor Nom Voltage · P1.9 Motor Nom Frequency The respective values can be taken from the name plate of the motor or from the data sheet of the motor manufacturer. They are used for the setting of the motor protection and define the V/f curve. 2018-01-15 AP040177EN DG1 Motor data and V/f curves Page 6 2.1 Motor Nom Current Parameter P1.5 „Motor Nom Current" is set to the rated current Ie of the variable frequency drive by default. At the same time it is the set value for the thermal protection of the motor. In case the mo- tor has a nominal current different to the one of the VFD, P1.5 must be set accordingly to ensure motor protection. It must be pointed out, that this current value is set, which is assigned to the type of connection of the motor. In the example above it is 3,2 A at 230 V (Delta) respectively 1,9 A at 400 V (Star). Parameter Name Range Default P1.5 Motor Nom Current 0,1 · Ie … 2 · Ie Ie Ie = Rated current of the variable frequency drive All measures to protect the connected motor are described in the Application Note AP040176EN "Starting, stopping and operation". 2.2 Motor Nom Speed The setting of P1.6 „Motor Nom Speed" is necessary for three reasons: · to display the right speed value in all modes of operation · for calculation of the slip compensation in operation mode "Speed Control" (P8.1 = 1) · for calculations inside the motor model when operating in vector mode (P8.1 = 5 „Open Loop Speed Control" Please use the name plate value for setting P1.6. Parameter Name Range Default P1.6 Motor Nom Speed 300 … 20000 rpm 1750 rpm 2.3 Motor PF In vector mode (P8.1 = 5 „Open Loop Speed Control") the power factor (cos ϕ), which is specified on the motor's name plate, must be set. Parameter Name Range Default P1.7 Motor PF 0.3 … 1 0.85 2.4 Motor Nom Voltage Motor rated voltage (name plate) taking the connection (star / delta) into account. In exceptional cases, a different setting of P1-07 is necessary. See section 4.2 "87 Hz curve" Parameter Name Range Default P1.8 Motor Nom Voltage 180 … 690 V Ue Ue = Rated voltage of the variable frequency drive, e.g. 230 V or 400 V depending on the device type 2018-01-15 AP040177EN DG1 Motor data and V/f curves Page 7 2.5 Motor Nom Frequency Rated frequency of the motor. By default this parameter is set to the mains frequency (50 Hz in Eu- rope, 60 Hz in USA) and doesn't need to be changed in the majority of cases. In case, motors with rated frequencies different from the mains frequency (e.g. 200 Hz for fast rotat- ing motors) or if the 87 Hz curve is used (see section 4.2), P1.9 has to be set accordingly. When changing the value of P1.9 the setting of P8.5 "Field Weakening Point" is set to the same value. If the application requires different values for P1.9 and P8.5, Motor Nom Frequency must be set first, before adopting the value for the field weakening point Parameter Name Range Default P1.9 Motor Nom Frequency 0.00 … 400.00 Hz 50 Hz 2.6 Motor Identification The motor identification MUST be performed in vector mode (P8.1

= 5 or 6) to gain the required pa- rameter values for an optimal performance of the motor. ATTENTION: The motor data (e.g. the resistance) change with the temperature. Therefore the motor identification run shall be performed with a warm motor. The kind of motor identification run is determined by the setting of P8.14 „Identification“. The fol- lowing motor data are identified: · Motor Stator Resistance R1 (P8.50) · Motor Rotor Resistance R2 (P8.51) · Motor Leak Inductance X1 (P8.52) · Motor Mutual Inductance Xh (P8.53) · Motor Excitation Current (P8.54) P8.14 = 0: No Action No identification of the motor data will be performed. This is the setting during normal operation of the drive. P8.14 = 1: Identification Only Stator Resistor During the identification run only the stator resistance is identified. The other values remain un- changed. P8.14 = 2: Identification with Run The values for the parameters P8.50 ip to P8.54 are identified. The measurement is done with a run- ning motor. The motor must be unloaded (load decoupled, no gearbox …). P8.14 = 3: Identification No Run The values for the parameters P8.50 ip to P8.54 are identified. During the measurement the motor is standing still. 2018-01-15 AP040177EN DG1 Motor data and V/f curves Page 8 How to perform a motor identification run: · Before starting a motor identification run, the motor data (parameters P1.5 up to P1.9) must be set. · Select the motor control mode P8.1 = “3: Open Loop Speed Control”. · Select in P8.14 „Identification“, which kind of identification shall be performed (P8.14 = 1…3). · Remove any connection between the drive and a PC during identification run. · Apply START command · The identification of the motor data takes place automatically and is active for about 30 s re- spectively until the START signal will be removed. · On the keypad „Motor Identification“ is shown. · The motor data are identified and assigned to the respective parameters. · In case an identification is not possible, the fault message “Motor ID Fault” (#57) is displayed. One reason could be that the rated power of the connected motor deviates too much from the one of the variable frequency drive. Alternatively the motor data can be set manually on the basis of technical information supplied by the motor manufacturer. · After a motor identification run, the START signal must be reapplied to start the motor. The motor doesn’t start automatically, even when the START signal is still applied to the respec- tive terminal. · Parameter P8.14 “Identification” is reset to “0: No action” automatically as soon as the iden- tification run is finished. Parameter Name Range Default P8.14 Identification 0: No Action 1: Identification Only Stator Resistor 2: Identification with Run 3: Identification No Run 0: No Action P8.50 Stator Resistor 0.001 … 65535 W 0.033 W P8.51 Rotor Resistor 0.001 … 65535 W 0.034 W P8.52 Leak Inductance 0.01 … 655.35 mH 0.12 mH P8.53 Mutual Inductance 0.1 … 6553.5 mH 3.4 mH P8.54 Excitation Current 0.1 … 7.4 A 0.1 A 2018-01-15 AP040177EN DG1 Motor data and V/f curves Page 9 3 Motor Control Mode Parameter P8.1 „Motor Control Mode“ determines the way, how the motor is controlled (e.g. fre- quency or vector control). The information given inside the Application Note refer to the settings P8.1 = 0, 1 or 5. By default the variable frequency drive is configured for Frequency Control (P8.1 = 0), which is mainly used in simple applications. With speed control (P8.1 = 1 or 5) an improved speed accuracy and a better torque performance can be achieved. In this case the motor data must be set and with Open Loop Speed Control (P8.1 = 5) a motor identification run (P8.14, see section 2.6) is necessary. Parameter Name Range Default P8.1 Motor Control Mode 0: Frequency Control 1: Speed Control 5: Open Loop Speed Control 6: Open Loop Torque Control 0 3.1 Frequency Control (V/f) P8.1 = 0 The output frequency of the variable frequency drive is proportional to the reference, which is for example applied to an analog input. The ratio between the output voltage and the frequency is kept constant. This leads to a speed change when the load is changing, like with a single speed motor connected DOL to the mains. This control mode is preferred, when multiple motors are connected in parallel at the output of one single variable frequency drive respectively in simple applications, where no special requirements concerning speed accuracy at variable load exist. 3.2 Speed Control P8.1 = 1 In principle the Speed Control works like the Frequency Control described in section 3.1. At Speed Control the slip compensation is activated in addition, which takes care, that the motor speed is kept approximately constant even in case of load changes. In this motor control mode the motor data must be set (P1.5 up to P1.9) The slip is the difference between a synchronous speed because of a rotating field and the actual speed of the motor. The name plate in section 2 shows a rated speed of 1410 rpm. It is a 4 pole mo- tor with a synchronous speed of 1500 rpm. Between no load and rated load there is a slip of 90 rpm. Running the motor with a variable frequency drive, one wants to prevent the speed variance by compensating the slip. 2018-01-15 AP040177EN DG1 Motor data and V/f curves Page 10 with slip compensation without slip compensation With slip compensation: at load increase j voltage and frequency are increased accordingly k. The speed n1 remains constant. At load decrease voltage and frequency are reduced. Without slip compensation: with load j the speed drops from n1 to n2 k, when unloading the speed increases again. 3.3 Open Loop Speed Control P8.1 = 5 Open loop means, that a feedback of the motor speed to the variable frequency drive, e.g. by using an encoder, is not required. The speed information used in the control algorithm is the result of a calculation by the motor model. To ensure an optimal performance, the motor data (parameters P1.5 up to P1.9) must be set and a motor identification run must be performed (see section 2.6). Speed accuracy and torque performance are improved compared to the motor control mode “Speed Con- trol” described in section 3.2. Note: When multiple motors are connected in parallel to one single variable frequency drive, this motor control mode may not be used! 2018-01-15 AP040177EN DG1 Motor data and V/f curves Page 11 4 V/f curve The V/f curve determines the magnetization of the motor and therefore the torque behavior signifi- cantly. In addition the energy efficiency of the complete system can be impacted. As described in section 3, multiple motor control modes exist. Common to all of them is, that the field weakening point (FWP) and the maximum frequency must be defined. In case of open loop speed control (P8.1 = 5), the variable frequency drive calculates the necessary settings on the basis of this information and the determined motor data. In case of frequency control (P8.1 = 0) or speed control with slip compensation (P8.1 = 1) it is possible to modify the V/f curve to improve the torque behavior (see section 4.1). · P1.2 „Max Frequency“ maximum frequency for the application. This frequency may be above the „Motor Nom Fre- quency“ (P1.9). · P8.5 „Field Weakening Point“ This parameter defines the frequency, at which the maximum output voltage, defined with P8.6, is reached. · P8.6 „Voltage at FWP“ Maximum voltage of the variable frequency drive in percent of the Motor Nom Voltage (P1.8). This voltage is reached at the field weakening point (FWP) defined with P8.5. Note: At a change of parameter P1.9 „Motor Nom Frequency“ P8.5 is automatically set to the same frequency value. In applications, where the frequency at FWP is different to the Motor Nom Fre- quency, P1.9 must be set first, before setting P8.5. The same is true for the voltage. Here P1.8 “Mo- tor Nom Voltage” must be set before P8.6 “Voltage at FWP”. Parameter Name Range Default P1.2 Max Frequency P1.1 … 400 Hz 50.0 Hz P8.5 Field Weakening Point 8.0 Hz … P1.2 P1.9 P8.6 Voltage at FWP 10 … 200 % – P1.8 P1.8 2018-01-15 AP040177EN DG1 Motor data and V/ f curves Page 12 4.1 Optimizing the V/f curve at Frequency Control and Speed Control The V/f curve shown in section 4 is idealized (P8.4 = 0 “Linear”) and sufficient for many applications. There are two cases, where the shape of the V/f curve should be adopted: · where a higher starting torque is required, respectively where the motor has to run at lower speed stationary · in pump and fan applications, where the motor losses shall be reduced by field weakening under part load conditions. The different shapes of the V/f curve can be selected with P8.4 “V/Hz Ratio”. · P8.4 = 0 „Linear“ Voltage and frequency change linearly from zero up to the field weakening point (FWP) · P8.4 = 1 „Squared“ Voltage and frequency change squared from zero up to the field weakening point (FWP). See also section 4.1.2. · P8.4 = 2 „Programmable“ The shape of the curve can be configured, see also section 4.1.1- · P8.4 = 3 „Linear + Flux Optimization“ The shape of the V/f curve is adopted to the load conditions automatically, see also section 4.1.2. Parameter Name Range Default P8.4 V/Hz Ratio 0: Linear 1: Squared 2: Programmable 3: Linear + Flux Optimization 0: Linear 2018-01-15 AP040177EN DG1 Motor data and V/f curves Page 13 4.1.1 Improving the torque behavior When operating with lower speeds, the voltage drop inside the motor becomes particularly noticea- ble, which leads to a reduced speed, unbalanced run and in extreme cases to a standstill of the motor with current flow at the same time. This effect can be reduced by increasing the output voltage in the lower speed range. P8.3 “V/Hz Optimization” determines, in which way this will be achieved: · P8.3 = 1 „Enabled“ The voltage is increased automatically. The value depends on the motor rating and the values are based on experience. Setting: o Set motor data in parameter group 1 (P1.5 up to P1.9) o P8.3 = 1: Enabled · P8.3 = 0 „Disabled“ The shape of the V/f curve can be configured manually. In this case P8.4 „V/Hz Ratio“ has to be set to „2: Programmable“. · P8.7 „V/Hz Mid Frequency“ · P8.8 „V/Hz Mid Voltage“ · P8.9 „Zero Frequency Voltage“ The V/f curve is divided into two sections. It starts at zero frequency with a voltage defined with P8.9 „Zero Frequency Voltage“, proceeding linearly to a point defined by P8.7 “V/Hz Mid Frequency” for the frequency and by P8.8 “V/Hz Mid Voltage” for the voltage, and from there to the field weakening point (FWP). With this measure it is possible to increase the voltage in the lower range above aver- age to compensate the voltage drop inside the motor and to improve the torque behavior. Beside other cases this measure is used, when a drive is operated in the lower speed range station- ary. It has to be noted, that the cooling of the motor is usually realized by a fan, which is mounted on the motor’s shaft and whose cooling effect is reduced correspondingly. When a certain torque is required in this range, it must be ensured, that the motor will not be overheated. Eventually a sepa- rately driven fan must be used. 2018-01-15 AP040177EN DG1 Motor data and V/f curves Page 14 When setting the parameters, the motor must initially be operated unloaded with linear V/f curve. It is presumed, that the motor data (P1.5 up to P1.9) are set already and that the general settings for the V/f curve (see section 4) are completed. · P8.4 „V/Hz Ratio“ = 0: Linear · Run the motor with 2/3 of its rated speed. · Read the motor current on the keypad or in the configuration software inControl (M4). Be- cause of the unloaded motor the actual current corresponds approximately to the excitation current. · Remove START signal · Set P8.54 „Excitation Current“ to the value measured before. It is required for internal calcu- lations. · P8.4 „V/Hz Ratio“ = 2: Programmable · During the following settings P1.1 “Min Frequency” must be set to zero, even when the ap- plication requires higher values for the minimal frequency during normal operation. When the V/f settings are completed, P1.1 can be set back to the value, which is required by the application. · Frequency reference = 0, start variable frequency drive · Increase the value of P8.9 “Zero Frequency Voltage”, until the current is as high as measured before. · Stop drive · Set P8.7 and P8.8 to the required values. The setting is application dependent. Additional to the settings here it is possible to set the motor control mode (P8.1) to “1: Speed Control” and/or to enable the “V/Hz Optimization” with P8.3. In general good results can be achieved by using the following rule of thumb: o P8.8 = 1,4 – P8.9 o P8.7 = P8,5 – (P8.8 : P8.6) Parameter Name Range Default P8.3 V/Hz Optimization 0: Disabled 1: Enabled 0: Disabled P8.7 V/Hz Mid Frequency 0 Hz … P8.5 0 Hz P8.8 V/Hz Mid Voltage P8.9 … P8.6 P8.9 Zero Frequency Voltage 0 % … 40 % P8.6 0 % P8.54 Excitation current Depends on drive rating 2018-01-15 AP040177EN DG1 Motor data and V/f curves Page 15 4.1.2 Increasing energy efficiency Objective is to reduce the losses inside the motor to increase the overall system efficiency. Because of the voltage reduction the field of the motor is weakened, which leads to a reduction of the reac- tive current, while the active one is increasing at the same time, but not as much as the reactive cur- rent decreases. This leads to a decrease of the overall motor current. This principle is only applicable, when the application doesn’t require full torque in the complete speed range. The device series DG1 has two possibilities to achieve this: · P8.4 „V/Hz Ratio“ = 1: Squared with this setting the voltage increases squared with the frequency, until it reaches it maxi- mum at the FWP, see also drawing in section 4.1.1 · P8.4 „V/Hz Ratio“ = 3: Linear + Flux Optimization In principle the V/Hz curve is linear. When the drive operates under part load conditions for a certain time (approximately 1 minute), the voltage is automatically decreased by some Volts. The procedure is repeated until the current is at its minimum. This leads to less losses inside the motor and to a noise reduction. In case a higher torque is required the drive returns to its linear V/f curve and the process starts again. This kind of energy optimization makes sense, when different torque can be required at the same speed. This principle is only applicable to drives without short term speed changes, but with constant speed for a certain time. 4.2 87 Hz curve In the majority of cases standard asynchronous motors are used up to their rated frequency. The maximum output frequency of the variable frequency drive is 50 Hz. The power of the motor can be increased by √3, by increasing the frequency from 50 Hz to 87 Hz (50 Hz · √3), keeping the flux (mag- netizing current) constant at the same time. Conditions at a 400 V mains · The motor is wounded for 230/400 V (not 400/690 V) · The windings are connected in delta. · The variable frequency drive has a maximum output voltage of 400 V and a maximum frequency of 87 Hz. This results in 50 Hz at 230 V. · The variable frequency drive is selected for a current which is the rated current of the motor at 230 V. Parameters · P1.8 = 400 V · P1.9 = 87 Hz (with 50 Hz on the name plate) ATTENTION: When using a 50 Hz motor at 87 Hz, possible imbalances of the rotor can cause mechan- ical damages. It is recommended to contact the motor manufacturer before using this motor at speeds above rated speed. 2018-01-15 AP040177EN DG1 Motor data and V/f curves Page 16 Example for selection: Motor data · 230 / 400 V · 3,2 / 1,9 A · 0, 75 kW · 1410 min-1 · 50 Hz Selection · Device rated for 400 V, but for the current which is assigned to 230 V (here: 3,2 A) à DG1-343D3FB-C21C. · The power of the motor results in 0,75 kW · √3 = 1,3 kW (rated torque at √3 times rated speed). · The synchronous speed of the motor is 1500 rpm · √3 = 2598 rpm · The expected speed at rated load is 2598 rpm – 90 rpm = 2508 rpm Remark: 90 rpm corresponds to the slip speed (1500 min-1 – 1410 min-1) MTL5500 range Isolating interface units June 2024 INM 5500 Rev 18 Instruction manual MTL intrinsic safety solutions INM 5500 Rev 18ii DECLARATION OF CONFORMITY A printed version of the Declaration of Conformity has been provided separately within the original shipment of goods. However, you can find a copy of the latest version at: http://www.mtl-inst.com/certificates INM 5500 Rev 18iii CONTENTS DECLARATION OF CONFORMITY ii IMPORTANT NOTE v ATEX/UKCA/IECEX SAFETY INSTRUCTIONS vi/vii 1 INTRODUCTION 1 2 DESCRIPTION 1 3 INSTALLATION 2 3 1 Modules – pre-installation 3 3 2 Installing columns of isolators 4 4 ACCESSORIES 6 4 1 MTL5500 power bus - Installation and use 6 4 2 MPA5500 AC power adaptor 7 4 3 Earth rail and tagging accessories 8 5 DX ENCLOSURES 12 5 1 Environmental conditions 12 5 2 Mounting 16 5 3 Accessories in enclosures 17 5 4 IS warning label 17 6 UNIT DESCRIPTIONS, SETTING-UP AND CONNECTIONS 18 6 1 Digital Input modules 19 6.1.1 Phase reversal . . . . 19 6.1.2 Line-Fault Detection (LFD) . . . . 19 6.1.3 MTL5501-SR - Fail-safe Switch/ Proximity detector interface . . . . .20 6.1.4 MTL5510 &

MTL5510B - Switch/Proximity detector interface . . . . .21 6.1.5 MTL5511 - Switch/Proximity detector interface . . . . .25 6.1.6 MTL5513 - Switch/Proximity detector interface . . . . .26 6.1.7 MTL5514/ MTL5514D/MTL5514-T - Switch/Proximity detector interface . . . . .27 6.1.8 MTL5516C - Switch/Proximity detector interface . . . . .28 6.1.9 MTL5517 - Switch/Proximity detector interface . . . . .29 6 2 Digital Output modules 30 6.2.1 MTL5521/MTL5521-T - Solenoid Alarm driver . . . . .30 6.2.2 MTL5522 - Solenoid Alarm driver . . . . .31 6.2.3 MTL5523 - Solenoid Alarm driver . . . . .32 6.2.4 MTL5523V/MTL5523VL - Solenoid Alarm driver . . . . .33 6.2.5 MTL5524 - Solenoid Alarm driver . . . . .34 6.2.6 MTL5525 - Solenoid Alarm driver . . . . .35 6.2.7 MTL5526 - Switch Operated Relay . . . . .36 6 3 Pulse, Vibration and Foundation Fieldbus modules 37 6.3.1 MTL5531 - Vibration Transducer Interface . . . . .37 6.3.2 MTL5532 - Pulse Isolator . . . . .38 6.3.3 MTL5533 - Vibration Transducer Interface . . . . .40 6.3.4 MTL5553- Isolator/power supply for 31.25kbits/s fieldbuses . . . . .41 6 4 Analogue Input modules 42 6.4.1 MTL5541/MTL5541S/MTL5541S-T - Repeater Power Supply . . . . .42 6.4.2 MTL5541A/MTL5541AS - Repeater Power Supply . . . . .43 6.4.3 MTL5544/ MTL5544S - Repeater Power Supply . . . . .44 6.4.4 MTL5544A/MTL5544AS - Current Repeater . . . . .45 6.4.5 MTL5544D - Repeater Power Supply . . . . .46 (continued on next page) 6 5 Analogue Output modules 47 6.5.1 MTL5546/MTL5546Y/MTL5546Y-T - Isolating Driver . . . . .47 6.5.2 MTL5549/ MTL5549Y - Isolating Driver . . . . .48 6 6 Fire and Smoke Interface modules 49 6.6.1 MTL5561 - Fire and Smoke Detector Interface . . . . .49 6 7 Temperature Input module 50 6.7.1 MTL5573 - Temperature Converter . . . . .51 6.7.2 MTL5575 - Temperature Converter . . . . .52 6.7.3 MTL5576-RTD - Temperature Converter . . . . .53 6.7.4 MTL5576-THC - Temperature Converter . . . . .54 6.7.5 MTL5581 - mV/Thermocouple Isolator . . . . .55 6.7.6 MTL5582/MTL5582B - mV/Resistance Isolator . . . . .56 6 8 General modules 57 6.8.1 MTL5599 - Dummy Isolator . . . . .57 6.8.2 PSG60E24RM Power Supply . . . . .58 6 9 PCS45/PCL45USB configurator for MTL temperature converters 59 7 FAULT FINDING AND ROUTINE MAINTENANCE 59 7 1 Maintenance precautions 59 7 2 Fault finding 59 7 3 Routine maintenance 59 8 BENCH TESTING MODULES 60 8 1 Digital Input (DI) modules 60 8 2 Digital Output (DO) modules 61 8 3 Analogue Input (AI) Modules 62 8 4 Analogue Output (AO) Modules 65 8 5 Testing the functioning of other modules 65 9 APPLICATIONS INVOLVING ZONE 2 AND/OR ZONE 22 HAZARDOUS AREAS 66 9 1 Enclosure 67 10 APPENDIX 1 68 10 1 MTL5000 68 10 2 MTL5018AC - Switch/proximity detector 69 10 3 MTL5051 serial data comms isolator 71 10 4 MTL5314 trip amplifier for 2– or 3– wire transmitters 74 11 APPENDIX 2 77 11 1 Table A - Safety descriptions 77 11 2 Table B - Maximum cable parameters - IIC gas group 78

IMPORTANT NOTE WARNING This manual has content describing the use and installation of safety equipment This equipment must be installed, operated and maintained only by trained competent personnel and in accordance with all appropriate international, national and local standard codes of practice and site regulations for intrinsically safe apparatus and in accordance with the instructions contained here WARNING This equipment must be used in accordance with the instructions in this manual otherwise the protection provided by the equipment may be impaired ATEX If the country of installation is governed by the Essential Health and Safety Requirements (Annex II) of the EU Directive 2014/34/EU [the ATEX Directive - safety of apparatus] then consult the ATEX safety instructions for safe use in this manual before installation.

Note: Refer to the website for multiple language safety instructions. ELECTRICAL PARAMETERS Refer to the certification documentation for the electrical rating of these products. CERTIFICATION DOCUMENTATION Our website http://www.mtl-inst.com contains product documentation regarding intrinsic safety certification for many locations around the world. Consult this data for information relevant to your local certifying authority. FUNCTIONAL SAFETY If the MTL5500 range of products are to be used in functional safety applications check that each module has been assessed for that service and refer to the Safety Manual for details. REPAIR MTL5500 range of products MUST NOT be repaired. Faulty or damaged products must be replaced with an equivalent certified product. Symbols used on the product and in this manual CAUTION - Read the instructions CAUTION - Hot surface INM 5500 Rev 18vi ATEX/UKCA/IECEx SAFETY INSTRUCTIONS The following information is in accordance with the Essential Health and Safety Requirements (Annex II) of the EU Directive 2014/34/EU [the ATEX Directive - safety of apparatus), and Schedule 1 of the Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres Regulations 2016 (UK S.I. 2016/1107) and is provided for those locations where the ATEX Directive or UKCA regulations are applicable. General a) This equipment must only be installed, operated and maintained by competent personnel. Such personnel shall have undergone training, which included instruction on the various types of protection and installation practices, the relevant rules and regulations, and on the general principles of area classification. Appropriate refresher training shall be given on a regular basis. [See clause 4.2 of IEC/EN 60079-17]. b) This equipment has been designed to provide protection against all the relevant additional hazards referred to in Annex II of the ATEX directive (such as clause 1.2.7) or Schedule 1 of the UK regulation (such as clause 13). c) This equipment has been designed to meet the requirements of IEC/EN 60079-0, IEC/EN 60079-7, IEC/EN 60079-11 and IEC/EN 60079-15. Installation a) The installation must comply with the appropriate European, national and local regulations, which may include reference to the IEC code of practice IEC/EN 60079-14. In addition, particular industries or end users may have specific requirements relating to the safety of their installations and these requirements should also be met. For the EU, Directive 1999/92/EC [the ATEX Directive - safety of installations} is also applicable. For the UK, the Dangerous Substances and Explosive Atmospheres Regulations 2002 (DSEAR) is also applicable. b) This apparatus is an associated electrical apparatus and is normally mounted in a non- hazardous [safe] area. The equipment may be installed in a Zone 2 location providing that equipment is covered by a suitable certificate and the relevant installation conditions are met. Refer to “Special Conditions for Safe Use – Zone 2 mounting” below. c) Unless already protected by design, this equipment must be protected by a suitable enclosure against: i) mechanical and thermal stresses in excess of those noted in the certification documentation and the product specification ii) aggressive substances, excessive dust, moisture and other contaminants. Read also the Special Conditions for Safe Use (below) for any additional or more specific information. Special Conditions of Safe Use for Zone 2 applications a) When used in Zone 2, the equipment must be installed in an area of Pollution Degree 2 or better, as defined in IEC 60664-1, and in an enclosure or an environment that provides a degree of protection of at least IP54 and meets the relevant material and environmental requirements of IEC/EN 60079- 0, and IEC/EN 60079-7 or IEC/EN 60079-15 as appropriate. b) The equipment must not be inserted or removed unless either: i) the area in which the equipment is installed is known to be non-hazardous or ii) the circuit to which it is connected has been de-energised. c) The 24V supply for this equipment must be derived from a regulated power supply complying with the requirements of European Community Directives. d) For MTL5511, MTL5514, MTL5514D, MTL5516C, MTL5517, MTL5526 & MTL5532 only: Relay contacts may switch up to 35V, 2A and 100VA. For MTL5575: Relay contacts may switch up to 35V, 250mA. e) For MTL5573: Maximum Input/Output parameters – see certificate f) For MTL5553: The ambient temperature stated on the certificate refers to the temperature within the enclosure into which it must be installed in accordance with condition number 1). It is the responsibility of the installer to ensure that there is adequate isolation between the MTL 5553 Isolator and the frame of the supplementary enclosure. The equipment must be capable of withstanding the 500V dielectric strength test in accordance with clause 6.1 of IEC 60079-7 between the equipment and the supplementary enclosure. This must be taken into account during installation. The maximum values for the intrinsically safe circuits have to be taken from the IECEx Certificate of Conformity IECEx BAS 18.0060. g) Special Conditions will vary on individual certificates. INM 5500 Rev 18vii Inspection and maintenance a) Inspection and maintenance should be carried out in accordance with European, national and local regulations which may refer to the standard IEC/EN 60079-17. In addition specific industries or end users may have specific requirements which should also be met. b) Access to the internal circuitry must not be made during operation. Repair a) This product cannot be repaired by the user and must be replaced with an equivalent certified product. Marking Each device is marked in compliance with the EU Directive and UK regulation, and CE and UKCA marked accordingly. Example label showing markings: INM 5500 Rev 18viii This page is left intentionally blank INM 5500 Rev 181 1 INTRODUCTION This instruction manual describes the procedures for installing, connecting, checking and maintaining MTL5500 range of isolating interfaces and accessories. The MTL5500 products provide a DIN-rail mounted, intrinsically safe interface to hazardous areas of a process plant. The individual sections of this manual cover the following topics • Section 2 describes the range • Section 3 specifies precautions both before and during installation • Section 4 describes mounting accessories and the power adaptor • Section 5 discusses the DX range of enclosures • Section 6 provides relevant technical data • Section 7 outlines fault-finding and maintenance procedures • Section 8 describes bench test procedure • Section 9 provides hazardous-area application information • Section 10 provides MTL5000 products information • Section 11 provides safety parameter information 2 DESCRIPTION MTL5500 range of isolators provide intrinsically safe (IS) communication and signal conditioning for a wide range of hazardous-area devices. Total AC and DC isolation exists between input, output and power supply on separately powered units, and between input and output on loop-powered units. No IS earth is required. DIN-rail mounting and plug-in signal and power connectors simplify installation and maintenance. Units are powered from a 20 to 35V DC supply, or, in some cases, from the signal itself. Our latest generation of IS interfaces utilises an innovative “One-Core” technology to ensure the highest quality and availability while maintaining maximum flexibility at lowest cost. Incorporating advanced circuit design, a common set of components and innovative isolating transformer construction, they achieve a significant reduction in power consumption while increasing channel packing densities. The compact, 16mm wide design reduces weight and gives exceptionally high packing density. They build on the proven success of the MTL2000, 3000, 4000 and 5000 ranges to bring the benefits of new developments in galvanic isolation without compromising the reliability of the designs from which they have evolved. The backplane mounting MTL4500 range is designed with system vendors in mind for “project- focussed” applications such as Distributed Control System (DCS), Emergency Shutdown Systems (ESD) and Fire and Gas monitoring (F&G). The DIN-rail mounting MTL5500 range meets the needs of the IS interface market for “application focussed” projects, ranging from single instrument loops, through to fully equipped cabinets, across all industries where hazardous areas exist. Both new ranges have been designed for compatibility with earlier models. The MTL4500 range provides plug-replacements for earlier MTL4000 range of units, while the MTL5500 models can easily replace MTL5000 range of units. Each offer the latest in modern technology and efficiency without compromise. In addition to their use in IS circuits, specific models within the MTL4500 and MTL5500 ranges have been assessed and approved for use in Functional Safety applications. These have been verified under the certified Functional Safety Management (FSM) programme implemented by us. INM 5500 Rev 182 The table below lists the modules in the MTL5500 range. Refer also to the individual MTL5500 range of data sheets. Digital Input Channels Function MTL5501-SR 1 fail-safe, solid-state output + LFD alarm MTL5510 4 switch/prox input, solid-state output MTL5510B 4 multi-function, switch/prox input, solid-state output MTL5511 1 switch/prox input, c/o relay output MTL5513 2 switch/prox input, solid-state output MTL5514/5514-T 1 switch/prox input, relay + LFD MTL5514D 1 switch/prox input, dual relay output MTL5516C 2 switch/prox input, relay + LFD outputs MTL5517 2 switch/prox input, c/o relay + LFD outputs Digital Output MTL5521/5521-T 1 loop-powered solenoid driver MTL5522 1 loop-powered solenoid driver, IIB MTL5523 1 solenoid driver with LFD MTL5523V 1 solenoid driver with LFD + voltage control, IIC MTL5523VL 1 solenoid driver with LFD + voltage control, IIC MTL5524 1 switch operated solenoid driver MTL5525 1 switch operated solenoid driver, low power MTL5526 2 switch operated relay Pulse, Vibration and Foundation Fieldbus modules MTL5531 1 vibration probe interface MTL5532 1 pulse isolator, digital or analogue output MTL5533 2 vibration probe interface MTL5553 1 isolator/power supply for 31.25kbits/s fieldbuses Analogue Input MTL5541/MTL5541-T 1 2/3 wire transmitter repeater MTL5541A 1 transmitter repeater, passive input MTL5541AS 1 transmitter repeater, passive input, current sink MTL5541S/5541S-T 1 2/3 wire transmitter repeater, current sink MTL5544 2 2/3 wire transmitter repeater MTL5544A 2 transmitter repeater, passive input MTL5544AS 2 transmitter repeater, passive input, current sink MTL5544S 2 2/3 wire transmitter repeater, current sink MTL5544D 1 2/3 wire transmitter repeater, dual output Analogue Output MTL5546 1 4-20mA smart isolating driver + LFD MTL5546Y/5546Y-T 1 4-20mA smart isolating driver + oc LFD MTL5549 2 4-20mA smart isolating driver + LFD MTL5549Y 2 4-20mA smart isolating driver + oc LFD Fire and Smoke MTL5561 2 loop-powered for fire & smoke detectors Temperature Input MTL5573 1 temperature converter, THC or RTD MTL5575 1 temperature converter, THC or RTD MTL5576-RTD 2 temperature converter, RTD MTL5576-THC 2 temperature converter, THC MTL5581 1 mV/thermocouple isolator for low level signals MTL5582/5582B 1 mV/resistance isolator to repeat RTD signals General MTL5599 1 dummy module INM 5500 Rev 183 3 INSTALLATION Important • Make sure that all installation work is carried out in accordance with all relevant local standards, codes of practice and site regulations. • When planning the installation of MTL5500 range of isolators it is essential to make sure that intrinsically safe and non-intrinsically safe wiring is segregated, and that units are installed as required by a nationally accepted authority or as described in EN 60079-14, ISA RP 12.6 or DIN VDE-165. • External power supply shall contain double isolation from hazardous voltages or that unit shall be supplied by Limited Power Circuit per UL/IEC 60950 or Limited Energy Circuit per UL/IEC 61010 or Class II Power Supply per NEC. • Environmental conditions: indoor use, altitude (up to 2000m) and humidity less than 95% non condensing. • Check that the hazardous-area equipment complies with the descriptive system document. • If in doubt, refer to the certificate/catalogue for clarification of any aspects of intrinsic safety or contact Eaton's MTL product line or your local representative for assistance. • Make sure the correct hazardous-area connector (field-wiring plug) is plugged into the corresponding isolator. It is recommended that the connector is identified by the same tag number as the matching isolator. Figure 3 1: Dimensions of MTL5500 package Mount all MTL5500 range of isolators on low-profile (7mm) or high-profile (15mm) type T35 (top-hat) DIN-rail to EN50022, BS5584, DIN46277. This is available from Eaton, in 1 metre lengths (THR2 - DIN rail). Install isolators within the safe area unless they are enclosed in approved flameproof, pressurised or purged enclosures and ensure that the local environment is clean and free of dirt and dust. Note the ambient temperature considerations of section 3.1.4. It is recommended that, in normal practice, the DIN rail should be earthed/grounded to ensure the safety of personnel in the event of a.c. mains (line) power being applied accidentally to the rail. SAFEHAZ 104.8 109.8 123.6 118.8 Top of DIN rail PWR OPB OP A OPD OPC FLT Optional TH5000 tag holder for individual isolator identification. Accepts tag label 25 x 12.5 ±0.5mm, 0.2mm thick 15.8 +/– 0.2 INM 5500 Rev 184 3 1 Modules – pre-installation 3 1 1 Switch settings for operating conditions Some modules have operating conditions, such as Line-Fault Detection (LFD), Phase Reversal, etc., that can be established by the setting of switches on the unit. The subminiature switches are accessible through an aperture on the side of the module (see Figure 3.2) and can be set in the required positions with, for example, the blade of a small screwdriver. The switch setting options are always indicated on the side label of the module, but the user may also consult the individual module information in Section 6 of this manual for details. Figure 3 2: Location of switches 3 1 2 Relay outputs Reactive loads on all units with relays should be adequately suppressed. To achieve maximum contact life on all mechanical output relays, the load should not be less than 50mW, e.g. 10mA at ≥ 5V DC. 3 1 3 Ambient temperature considerations Ambient temperature limits for unenclosed MTL5500 range of isolators are from –20°C to +60°C with units close-packed and modules with the -T suffix have an extended temperature rating of +65°C, unless otherwise specified. 3 2 Installing columns of isolators On new installations, if isolators are mounted in several rows or columns, mount alternate rows or columns so that units face in opposite directions. This allows safe- and hazardous-area wiring looms to be shared. See Figure 3.1 for isolator dimensions. 3 2 1 Mounting isolators on DIN rail Figure 3 3: DIN rail mounting and removal of isolators Clip an isolator onto the DIN rail as shown in Figure 3.3, with the blue signal plugs facing towards the hazardous-area. To remove an isolator from the rail, insert a screwdriver blade (2.5 - 5.0mm diam.) into the clip as shown. This will release the clip so that the isolator may be pivoted off the rail - there is no need to lever the clip. Allow a maximum mounting pitch of 16.2mm for each unit. OFF position ON position 1 2 3 4 Mounting Removal INM 5500 Rev 185 3 2 2 Wiring up isolators Each unit is supplied with the appropriate number and type of safe- and hazardous-area connectors (see Figure 3.4), as dictated by the terminals used and the type of power supply. Figure 3 4: Removable power and signal plugs Note: Earth Leakage Detection requires the use of hazardous area connector type HAZ1-3, which may need to be ordered separately. See datasheet for ordering information. Loop-powered devices do not require power connectors. Depending on the installation, it may be easier to wire up isolators with power and signal plugs either in place or removed. Either way, allow sufficient free cable to permit plugs to be removed easily for future maintenance and/or replacement purposes. See Section 6 for instructions on wiring individual modules. 3 2 2 1 Signal and power conductors Removable signal and power plugs are fitted with screw clamp terminals. Note that the conductors should be between 14 and 24 AWG (1.6 and 0.5mm diam.) in size. Signal plugs, located on top of the modules, are mechanically keyed to fit in only one position. They are coloured grey, for safe-area connections, and blue, for hazardous-area connections. For externally powered units, a power plug slots into the socket at terminals 13 and 14 on the safe-area side of each module. The socket is coloured black if the unit is dc powered. Power plugs are coloured grey, for plugging into the black sockets of dc powered units. 3 2 2 2 Making connections a) Trim back the insulation of conductors by 12mm. b) Check the terminal assignments shown in section 6 or on the side label of the unit.

c) Insert conductors according to the terminal assignments and tighten screws. If the wires are to be fitted with crimp ferrules, the following is a list of those recommended with required trim lengths for each: Plug type Entry Wire size (mm2) Metal tube length (mm) Trim length Recommended ferrules Signal Single 0.75 12 14 Weidmuller 902591 Signal Single 1.0 12 14 Cembre PKC112 Signal Single 1.0 12 14 Phoenix Contact AI 1-12 RD (3200674) Signal Single 1.5 12 14 Cembre PKE1518† Signal Single 2.5 12 14 Cembre PKE2518† Power Twin 2x0.75 10 12 Cembre PKET7510 Power Twin 2x0.75 10 12 AMP (non-preferred) 966144-5 Power Twin 2x1.0 10 12 Phoenix Contact AI-TWIN 2X 1-10 RD Power Single 0.75 10 12 AMP 966067-0 Power Single 1.0 10 12 Phoenix Contact AI 1-10 RD TABLE 3 1: Crimp Ferule Options † These ferrules with 18mm length metal tubes should be cut to 12mm after crimping Note: Smaller section wire than that stated can often be successfully used if the crimping is good. Crimp tool: Phoenix Contact Crimpfox UD6 part number 1204436 Power Plugs Grey: dc supplies (PWR5000) Signal Plugs Grey: safe-area side Blue: hazardous-area side 12mm trim length with ferrule see table below INM 5500 Rev 186 3 2 2 3 Finishing Wire up individual isolators in accordance with wiring schedules. Daisy-chain power supply connections between individual power plugs or use the power bus (see section 4.1). Segregate hazardous- and safe-area wiring into separate trunking or looms wherever possible to avoid errors and maintain a tidy installation. Use an MTL5599 dummy isolator to provide termination and earthing for unused cores from the hazardous area. 4 ACCESSORIES 4 1 MTL5500 power bus - Installation and use 4 1 1 MTL5500 range power bus A power bus kit enables power supply terminals (13 and 14) of up to 32 installed MTL5500 range of units to be linked to a standard 24V power supply. The bus consists of a chain of power plugs and different lengths are available to suit various numbers of modules as follows. Number of modules Kit ID code (contains grey power plugs for 24V dc supply) 1 to 8 PB-8T 9 to 16 PB-16T 17 to 24 PB-24T 25 to 32 PB-32T Table 4 1: Power bus kit options 4 1 2 Installation 1. Check to make sure the bus length is correct for the number of modules involved. 2. If the number of modules is less than the maximum number the chain will support, cut off the surplus power plugs at the tail end of the chain - leaving sufficient cable to attach further power plugs if it becomes necessary later. 3. Insert power plugs into the power terminals on the safe- area side of each module in sequence. 4. Connect the power supply source to the tail end of the chain (using the insulation displacement connectors [Scotchloks] provided if required). Notes: 1. To avoid excessive voltage drop or over-current, DO NOT connect power buses in . 2. Surplus sections can be used (and, if required) connected together provided the cut ends are safely terminated and/or connected together. Use single ferrules with a crimp tool or insulation displacement connectors (Scotchloks). Suitable ferrules and connectors are provided with the kits. Figure 4 1: Power bus wiring, joining and terminating – + Optional insulation displacement connectors x2 INM 5500 Rev 187 4 2 MPA5500 AC power adaptor When only one or two MTL5500 modules are required for a particular application, it may be desirable to power the units from the AC mains supply directly, rather than use a separate DC supply unit. The MPA5500 is an adaptor that plugs into the DC power socket on the side edge of an MTL5500 module and clips securely onto the module housing. Its 25V DC power output is sufficient to supply a single module and can be connected to any normal ac power source. Figure 4 2: MPA5500 AC power adaptor To fit the adaptor, locate the tongue of the adaptor into the top slot on the side of the MTL5500 module and press the adaptor until it fits closely to the body of the module, as shown. Use double-insulated AC power cable with conductor parameters of 0.2–1.5mm2, or 0.25– 1.5mm2 if using ferrules. Strip the outer insulation by no more than 30mm, then strip the inner conductors by 8mm. Insert the cables appropriately in the cage-clamp connectors marked ‘L’ and ‘N’. The incoming AC power must have some form of power disconnection device, such as a switch or circuit breaker; a coupler that can be disconnected without the use of a tool; or a separable plug, without a locking device, to mate with an adjacent socket outlet. In addition, some form of cable anchorage must be used to relieve the cable conductors from strain, including twisting, where they connect to the adaptor, and which will also protect the insulation of the cable from abrasion. WARNING This adaptor is not suitable for use with MTL5000 range of modules. Direction of removal of MPA5500 Area required for removal of MPA5500 11 20 15.8 118.8 133 AC inputs Top of DIN rail INM 5500 Rev 188 4 3 Earth rail and tagging accessories This section explains how to specify and assemble earth rail and tagging strip accessories for the MTL5500 range. The accessories consist of mounting brackets, earth rails, tagging strips and associated parts. They provide facilities for earthing, terminating cable screens and tagging (identifying) the positions of individual units. 4 3 1 Parts list IMB57 Insulating mounting block (Figures 4 3, 4 4 & 4 5) One required at each end of a tagging strip/earth rail. Suitable for low-profile (7.5mm) and high-profile (15mm) symmetrical DIN rail. ERB57S Earth-rail bracket, straight (figure 4 3, 4 4 & 4 9) Nickel-plated bus bar; supplied with two push fasteners, one earth-rail clamp (14mm, 35mm2) and one earth cable clamp (10mm, 16mm2). Note: ERB57S is the preferred choice of earth-rail bracket. It is usually fitted in the upper slot on insulating mounting block IMB57. Where the earth rail is required to be positioned at a lower height and to allow access to the IMB57 mounting screws, the straight earth-rail bracket ERB57S can be inserted in the lower slot, but only after insulating mounting blocks IMB57 are clamped to the DIN rail. This may not be possible if, for example, trunking is fitted. In this case, fit offset earth-rail bracket ERB570 (see figure 4.4 & 4.10) in the upper slot: the mounting blocks can then be fitted in a restricted space with this bracket already fitted. ERB570 Earth-rail bracket, offset (figure 4 9) Nickel-plated bus bar; supplied with two push fasteners, one earth-rail clamp (14mm, 35mm2) and one earth cable clamp (10mm, 16mm2). ERL7 Earth rail, 1m length (figure 4 9) Nickel-plated bus bar; may be cut to length. TAG57 Tagging strip, 1m length (figure 4 3, 4 4 & 4 6) Cut to size. Supplied with tagging strip label. TGL57 Tagging strip labels, set of 10 x 0 5m (figure 4 3 & 4 4) Spares replacement, for use with TAG57 tagging strip. MS010 DIN rail module spacer, 10mm, pack of 5 (figure 4 7) Grey spacer; Used to provide 10mm air-circulation space between modules, if necessary. ETM7 Earth terminal, bag of 50 (figure 4 8) For terminating cable screens and 0V returns on the ERL7 earth rail. For cables ≥ 4mm2. TH5000 Tag holder Spares replacement. Connectors (Figure 4 5) Spares replacement: HAZ1-3, HAZ4-6, HAZ-CJC, PWR5000, SAF7-9, SAF10-12 (SAF1-3 and SAF4-6 grey connectors, also available for use in safe-area applications). 4 3 2 Assembly 4 3 2 1 Fitting earth rails a) In upper position Before fitting insulating mounting blocks IMB57, check that the swing nuts in the base of each unit are turned back into the moulding. Locate the mounting blocks on the DIN rail in the chosen position and tighten the screws (see figure 4.10). Check that the swing nuts rotate correctly to locate underneath the flanges of the DIN rail. INM 5500 Rev 189 TGL57 TAG57 ERB57 ERB570 ETM7 Snap off extension when using IMB57 as central support 10mm Earth clamp ERB57S in upper position ERB57S in lower position IMB57 Push fastener 14mm Earth-rail clamp ERL7 THR2 IMB57 ERL7 HAZ1-3 HAZ4-6 TH5000 TAG57 TGL57 SAF7-9 SAF10-12 ERB57S ETM7 PWR5000 Figure 4 3: Assembly drawing showing part numbers Figure 4 4: Mounting details Figure 4 5: IMB57 Insulating mounting block Figure 4 6: TAG57 Tagging strip, 1m length Figure 4 7: MS010 DIN rail module spacers Figure 4 8: ETM7 Earth terminals Figure 4 9: Earth rails and clamps INM 5500 Rev 1810 Figure 4 10: Fitting IMB57 Slide a straight earth-rail bracket ERB57S into the upper slot in each mounting block. Push two plastic push fasteners into each bracket to locate the brackets in the mounting blocks. Cut earth rail ERL7 to the length needed. Slide the required number of ETM7 earth terminals (5mm or 7mm wide) onto the rail. Clamp each end of the earth rail to earth-rail brackets ERB57S using the terminal clamps (14mm, 35mm2) supplied. Fit an earth clamp (10mm, 16mm2) to the free end of each earth-rail bracket. Note: For lengths of earth-rail greater than 500mm, provide additional support by installing a third IMB57 mounting block and earth-rail bracket, mid-way between the end mounting blocks. Snap out the perforated extension between the lugs on this mounting block if a continuous tagging strip is to be fitted (see figure 4.6). b) In lower position, where at least 150mm clearance exists on one side, measured from the edge of the mounting block. As for a), but slide earth-rail brackets ERB57S into the lower slots in each mounting block. c) In lower position, where there is insufficient clearance to fit earth-rail brackets ERB57S. As for a), but slide offset earth-rail brackets ERB57O into the upper slot in each mounting block before assembling the mounting blocks to the DIN rail. ERB57S brackets cannot be used because they obscure the fixing screws on the mounting blocks. 4 3 2 2 Fitting tagging strips Assemble mounting blocks IMB57 to the DIN rail as above. Cut TAG57 tagging strip and label to the length needed, and insert label so that the appropriate side is visible. Clip the strip onto the lugs on the mounting blocks. Hinge up the strip to provide access to the tops of the isolators. Note: If necessary, provide additional support for long lengths of tagging strip by installing an extra IMB57 mounting block mid-way between the end mounting blocks. Snap out the perforated extension between the lugs on this mounting block. 4 3 3 Completed assemblies Figure 4.11 illustrates a complete assembly of MTL5500 isolators using the accessories mentioned above. The broken-line boxes either side of the assembly represent cable trunking, and the accompanying dimensions represent the recommended minimum spacing between the trunking and the module assemblies. INM 5500 Rev 1811 Colour Module no Function Yellow MTL5501-SR Digital Inputs White MTL551x Red MTL552x Digital Outputs Blue MTL5531/33 Vibration Purple MTL5532 Pulse Blue MTL5541x MTL5544x Analogue Inputs Green MTL5546x MTL5549x Analogue Outputs Blue MTL556x Fire & Smoke Orange MTL557x MTL558x Temperature inputs Grey MTL5599 Dummy isolator Table 4 2: MTL5500 front label colour coding Figure 4 11: MTL5500 complete assembly INM 5500 Rev 1812 5 DX ENCLOSURES Enclosures are usually selected on the basis of the number of units they will accommodate and Table 5.1 shows the capacity of each of the enclosures. Figure 5.2 shows each type of enclosure containing MTL5500 modules. Table 5 1: DX range of enclosures - module capacities Enclosure Number of MTL5500 isolators 16mm mounting pitch DX070 4 (2*) DX170 10 (8*) (DX430) 26 (24*) no longer available * Use these figures when two IMB57 mounting brackets for tagging/

earth-rail accessories are included. Note: The user should be aware that some workshop preparation may be required for the cable gland plates before the enclosure is ready for on-site installation. 5 1 Environmental conditions Environmental conditions that should be taken into account when installing DX enclosures include:- See section Maximum ambient temperature limits 5.1.1 Storage temperatures 5.1.2 Humidity 5.1.3 Corrosion resistance 5.1.4 Flammability 5.1.5 Impact resistance 5.1.6 Chemical resistance 5.1.7 5 1 1 Maximum outside enclosure temperature limits Figure 5 1: Graph depicting outside enclosure temperature limits for DX enclosures used with MTL5500 isolators The maximum outside enclosure temperature depends upon the total power dissipated by the installed modules which, in turn, depends upon their number and type. It can also be influenced by the Authority whose standards may need to be applied to the system, e.g. Baseefa, Factory Mutual Research Corporation, Canadian Standards Association. Figure 5.1 shows, in graphical form, the maximum outside enclosure temperatures (TMO) for given levels of power dissipation. The graph was derived from the following equation and should be used to calculate accurately the suitability of any particular mix of modules. TMO = 60°C - ∂T where ∂T = k1 x P P = total power (watts) dissipated by modules in an enclosure k1 = is a dissipation constant for a given enclosure and module . Select the relevant value from Table 5.2. (60°C is the temperature inside the enclosure) 60 40 20 10 30 50 0 10 20 30 40 Power dissipation (watts) Max. outside enclosure temperature (°C) Enclosures DX070 DX170 DX430 INM 5500 Rev 1813 Figure 5 3: Optimum orientation for wall mounted enclosure DX070 DX170 MTL5500 4.03 1.88 Table 5 2: Dissipation constant k1 for enclosures (°C/watt) Orientation of the enclosures is also important - the optimum position being on a vertical surface with the internal DIN-rail horizontal as shown in Figure 5.3. Any other position can reduce the maximum allowable ambient temperature by up to 5°C. Examples Tables 5.3 and 5.4 list likely combinations of MTL5500 modules in the three enclosure types and indicate the acceptable maximum permitted outside enclosure temperature for these based on the graph in Figure 5.1. See the specifications included in the datasheets for the power dissipation figures of individual MTL5500 modules. Table 5 3: Typical mix of MTL5500 modules Enclosure Modules installed Power dissipation of modules in watts (P) Maximum outside enclosure temp (TMO)°C DX070 2 x MTL5511 + 2 x MTL5544 (2 x 0.72) + (2 x 1.4) = 4.24 42.9 DX170 5 x MTL5511 + 5 x MTL5544 (5 x 0.72) + (5 x 1.4) = 10.6 40.1 Table 5 4: Power versus maximum outside enclosure temperature Enclosure Number of installed modules k °C/watt Power dissipation of modules in watts (P) Maximum outside enclosure temp (TMO) °C DX070 4 4.03 4.0 43.9 4 4.03 6.0 35.8 DX170 10 1.88 10.0 41.2 10 1.88 15.0 31.8 5 1 2 Storage temperatures Storage temperatures are safe within the range -40°C to +80°C. 5 1 3 Humidity limits Safe humidity limits are within the range 5 to 95% RH. 5 1 4 Extended ambient temperature modules Modules with the -T suffix are rated for use in an ambient temperature up to 65°C if suitably certifed. INM 5500 Rev 1814 Figure 5 2: DX range of enclosures 150 DX070 130 113.5 153.5 70 180 163.5 203.5 Ø 5.2 184 147 (inside) Top of DIN rail 270 8080 540 430 520 576 249 305 Ø 7.2 DX430 184 147 (inside) Top of DIN rail 170 249 305 102 102 360 339 395 270 Ø 7.2 DX170 131 (inside) n b DX430 no longer available INM 5500 Rev 1815 5 1 5 Corrosion resistance The effect of corrosion on DX enclosures is negligible. 5 1 6 Flammability rating The flammable properties of the materials used in the construction of the enclosures are well understood by manufacturers and ratings have been established to a number of standards. One of the better known standards is the Underwriter's Laboratory standard UL 94 and the ratings for the enclosure materials are given as: Materials UL94 rating Polycarbonate (all lids) V2/V0 Polycarbonate with glass reinforcement (DX070 base) V1/V0 Polyester with glass reinforcement (DX170 & DX430 bases) V0 Items made from similar materials are well established as suitable for use in process I/O marshalling areas. 5 1 7 Impact resistance The enclosure designs have been tested to an impact resistance of greater than 2 Joules which exceeds the BS EN 61010-1 requirements of 0.5 Joules. 5 1 8 Chemical resistance The overall chemical resistance of the enclosures is limited by the resistance of the transparent polycarbonate lid. The glass-reinforced polycarbonate/polyester (GRP) bases have a higher resistance than plain polycarbonate. Table 5.5 lists qualitative evaluations of resistance to a variety of chemical agents. Table 5 5: Qualitative evaluations of resistance to various chemical agents Chemical agents Qualitative evaluation of resistance Salt water; neutral salts; acids (low concentrations); hydraulic oil Excellent Alcohols Very good Acids (high concentrations); alkalis (low concentrations); petrol; cooling fluids Good Alkalis (high concentrations); solvents. Poor 5 2 Mounting 5 2 1 General These instructions are concerned solely with mounting the DX enclosures. Instructions for wiring and testing individual modules within the enclosures are provided in Section 6. Sufficient space is provided within the enclosures to accommodate tagging and earth-rail accessories but this is at the expense of a reduction in the number of modules that can be fitted. 5 2 2 Location and orientation 5 2 2 1 Location The DX enclosures are intended for safe (non-hazardous) area use. The enclosures are rated NEMA 4X; consequently, in N. America or Canada, assuming the modules have the required approvals, they can be used in Class 1, Division 2 (gases) location, but check with local requirements and ensure all cable entries also conform. In this case, an additional warning label will be required on or near the enclosure warning that the MTL5500 interfaces must not be removed unless the area is known to be non-hazardous. The enclosures are NOT suitable for Class II or III, Division 2 hazardous locations. INM 5500 Rev 1816 5 2 2 2 Orientation As noted earlier (see section 5.1.1), for optimum temperature performance the enclosures should be mounted on a vertical surface with the internal DIN rail horizontal. 5 2 3 Mounting details See Figure 5.2 for the dimensions and mounting hole distances, etc., of the three DX enclosures. The recommended method of mounting-described here-uses the four wall-mounting lugs supplied with each enclosure. An alternative method of mounting is by direct attachment to the mounting surface through the corner holes. Note: When the wall-mounting lugs are used to attach the enclosures, the overall depth of the enclosure is increased by an additional 3.3 mm (DX070) or 7 mm (DX170 and DX430). a) At each of the four corner fixing holes, insert one of the screws provided and use it to attach a fixing lug to the base of the enclosure. b) Each lug can be used in one of two positions as shown in Figure 5.2. c) Attach the lugs to the mounting surface with suitable fasteners. d) Diameters of fixing holes in lugs are 5.5mm (DX070) and 7.0mm (DX170 and DX430) e) Appropriate fixing hole distances are shown in Figures 5.2. 5 2 4 Cable glanding All cables into the enclosures must be glanded to IP65 standards to maintain this rating for the enclosure as a whole. Cable glands and gland plates are not supplied. Glanding requirements vary for each enclosure as follows: DX070 On the DX070, 'knockout' holes are provided, in two different sizes (15.5 mm and 21 mm), on the side faces of the base. See Table 5.7 for recommended cable glands. DX170 The DX170 can accommodate one gland plate on each side - see figure 5.2 for details. Table 5.6 lists suppliers of suitable gland plate kits and Table 5.7 lists recommended glands. Table 5 6: Recommended gland plate kits for the DX170 and DX430 enclosures. Manufacturer/agent Manufacturer’s part number Enclosure DX170 Hellermann Tyton TL-27/360 Sarel 21128 Table 5 7: Recommended cable glands for use with DX enclosures. Gland thread size Cable sizes (mm) Gland plate hole size (mm) Weidmuller part nos Sarel part nos Gland Locknut Gland Locknut PG9 5 to 8 15.2 951891 952216 08871 08881 PG13,5 8 to 13 20.4 951893 952218 08873 08883 Weidmuller (UK) http://www.weidmuller.co.uk Sarel (UK) http://www.sarel.co.uk Hellermann Tyton (UK) http://www.hellermantyton.co.uk INM 5500 Rev 1817 5 3 Accessories in enclosures Apart from mounting, there are some other installation details which should be considered before adding the appropriate interface modules and making the necessary cabling connections. A range of accessories is available to accompany the MTL5500 units (see section 4) and the following points should be observed. 5 3 1 Insulating mounting block (IMB57) A pair of these can be attached to the DIN rail, at either end of the modules, to provide a mounting for earth rails. Use of mounting blocks will reduce the space available for isolator modules. 5 3 2 Earth rails (ERL7) Earth rail is produced in 1 metre lengths and will require cutting to length before mounting. ERL7 earth rails can be mounted either side of the modules but are typically mounted on the hazardous side of the DIN rail. 5 3 3 Tagging strip (TAG57 and TGL57) Tagging strip is produced in 1 metre lengths and will require cutting to length before mounting. Similarly, the labels will require cutting to fit the tagging strip. 5 4 IS warning label A 'Take Care' IS warning label is provided inside each enclosure. This should be attached to the inside of the transparent lid when its orientation has been established. INM 5500 Rev 1818 6 UNIT DESCRIPTIONS, SETTING-UP AND CONNECTIONS This section describes the function (briefly), the setting-up procedure and the wiring connections for each MTL5500 unit. For a fuller functional description and a detailed technical specification, refer to the individual datasheets, which can be found on our website at www.eaton.com or in the current MTL IS catalogue. If a fault is suspected, first check that the power LED is lit (not applicable to loop-powered devices). If necessary, check that all signal and power plugs are properly inserted, that no wires are loose and that the unit is mounted correctly. If operation is still suspect, the unit should be replaced with a serviceable unit. There are no replaceable parts inside MTL5500 units, so any that appear to be inoperative should be returned to the manufacturer/supplier for repair or replacement. WARNING When disconnecting units for maintenance purposes, take care to segregate hazardous and safe-area cables. • Short circuit hazardous-area cable cores to an IS earth or insulate and secure the ends. • Insulate and secure safe-area cables. If testing a unit ‘in situ’ note that the test equipment used MUST be intrinsically safe. The rest of this section is divided into sub-sections based upon the type of module, as follows. 6 1 Digital Input modules MTL5501-SR, MTL5510, MTL5510B, MTL5511, MTL5513, MTL5514, MTL5514-T, MTL5514D, MTL5516C, MTL5517 6 2 Digital Output modules MTL5521, MTL5521 -T, MTL5522, MTL5523, MTL5523V, MTL5523VL, MTL5524, MTL5525, MTL5526 6-3 Vibration, Pulse and Foundation Fieldbus modules MTL5531, MTL5532, MTL5533, MTL5553 6 4 Analogue Input modules MTL5541, MTL5541-T, MTL5541A, MTL5541AS, MTL5541S, MTL5541S-T, MTL5544,

MTL5544A, MTL5544AS, MTL5544D, MTL5544S 6 5 Analogue Output modules MTL5546, MTL5546Y, MTL5546Y-T, MTL5549, MTL5549Y 6 5 Fire and Smoke interface modules MTL5561 6 7 Temperature Input modules MTL5573, MTL5575, MTL5576-RTD, MTL5576-THC, MTL5581, MTL5582, MTL5582B 6 8 General modules MTL5599, MTL5991 6 9 PCS45/PCL45USB configurator for MTL temperature converters Note: Any LED indicator provided on the modules will display in the following colours: LED label LED colour PWR (power) Green STS (status) Yellow LFD (line fault) Red FLT (fault) Red OPx (o/p status) Yellow INM 5500 Rev 1819 6 1 Digital Input modules The Digital Input (DI) module range offers solid state or relay output switches in a safe area that respond to input switches located in a hazardous area. Single or multiple channel (2 or 4) options are available, as well as Line-Fault Detection (LFD). Modules with LFD can recognise open or short circuit conditions on the input wires going to the field sensors, and some DI modules have the facility to reverse the effect of the input on the output i.e. phase reversal. These options are chosen with switches located on the edge of the module on the hazardous area terminal side. In some applications it may be easier to set these switches before fitting the module to the DIN-rail. Figure 6 1: Switches to set LFD and phase reversal 6 1 1 Phase reversal Set the PR switch ON or OFF for the appropriate channel(s). 6 1 2 Line-Fault Detection (LFD) Where fitted, set the LF switch ON or OFF for the appropriate channel(s). Note: LFD is permanently active on the MTL5501-SR. For all DI modules with LFD except for the MTL5501-SR; when using the LFD facility with a contact input, resistors must be used. Fit 500Ω to 1kΩ (preferred value 680Ω) in with the switch and 20kΩ to 25kΩ (preferred value 22kΩ) in parallel with the switch. For modes of operation of the MTL5510 & MTL5510B that include LFD, resistors should be fitted as described above. For MTL5501-SR use 1k4Ω in and 10kΩ in parallel with switch contact inputs. For hazardous-area inputs conforming to EN 60947-5-6:2001 (NAMUR), a line fault is judged by the following rules: • Open circuit condition if hazardous-area current 250μA • Short circuit condition if hazardous-area load 360Ω Note: the open circuit window (between 250μA and 50μA), and the short circuit window (between 100Ω and 360Ω), is not hysteresis. All MTL5500 modules, with inputs conforming to EN 60947-5-6:2001 (NAMUR), will switch between open and complete circuit conditions within these limits. The MTL5501-SR LFD relay de-energises when a fault condition is detected. The MTL5514 and the MTL5517 energise the LFD relay to indicate a fault condition. INM 5500 Rev 1820 6 1 3 MTL5501-SR - Fail-safe Switch/Proximity detector interface Single channel, fail-safe module with line-fault detection The MTL5501-SR enables a fail-safe switch/proximity detector located in the hazardous area to control an isolated fail-safe electronic output. It provides line-fault detection (LFD) alarm contacts and is designed for use with approved fail-safe sensors in loops that require operation up to SIL3 according to the functional safety standard IEC 61508. Note: For reliable, long-term operation the load on the LFD switching relay should be not less than 50mW, e.g. 10mA at 5V DC. Hazardous area Safe area Vs– Vs+ 20 to 35V dc 10kΩ 1k4Ω + – LFD Failsafe output + –Resistors must always be fitted for switch inputs 6 5 4 3 2 1 7 8 9 10 11 12 13 14 Terminal Function 1 Input –ve 2 Input +ve 7 Output –ve 8 Output +ve 10 LFD 11 LFD 13 Supply –ve 14 Supply +ve Figure 6 2: Top label for MTL5501-SR Input / output characteristics Input value in sensor circuits Fail–safe output Operation LFD contacts 2.9mA < Is < 3.9mA ON Normal CLOSED Is 5.1mA OFF Normal CLOSED Is < 50μA OFF Broken line OPEN Rs < 100Ω OFF Shorted line OPEN Correct operation of the fail-safe output and LFD is indicated by the LEDs on the front of the unit. The yellow O/P LED is ON when the fail-safe output is energised. The red LFD LED flashes if a line fault is detected. The fail-safe output is de-energised (OFF) if the module detects an incorrect sensor current, an open circuit or a short circuit in the sensor circuit. Input signal sensors may be either suitable proximity sensors or switches. The proximity sensor properties are specified in the standard EN60947-5-6:2001; however, when used with MTL5501-SR modules, additional requirements for the “low-impedance” current of 3.4 ±0.5mA must be met. The list below shows suitable proximity sensors, all manufactured by Pepperl+Fuchs Group, Germany, and specified as usable to SIL3, according to IEC 61508: SJ 2-SN NJ 4-12GK-SN NJ 10-30GK-SN SJ 3,5-SN NJ 5-18GK-SN NJ 15-30GK-SN SJ 3,5-S1N NJ 8-18GK-SN NJ 6S1+U1+N NJ 2-11-SN NJ 6-22-SN NJ 15S+U1+N NJ 2-11-SN-G NJ 6-22-SN-G NJ 20S+U1+N NJ 2-12GK-SN NJ 5-30GK-S1N NJ 40-FP-SN-P1 INM 5500 Rev 1821 6 1 4 MTL5510 & MTL5510B - Switch/Proximity detector interface 4-channel, digital input and multifunction modules These digital modules provide solid state output switches in a safe area that respond to switches (inputs) located in a hazardous area. The way they respond - their “mode” - can be configured using a bank of four DIL selector switches accessible through the side of the module - see Figure 6.4. Model MTL5510 has an one output channel for each input channel and the user can reverse the output phase if necessary to suit the application. Model MTL5510B has more varied modes that can, for example, enable one input to affect multiple outputs or create latched outputs, etc.) The channel output transistors - Ch1/Ch2 and Ch3/Ch4 - share a common terminal and can switch +ve or –ve polarity signals.

Note that parallel resistors are required for switch inputs with LFD - see Section 6.1.2 for recommended values. Hazardous area Ch B Vs– Vs+ 20 to 35V dc – + – – + – Ch D Ch C Ch A 1 2 3 4 common common Outputs 6 5 4 3 2 1 7 8 9 10 11 12 13 14 Safe area Terminal Function 1 Input channel A 2 Input channel AB common (+) 3 Input channel B 4 Input channel C 5 Input channel CD common (+) 6 Input channel D 7 Output channel 4 8 Output channel 3/4 common 9 Output channel 3 10 Output channel 2 11 Output channel 1/2 common 12 Output channel 1 13 Supply –ve 14 Supply +ve Figure 6 3: Top labels for MTL5510 & MTL5510B INM 5500 Rev 1822 Figure 6 4: DIL switches for setting mode Tables 6.1 and 6.2 show details of the modes available and the switch settings required to obtain them. For ease of access, it is recommended that switches are set to the required mode before installation. Table 6.1 indicates whether the output follows the input, or the output is the reverse or antiphase of the input. For example, in mode 0, o/p 1 = chA; so, if channel A switch is closed, then output 1 will also be closed or short circuit. However, in mode 1, o/p 1 = chA rev., so if channel A switch is closed, then output 1 will be the reverse, i.e. open-circuit. Table 6.2 shows the MTL5510B modes. The logic tables and timing diagrams on the following pages provide more detailed information on these modes. *Mode of operation changed August 2015 MTL5510 & MTL5510B diagnostics If an internal fault is detected, all outputs and channel LEDs will turn off and the red Fault LED will turn ON. Table 6 2 - MTL5510B mode options Switch settings MODE Function Equivalent 1 2 3 4 OFF OFF OFF OFF 0 4-ch switch input (see MTL5510 mode 0) MTL5510 ON OFF OFF OFF 1 2-ch each channel one input, two outputs OFF ON OFF OFF 2* Same as mode 1 with all outputs phase reversed ON ON OFF OFF 3 2-ch, 2-pole changeover output OFF OFF ON OFF 4 1-ch with line fault output MTL5014 ON OFF ON OFF 5 As mode 4 with changeover outputs OFF ON ON OFF 6 1-ch with start-stop latch MTL2210B ON ON ON OFF 7* As mode 2 with LFD enabled OFF OFF OFF ON 8 4-ch switch input, see MTL5510 mode 8 MTL5510 ON OFF OFF ON 9 2-ch with line fault output MTL5017 OFF ON OFF ON 10 As mode 9 with LFD changeover ON ON OFF ON 11 As mode 10 with channel phase reversed OFF OFF ON ON 12 3-ch with normally-open LFD output ON OFF ON ON 13 3-ch with normally-closed LFD output OFF ON ON ON 14 2-ch monostable, pulse stretcher ON ON ON ON 15 4-ch switch input, see MTL5510 mode 15 MTL5510 Table 6 1 - MTL5510 mode options Switch setting MODE o/p 1 o/p 2 o/p 3 o/p 4 i/p type 1 2 3 4 OFF OFF OFF OFF 0 chA chB chC chD switch / prox. detector ON OFF OFF OFF 1 chA rev. chB chC chD OFF ON OFF OFF 2 chA chB rev. chC chD ON ON OFF OFF 3 chA chB chC rev. chD OFF OFF ON OFF 4 chA chB chC chD rev. ON OFF ON OFF 5 chA rev. chB chC rev. chD OFF ON ON OFF 6 chA chB rev. chC chD rev. ON ON ON OFF 7 chA rev. chB rev. chC rev. chD rev. OFF OFF OFF ON 8 chA chB chC chD Switch/ prox. detector + LFD ON OFF OFF ON 9 chA rev. chB chC chD OFF ON OFF ON 10 chA chB rev. chC chD ON ON OFF ON 11 chA chB chC rev. chD OFF OFF ON ON 12 chA chB chC chD rev. ON OFF ON ON 13 chA rev. chB chC rev. chD OFF ON ON ON 14 chA chB rev. chC chD rev. ON ON ON ON 15 chA rev. chB rev. chC rev. chD rev. INM 5500 Rev 1823 MTL5510B modes The following logic and timing diagrams are provided to assist the user in understanding the behaviour of the MTL5510B module when a specific mode is chosen. The open switch ( ) and closed switch ( ) symbols are used to represent both the input conditions of Ch A, Ch B, Ch C or Ch D and then the output conditions of o/p 1, 2, 3 or 4. Note that in certain modes a Line Fault can cause an override of the output. How to use these mode tables - examples The logic tables for Mode 1 represent Ch A controlling outputs 1 & 3, while Ch C controls outputs 2 & 4. Output 1 & 3 are shown following input Ch A (open or closed) while Outputs 2 & 4 follow input Ch C. Mode 2 however shows o/p 1, 2, 3 and 4 being in antiphase to their inputs. Mode 9 operates with both outputs for each channel being in antiphase to their inputs. Mode 3: 2 ch, 2 pole c/o output i/p - Ch A i/p - Ch C o/p 1 - - o/p 2 - - - - o/p 3 - - o/p 4 i/p - Ch A No fault Line fault No fault Line fault o/p 1 Mode 4: 1 ch with line fault output No fault Line fault No fault Line fault o/p 3 i/p - Ch A No fault Line fault No fault Line fault o/p 1 o/p 2 Mode 5: As mode 4 with c/o outputs No fault Line fault No fault Line fault LFD o/p 3 LFD o/p 4 A Start B Stop i/p Ch A i/p Ch B o/p 2&4 o/p 1&3 BRes et * * i/p Ch A can be open or closed when i/p Ch B opens to stop latch Latching Ch C closed * i/p Ch A can be open or closed when i/p Ch B opens to stop latch o/p 2&4 o/p 1&3 (enable) i/p Ch A i/p Ch B Non-latching Ch C open Mode 1: 2 ch, each ch 1 input 2 outputs i/p - Ch A i/p - Ch C o/p 1 - - - - o/p 2 o/p 3 - - - - o/p 4 Mode 2: As mode 1 with all outputs phase reversed i/p - Ch A i/p - Ch C o/p 1 - - - - o/p 2 o/p 3 - - - - o/p 4 Mode 7: As mode 2 with LFD enabled i/p Ch C Non-latching i/p Ch B Enable i/p Ch A o/p 1 o/p 2 o/p 3 o/p 4 Mode 6: 1 ch with start/stop latch OR i/p Ch C Latching i/p Ch A i/p Ch B No effect o/p 1 o/p 2 o/p 3 o/p 4 Start Reset Stop i/p - Ch A No fault Line fault No fault Line fault o/p 1 o/p 3 i/p - Ch C o/p 2 o/p 4 INM 5500 Rev 1824 MTL5510B modes - continued Mode 14 This mode provides a two channel pulse stretcher for in- puts A and C. Outputs 1 and 2 respond to Ch A, while 3 and 4 respond to Ch C. Input B (or D) being open or closed affects the input i/p A (C) o/p 2 (4) o/p 1 (3) Initiate 1sec (min.) Endi/p B (D) 1sec (min.) i/p A (C) o/p 2 (4) o/p 1 (3) i/p B (D)

Initiate End transition and the output polarity as shown in the timing diagrams below. When triggered by A (or C) the outputs hold the change of state for a minimum of 1 second or as long as the input (A or C) remains in the same triggered state. Input Ch B (or D) closed Input Ch B (or D) open Mode 9: 2 ch with line fault output i/p - Ch A No fault Line fault No fault Line fault o/p 1 No fault Line fault No fault Line fault LFD o/p 3 i/p - Ch C No fault Line fault No fault Line fault o/p 2 No fault Line fault No fault Line fault LFD o/p 3 LFD o/p 4 Mode 10: As mode 9 with line fault c/o i/p - Ch A No fault Line fault No fault Line fault o/p 1 i/p - Ch C No fault Line fault No fault Line fault o/p 2 No fault Line fault No fault Line fault LFD o/p 3 LFD o/p 4 Mode 11: As mode 10 with ch phase reversed i/p - Ch A No fault Line fault No fault Line fault o/p 1 i/p - Ch C No fault Line fault No fault Line fault o/p 2 No fault Line fault No fault Line fault LFD o/p 4 Mode 12: 3 ch with common LFD output i/p - Ch A No fault Line fault No fault Line fault o/p 1 i/p - Ch B No fault Line fault No fault Line fault o/p 2 i/p - Ch C No fault Line fault No fault Line fault o/p 3 Mode 13: As mode 12 but with LFD o/p 4 reversed No fault Line fault No fault Line fault LFD o/p 4 INM 5500 Rev 1825 6 1 5 MTL5511 - Switch/Proximity detector interface Single channel, with line-fault detection The MTL5511 contains a changeover relay, which enables a safe-area load to be controlled by a switch or proximity detector located in a hazardous-area. When selected, the line-fault detect (LFD) facility detects open or short circuit conditions in the field wiring and also indicates this on the top of the module. Line-Fault Detect and Phase Reversal for the channel are selected by DIL switches on the side of the module and output is provided by the changeover relay contacts. See page 19 for LFD and PR switch details. Channel 1 only switch settings apply. For switch sensor inputs, with LFD selected, make sure resistors (22kΩ and 680Ω) are fitted. Note: For reliable, long-term operation the load on the output switching relay should be not less than 50mW, e.g. 10mA at 5V DC. Vs– Vs+ 20 to 35V dc 22kΩ 680Ω + – Output Switch-type sensors require resistors if LFD is selected 6 5 4 3 2 1 7 8 9 10 11 12 13 14 Hazardous area Safe area Terminal Function 1 Input –ve 2 Input +ve 10 Output normally-closed contact 11 Output common 12 Output normally-open contact 13 Supply –ve 14 Supply +ve Figure 6 5: Top label for MTL5511 INM 5500 Rev 1826 6 1 6 MTL5513 - Switch/ Proximity detector interface Two-channel, with line-fault detection and phase reversal The MTL5513 enables two solid-state outputs in the safe area to be controlled by two switches or proximity detectors located in the hazardous area. The Ch1/Ch2 output transistors share a common terminal and can switch +ve or -ve polarity signals. Line-Fault Detect and Phase Reversal for the channel are selected by DIL switches on the side of the module. LFD indication is provided on the top of the module. See page 19 for LFD and PR switch details. Channel 1 & 2 switch settings apply. For switch sensor inputs, with LFD selected, make sure resistors (22kΩ and 680Ω) are fitted. Vs– Vs+ 20 to 35V dc Ch 1 Ch 2 Outputs + – 22kΩ 680Ω + – Switch-type sensors require resistors if LFD is selected 22kΩ 680Ω 6 5 4 3 2 1 7 8 9 10 11 12 13 14 Hazardous area Safe area Terminal Function 1 Input –ve (Ch 1) 2 Input +ve (Ch 1) 4 Input –ve (Ch 2) 5 Input +ve (Ch 2) 10 Output (Ch 2) 11 Output (Ch 1/Ch 2) 12 Output (Ch 1) 13 Supply –ve 14 Supply +ve Figure 6 6: Top label for MTL5513 INM 5500 Rev 1827 6 1 7 MTL5514(-T)/MTL5514D - Switch/ Proximity detector interface Single channel, with line-fault detection and phase reversal The MTL5514(-T) enables a safe-area load to be controlled, through a relay, by a proximity detector or switch located in a hazardous area. Line faults are signalled through a separate relay and indicated on the top of the module. The MTL5514D provides signal duplication, enabling two safe-area loads to be controlled by a single device in a hazardous area. Both relay outputs reflect the input signal instead of one showing the line fault condition as in the MTL5514. Line- Fault Detect and Phase Reversal for the channel are selected by DIL switches on the side of the module and output is provided by changeover relay contacts. See page 19 for LFD and PR switch details. Channel 1 only switch settings apply. For switch sensor inputs, with LFD selected, make sure resistors (22kΩ and 680Ω) are fitted. Note: For reliable, long-term operation the load on the output switching relays should be not less than 50mW, e.g. 10mA at 5V DC. Terminal Function MTL5514 (-T) MTL5514D 1 Input –ve (Ch 1) 2 Input +ve (Ch 1) 7 LFD Output contact N.C. Output 2 contact N.C. 8 LFD Output common Output 2 common 9 LFD Output contact N.O. Output 2 contact N.O. 10 Output contact N.C. Output 1 contact N.C. 11 Output common Output 1 common 12 Output contact N.O. Output 1 contact N.O. 13 Supply –ve 14 Supply +ve Figure 6 7: Top label for MTL5514 (-T) & MTL5514D Hazardous area Safe area Vs– Vs+ 20 to 35V dc 22kΩ 680Ω + – O/P LFD Switch-type sensors require resistors if LFD is selected 6 5 4 3 2 1 7 8 9 10 11 12 13 14 LFD O/P1 O/P2 7 8 9 10 11 12 INM 5500 Rev 1828 6 1 8 MTL5516C - Switch/Proximity detector interface Two channel, with line-fault detection The MTL5516C contains two changeover relays, which enable two safe-area loads to be controlled by switches or proximity detectors located in a hazardous-area. When selected, the line-fault detect (LFD) facility detects open or short circuit conditions in the field wiring and also indicates this on the top of the module. Line-Fault Detect and Phase Reversal for the channel are selected by DIL switches on the side of the module and output is provided by the changeover relay contacts. See page 19 for LFD and PR switch details. Channel 1 & 2 switch settings apply. For switch sensor inputs, with LFD selected, make sure resistors (22kΩ and 680Ω) are fitted. Note: For reliable, long-term operation the load on the output switching relays should be not less than 50mW, e.g. 10mA at 5V DC. Vs– Vs+ 20 to 35V dc + – + – Ch 2 Ch 1 22kΩ 680Ω 22kΩ 680Ω Switch-type sensors require resistors if LFD is selected 6 5 4 3 2 1 7 8 9 10 11 12 13 14 Hazardous area Safe area Terminal Function 1 Input –ve (Ch 1) 2 Input +ve (Ch 1) 4 Input –ve (Ch 2) 5 Input +ve (Ch 2) 7 Normally-closed contact (Ch 2) 8 Common (Ch 2) 9 Normally-open contact (Ch 2) 10 Normally-closed contact (Ch 1) 11 Common (Ch 1) 12 Normally-open contact (Ch 1) 13 Supply –ve 14 Supply +ve Figure 6 8: Top label for MTL5516C INM 5500 Rev 1829 6 1 9 MTL5517 - Switch/Proximity detector interface Two channel, with line-fault detection and phase reversal The MTL5517 enables two safe-area loads to be controlled, through a relay, by switches or proximity detectors located in a hazardous-area. When selected, the line-fault detect (LFD) is signalled through a separate relay and indicated on the top of the module. Line-Fault Detect and Phase Reversal for the channel are selected by DIL switches on the side of the module and output is provided by the relay contacts. See page 19 for LFD and PR switch details. Channel 1 & 2 switch settings apply. For switch sensor inputs, with LFD selected, make sure resistors (22kΩ and 680Ω) are fitted. Note: For reliable, long-term operation the load on the output switching relays should be not less than 50mW, e.g. 10mA at 5V DC. Vs– Vs+ 20 to 35V dc LFD + – + – Switch-type sensors require resistors if LFD is selected Ch 2 Ch 1 LFD 22kΩ 680Ω 22kΩ 680Ω 6 5 4 3 2 1 7 8 9 10 11 12 13 14 LFD Hazardous area Safe area Terminal Function 1 Input –ve (Ch 1) 2 Input +ve (Ch 1) 4 Input –ve (Ch 2) 5 Input +ve (Ch 2) 7 Line-fault detection 8 Output (Ch 2) 9 Output (Ch 2) 10 Line-fault detection 11 Output (Ch 1) 12 Output (Ch 1) 13 Supply –ve 14 Supply +ve Figure 6 9: Top label for MTL5517 INM 5500 Rev 1830 6 2 Digital Output modules The single channel Digital Output (DO) module range enables on/off devices in a hazardous area to be controlled from the safe area. Some units are loop powered while others enable solid-state switching by providing independent power supplies. 6 2 1 MTL5521(-T) - Solenoid Alarm driver Single channel, loop powered, IIC The MTL5521(-T) is a loop-powered module that enables a device located in the hazardous area (IIC gas group) to be controlled from the safe area. The MTL5521(-T) can drive a certified intrinsically safe low-power load, as well as non-energy-storing simple apparatus such as an LED. 6 5 4 3 2 1 7 8 9 10 11 12 13 14 Solenoid, alarm or other IS device 20 – 35Vdc – + + – To earth leakage detector * Hazardous area Safe area Terminal Function 1 Output –ve 2 Output +ve 11 Supply –ve 12 Supply +ve Figure 6 10: Top label for MTL5521(-T) INM 5500 Rev 1831 6 2 2 MTL5522 - Solenoid Alarm driver Single channel, loop powered, IIB The MTL5522 is a loop-powered module which enables a device located in the hazardous area (IIB gas group) to be controlled from the safe area. The MTL5522 can drive a certified intrinsically safe, low-power load as well as non-energy-storing simple apparatus such as an LED. 6 5 4 3 2 1 7 8 9 10 11 12 13 14 Solenoid, alarm or other IS device 20 – 35Vdc – + + – Hazardous area Safe area Terminal Function 1 Output –ve 2 Output +ve 11 Supply –ve 12 Supply +ve Figure 6 11: Top label for MTL5522 INM 5500 Rev 1832 Hazardous area Safe area 6 2 3 MTL5523 - Solenoid Alarm driver Single channel, with line-fault detection, IIC The MTL5523 interface controls an on/off device in a hazardous area using a volt-free contact or logic signal in the safe area, and is suitable for driving loads such as solenoids. Line-Fault Detection (LFD) operates independently of the output state and is signalled by a safe-area, solid-state switch output which, when a field line is open or short-circuited, becomes de- energised. Earth-fault detection can be provided by connecting an earth leakage detector to terminal 3. 6 5 4 3 2 1 7 8 9 10 11 12 13 14 Solenoid, alarm or other IS device + – Vs– Vs+ 20 to 35V dc + – LFD + ‡ ‡ link to reverse output phase Control Terminal Function 1 Output –ve 2 Output +ve 7 Line fault signal -ve 8 Phase reversal link 9 Phase reversal link 10 Line fault signal +ve 11 Control –ve 12 Control +ve 13 Supply –ve 14 Supply +ve Figure 6 12: Top label for MTL5523 INM 5500 Rev 1833 6 2 4 MTL5523V/MTL5523VL - Solenoid Alarm driver Single channel, voltage controlled with line-fault detection, IIC With the MTL5523V or MTL5523VL interface, an on/off device in a hazardous area can be controlled by a voltage signal in the safe area. It is suitable for driving loads such as solenoids. Line fault detection (LFD), which operates irrespective of the output state, is signalled by a safe- area, solid-state switch which energises if a field line is open or short–circuited. The VL version has a lower current capability to suit alternative load requirements - see datasheet. Hazardous area Safe area Terminal Function 1 Output –ve 2 Output +ve 7, 8, 9 Line fault signal –ve 10 Line fault signal +ve 11 Control –ve 12 Control +ve 13 Supply –ve 14 Supply +ve 6 5 4 3 2 1 7 8 9 10 11 12 13 14 Solenoid, alarm or other IS device + – Vs– Vs+ 20 to 35V dc + – LFD + ControlV PWR STS MTL5523V PWR STS MTL5523VL Figure 6 13: Top labels for MTL5523V & MTL5523VL INM 5500 Rev 1834 Hazardous area Safe area 6 2 5 MTL5524 - Solenoid Alarm driver Single channel, powered, logic drive with phase reversal The MTL5524 enables an on/off device in a hazardous area to be controlled by a volt-free contact or logic signal in the safe area. It can drive loads such as solenoids, alarms, LEDs and other low power devices that are certified as intrinsically safe or are classified as non-energy- storing simple apparatus. 6 5 4 3 2 1 7 8 9 10 11 12 13 14 Solenoid, alarm or other IS device + – Vs– Vs+ 20 to 35V dc + – Control ‡ ‡ use link to reverse phase Terminal Function 1 Output –ve 2 Output +ve 8 Phase reversal link 9 Phase reversal link 11 Control –ve 12 Control +ve 13 Supply –ve 14 Supply +ve Figure 6 14: Top label for MTL5524 INM 5500 Rev 1835 6 2 6 MTL5525 - Solenoid Alarm driver Single channel, low current, loop powered, IIC The MTL5525 enables an on/off device in a hazardous area (IIC gas group) to be controlled by a switch or voltage change in the safe area. It can drive loads such as solenoids, alarms, LEDs and other low power devices that are certified as intrinsically safe or are classified as non-energy-storing simple apparatus. Similar in function to the MTL5521, this module provides lower power output and corresponding reduced safety description. 6 5 4 3 2 1 7 8 9 10 11 12 13 14 Solenoid, alarm or other IS device 20 – 35Vdc – + + – Hazardous area Safe area   Terminal Function 1 Output –ve 2 Output +ve 11 Supply –ve 12 Supply +ve Figure 6 15: Top label for MTL5525 INM 5500 Rev 1836 6 2 7 MTL5526 - Switch Operated Relay Two channel, output The MTL5526 enables two separate IS circuits in a hazardous area to be relay-contact controlled by two on-off switches or logic signals in a safe area. Applications include the calibration of strain–gauge bridges; changing the polarity (and thereby the tone) of an IS sounder; the testing of IS fire alarms; and the transfer of safe-area signals into an annunciator with IS input terminals not segregated from each other. The output–relay contacts are certified as non–energy–storing apparatus, and can be connected to any IS circuit without further certification, provided that separate IS circuits are such that they would remain safe if connected together. 1 2 3 4 5 6 7 8 9 10 11 12 13 14 IS relay IS relay 1 Vs– Vs+ 20 to 35V dc + – 2 + – Control 20 to 35V dc + – + – Loop powered Contact inputs All contacts shown in normal position (relays de-energised) 1 2 Sw4 Hazardous area Safe area Terminal Function 1 IS relay output 1 (normally open) 2 IS relay output 1 (normally closed) 3 IS relay output 1 (common) 4 IS relay output 2 (common) 5 IS relay output 2 (normally closed) 6 IS relay output 2 (normally open) 8 Relay 1 control +ve 9 Relay 1 control –ve 10 Relay 2 control +ve 11 Relay 2 control –ve 13 Supply –ve 14 Supply +ve OFF position ON position 1 2 3 4 Table 6 3: Switch settings for modes Mode Function SW1 SW2 SW3 SW4 Contact/Logic Input 2 ch Off On On On 1in2out On On On On Loop Powered 2 ch Off Off Off Off Figure 6 16: Top label for MTL5526 INM 5500 Rev 1837 6 3 Pulse, Vibration and Foundation Fieldbus modules Single and dual channel modules are available to transfer vibration probe signals from a hazardous area to a safe one. Similarly, pulses from a switch, proximity detector, current pulse transmitter or voltage pulse transmitter, located in the hazardous area, can be safely transferred to the safe area. 6 3 1 MTL5531 - Vibration Transducer Interface Single channel The MTL5531 repeats a signal from a vibration sensor in a hazardous area, providing an output for a monitoring system in the safe area. The interface is compatible with 3-wire, eddy-current probes and accelerometers or 2-wire current sensors, and selection of the mode is made with a switch located on the side of the module Hazardous area Safe area 6 5 4 3 2 1 7 8 9 10 11 12 13 14 COM SIG V– Vibration transducer Vibration transducer Vs– Vs+ 20 to 35V dc –ve 0V Monitor 3- wire 2- wire 2 1 3 Terminal Function 1 Transducer power V– 2 Signal 3 Common 11 Signal output –ve 12 Signal output 0V 13 Supply –ve 14 Supply +ve OFF position ON position 2-/3-wire 2-/3-wire transducer setting switch Mode SW 2-wire (3 3mA)* OFF 3-wire (20mA) ON * Note: When using 2-wire sensors, ensure that terminals 1 and 2 are linked as shown in the wiring diagram above. WARNING - Revision status 05 and below* To enable optimum heat dissipation the recommended orientation for mounting is with the module vertical, i e with the vents in the case at the top and bottom This enables air to flow through the module In any other orientation, i e with the module horizontal, then the maximum ambient temperature is limited to: • Close packed = 45°C • Minimum of 10mm spacing = 55°C Eaton produce the MS010 DIN rail module spacer for this purpose (packs of 5 - see Section 4 3) *Revision status is the 2 digits after the +++ in the barcode number Figure 6 17: Top label for MTL5531 INM 5500 Rev 1838 6 3 2 MTL5532 - Pulse Isolator Pulse & 4/20mA current outputs The MTL5532 isolates pulses from a switch, proximity detector, current pulse transmitter or voltage pulse transmitter located in a hazardous area. It is ideal for applications involving high pulse rates and fast response times, by repeating the pulses into the safe area, and the transistors used on the pulse output will switch +ve or –ve polarity signals. It may be used immediately in simple or legacy mode, or it may be software configured for more specific applications - see next page for either option. With configuration, an analogue output proportional to frequency is available, together with a relay output, which may act as an alarm. Note: For reliable, long-term operation the load on the output switching relay should not be less than 50mW, e.g.10mA at 5VDC. Hazardous area Safe area 6 5 4 3 2 1 7 8 9 10 11 12 13 14 Vs– Vs+ 20 to 35V dc 3-wire current pulse 4/20 mA – + 3-wire voltage pulse 5 4 1 2-wire current pulse Voltage pulse Current pulse 5 1 Inhibit Load Alarm 4/20mA Configuration socket – + 1 4 +

Pulse – + Pulse 4 3 V 4/20 mA 3 1 3 4/20 mA Terminal Function 1 Common input –ve 2 Switch/proximity input +ve 3 Current pulse input +ve 4 Transmitter supply +ve 5 Voltage pulse input +ve 6 Inhibit input +ve 7 Alarm output 8 Current output –ve 9 Current output +ve 10 Alarm output 11 Pulse output –ve 12 Pulse output +ve 13 Supply –ve 14 Supply +ve Vsp SW1 SW2 3V ON ON 6V ON OFF 12V OFF OFF OFF position ON position 1 2 3 4 SW1 SW2 SW3 SW4 Vsp Vsp LFD Mode LFD SW3 OFF OFF ON ON Switches located on the edge of the module define the mode of operation. Figure 6 18: Top label for MTL5532 INM 5500 Rev 1839 Switch input operation If switch contacts are used for this Pulse Input (terminals 1 & 2), then and parallel resistors must be fitted - see Section 6.1.2 for recommended values. Simple or Legacy mode - SW4 - OFF If simple “pulse-in/pulse-out” operation is required or, if a replacement for the earlier MTL5032 pulse isolator is required, then SW4 should be set to OFF. The input switching point voltage (Vsp) thresholds can then be defined by Switches 1 & 2, and the LFD operation can be set with Switch 3. When Switch 3 is ON, the Alarm output (terminals 11 & 12) become active. Configurable mode - SW4 - ON In this mode, analogue, alarm and pulse outputs are available but the module must be software configured to define its operating mode. In this mode, software controls the LFD function and Switch 3 has no effect. Switches 1 & 2 continue to define the switching point threshold (Vsp). Configuration requires a personal computer, a PCL45USB interface and PCS45 software. See Section 6.9 for details of the configurator. Alarm inhibiting The Inhibit input is provided to inhibit alarm output operation. This facility is useful, for example, during power-up, when pulse rates are below the alarm threshold. When normal operational values are established the inhibit can be disabled. Such a facility is sometimes referred to as a start-up delay. Inhibit is enabled by connecting a switch or proximity detector between terminals 6 and 3. If switch contacts are used for this input, then and parallel resistors must be fitted - see Section 6.1.2 for recommended values. LED indicators Use the following LED information to understand the module status. LED Description PWR Power (green) ON - Power OK OFF - No power or insufficient voltage O/P Output (yellow) The LED will follow the pulse output state. If the output is pulsing then the LED brightness will pulse. If the pulsing is rapid or very short, the LED may dim if it is unable to respond to such changes. If the output is high, the LED will be ON. STS Status (red - flashing) In legacy mode a line fault will cause the LED to turn ON. In mC mode, the LED is programmable to display a line fault or an Alarm trip operation. In the event, it will also indicate a mC fault condition. INM 5500 Rev 1840 6 3 3 MTL5533 - Vibration Transducer Interface (Reference use only: Terminated product, use 2 x MTL5531) Two channel The MTL5533 repeats signals from vibration sensors in a hazardous area, providing outputs for monitoring systems in the safe area. The interface is compatible with 3-wire eddy-current probes and accelerometers or 2-wire current sensors, and selection of the mode for each channel is made with the switches on the side of the module. Hazardous area Safe area Vibration transducer Vibration transducer Vibration transducer Vibration transducer COM SIG V– COM SIG V– Vs– Vs+ 20 to 35V dc –ve 0V Monitor 3- wire 2 1 3- wire 2- wire 5 4 2- wire Monitor –ve 0V 3 6 Ch 1 Ch 2 Ch 1 Ch 2 6 5 4 3 2 1 7 8 9 10 11 12 13 14 Terminal Function 1 Transducer power V– (Ch1) 2 Signal (Ch1) 3 Common (Ch1) 4 Transducer power V– (Ch2) 5 Signal (Ch2) 6 Common (Ch2) 8 Signal output –ve (Ch2) 9 Signal output 0V (Ch2) 11 Signal output –ve (Ch1) 12 Signal output 0V (Ch1) 13 Supply –ve 14 Supply +ve OFF position ON position Ch 1 Ch 2 2-/3-wire transducer setting switches Mode SW 2-wire (3 3mA) OFF 3-wire (20mA) ON * Note: When using 2-wire sensors, ensure that terminals 1 & 2 and 4 & 5 have wiring links as shown in the wiring diagram above. WARNING! To enable adequate heat dissipation from the MTL5533 modules, they must be installed on the DIN rail with a 10mm space between adjacent units Eaton produce the MS010 DIN rail module spacer for this purpose (packs of 5 - see Section 4 3), and these then enable operation in ambient temperatures of up to 50°C in vertical or horizontal orientation Figure 6 19: Top label for MTL5533 INM 5500 Rev 1841 6 3 4 MTL MTL5553 isolator/power supply for 31 25kbit/s fieldbuses The MTL5553 has been specifically developed to extend 31.25kbit/s (H1) fieldbus networks into hazardous areas. It provides power, communication and IS isolation to devices powered through the signal conductors. The MTL5553 complies with the requirements of Fieldbus Foundation™ specified power supply Type 133 (IS power supply). To comply with fieldbus standards, each bus must be terminated at both ends. MTL's FBT1-IS or FCS-MBT fieldbus terminators (see section 6.33?) can be supplied for this purpose or, for installations in which the safe-area bus length is small, the MTL5553 includes an internal safe-area terminator which is enabled by making a link between terminals 7&8 on the top of the unit. For network and termination criteria, check applicable fieldbus standards and specification IEC 61158-2, ISA-S50.02 for 31.25kbit/s fieldbus systems, Foundation™ Fieldbus 31.25kbit/s Physical LayerProfile Specification FF-816 and MTL's Application Brief AB002.) Hazardous area Safe area 20-35V dc Vs+ Vs- +ve -ve +ve -ve Host (31.25kbit/s) Terminator 1 2 4 5 +ve -ve +ve -ve Field (31.25kbit/s) 6 3 2.6W Max 8 9 T 14 13 11 10 7 12 Link 7- 8 for Terminator Terminal Function

1 Hazardous-area fieldbus device(s) connection –ve 2 Hazardous-area fieldbus device(s) connection +ve 4 Optional HHC connection –ve 5 Optional HHC connection +ve 7 Link to 8 to enable internal terminator 8 & 11 Safe-area fieldbus device(s) connection –ve 9 & 12 Safe-area fieldbus device(s) connection +ve 13 Supply –ve 14 Supply +ve Note: To assist the process of terminating cable screens, screw terminals have been provided in terminals 3, 6, and 10. Please note, however, that there is no internal connection for these terminals so they are not earthed. NOTE To allow adequate heat dissipation under all likely thermal conditions, it is recommended that MTL5553s are installed on a horizontal DIN-rail mounted on a vertical surface* with a 10mm space between adjacent units. MTL MS010 10mm DIN-rail module spacers are available for this purpose. * If an MTL5553 is mounted in a non-optimum orientation, the maximum operating temperature is reduced to 45°C. INM 5500 Rev 1842 6 4 Analogue Input modules The analogue input (AI) modules support 2-wire or 3-wire 4/20mA or HART transmitters located in a hazardous area; repeating the current in other circuits to drive safe-area loads. 6 4 1 MTL5541/MTL5541-T/MTL5541S (-T) - Repeater Power Supply Single channel, for 4/20mA HART® for 2- or 3-wire transmitters The MTL5541 provides a fully-floating dc supply for energising a conventional 2- or 3-wire 4/20mA transmitter which is located in a hazardous area, and repeats the current in another floating circuit to drive a safe-area load. For HART 2-wire transmitters, the unit allows bi- directional communications signals superimposed on the 4/20mA loop current. Alternatively, the MTL5541S (-T) acts as a current sink for a safe-area connection rather than driving a current into the load. Separately powered current sources, such as 4-wire transmitters, can be connected but will not support HART communication. Hazardous area Safe area 6 5 4 3 2 1 7 8 9 10 11 12 13 14 Vs– Vs+ 20 to 35V dc 4/20mA MTL5541 MTL5541S – 4/20mA Load+ Load + — + Com Tx+ Input I I Terminal Function 1 Current input 2 Transmitter supply +ve 3 Common 10 Output +ve via 220Ω for HART apps. 11 Output –ve (+ve current sink) 12 Output +ve (–ve current sink) 13 Supply –ve 14 Supply +ve Figure 6 20: Top labels for MTL5541 & MTL5541S S INM 5500 Rev 1843 6 4 2 MTL5541A/MTL5541AS - Repeater Power Supply Single channel, for 4/20mA, HART® for 2- or 3-wire transmitters The MTL5541A provides an input for separately powered 4/20mA transmitters and also allows bi–directional transmission of HART communication signals superimposed on the 4/20mA loop current. Alternatively, the MTL5541AS acts as a current sink for a safe-area connection rather than driving a current into the load. Hazardous area Safe area Vs– Vs+ 20 to 35V dc – 4/20mA Load +– + MTL5541A MTL5541AS Load + — + 4/20mA 6 5 4 3 2 1 7 8 9 10 11 12 13 14 I I Terminal Function 1 Input –ve 2 Input +ve 11 Output –ve (+ve current sink) 12 Output +ve (–ve current sink) 13 Supply –ve 14 Supply +ve Figure 6 21: Top labels for MTL5541A & MTL5541AS INM 5500 Rev 1844 6 4 3 MTL5544/MTL5544S - Repeater Power Supply Two channel, for 4/20mA HART® for 2- or 3-wire transmitters The MTL5544 provides fully-floating dc supplies for energising two conventional 2-wire or 3-wire 4/20mA or HART transmitters located in a hazardous area, and repeats the current in other circuits to drive two safe-area loads. For HART transmitters, the unit allows bi-directional transmission of digital communication signals superimposed on the 4/20mA loop current. Alternatively, the MTL5544S acts as a current sink for a safe-area connection rather than driving a current into the load. Separately powered current sources, such as 4-wire transmitters, can be connected but will not support HART communication. Hazardous area Safe area Vs– Vs+ 20 to 35V dc – 4/20mA Load + – 4/20mA Load + Ch 2 Ch 1 MTL5544 MTL5544S Load + – Load + – 4/20mA 4/20mA Ch 2 Ch 1 Com Tx+ Input Com Tx+ Input 6 5 4 3 2 1 7 8 9 10 11 12 13 14 I I I I Terminal Function 1 Ch1 current input 2 Ch1 transmitter supply +ve 3 Ch1 common 4 Ch2 current input 5 Ch2 transmitter supply +ve 6 Ch2 common 7 Ch2 output +ve via 220Ω for HART apps. 8 Ch2 output –ve (+ve current sink) 9 Ch2 output +ve (–ve current sink) 10 Ch1 output +ve via 220Ω for HART apps. 11 Ch1 output –ve (+ve current sink) 12 Ch1 output +ve (–ve current sink) 13 Supply –ve 14 Supply +ve Hazardous area Safe areaThe MTL5544 or MTL5544S can also be used to drive two safe-area loads from a single 2-wire transmitter (i.e. 1 in, 2 out) by interconnecting the input channels as shown in the diagram (right). Note: In this mode the HART data is transferred via channel 1 output only. See also the MTL5544D. Vs– Vs+ 20 to 35V dc – 4/20mA Load + – 4/20mA Load + Ch 2 Ch 1 MTL5544 MTL5544S Load + – Load + – + –4/20mA 6 5 4 3 2 1 7 8 9 10 11 12 13 14 I I I I Figure 6 22: Top labels for MTL5544 & MTL5544S INM 5500 Rev 1845 6 4 4 MTL5544A/MTL5544AS - Current Repeater Two channel, for 4/20mA passive input for HART® transmitters The MTL5544A provides an input for separately powered 4/20mA transmitters and also allows bi–directional transmission of HART communication signals superimposed on the 4/20mA loop current. Alternatively, the MTL5544AS acts as a current sink for a safe-area connection rather than driving a current into the load. Hazardous area Safe area Vs– Vs+ 20 to 35V dc + – Ch 2 Ch 2 Ch 1 + – Ch 1 4/20mA 4/20mA 6 5 4 3 2 1 7 8 9 10 11 12 13 14 I I I I MTL5544A MTL5544AS – 4/20mA Load+ Load + — + – 4/20mA Load+ Load + — + Terminal Function 1 Ch1 input –ve 2 Ch1 input +ve 4 Ch2 input –ve 5 Ch2 input +ve 8 Ch2 output –ve (+ve current sink) 9 Ch2

output +ve (–ve current sink) 11 Ch1 output –ve (+ve current sink) 12 Ch1 output +ve (–ve current sink) 13 Supply –ve 14 Supply +ve Figure 6 23: Top labels for MTL5544A & MTL5544AS INM 5500 Rev 1846 6 4 5 MTL5544D - Repeater Power Supply Two channel, for 4/20mA HART® for 2- or 3-wire transmitters, two outputs The MTL5544D provides a fully-floating dc supply for energising a conventional 2- or 3-wire 4/20mA transmitter located in a hazardous area, and repeats the current in other circuits to drive two safe-area loads. For HART 2-wire transmitters, the unit allows bi-directional transmission of digital communication signals superimposed on the 4/20mA loop current via channel 1 only,Separately powered current sources, such as 4-wire transmitters, can be connected but will not support HART communication. Hazardous area Safe area Vs– Vs+ 20 to 35V dc Ch 2 Ch 1 – 4/20mA Load+ – 4/20mA Load+4/20mA 6 5 4 3 2 1 7 8 9 10 11 12 13 14 Com Tx+ Input I I I Terminal Function 1 Current input 2 Transmitter supply +ve 3 Common 7 Ch2 output +ve via 220Ω HART not supported. 8 Ch2 output –ve 9 Ch2 output +ve 10 Ch1 output +ve via 220Ω for HART apps. 11 Ch1 output –ve 12 Ch1 output +ve 13 Supply –ve 14 Supply +ve NOTE: For correct operation of the module, a suitable load must be present on both output channels. This is of particular importance during testing, commissioning or maintenance activities when the temporary disconnection, or absence, of a load can affect the transfer accuracy of the analogue variable. Figure 6 24: Top label for MTL5544D INM 5500 Rev 1847 6 5 Analogue Output modules The analogue output (AO) modules accept 4/20mA floating signals from safe-area controllers to drive current/pressure converters (or any other load up to 800Ω) in a hazardous area. 6 5 1 MTL5546/MTL5546Y(-T) - Isolating Driver Single channel, for 4/20mA HART® valve positioners with line-fault detection The MTL5546 accepts a 4/20mA floating signal from a safe-area controller to drive a current/ pressure converter (or any other load up to 800Ω) in a hazardous area. For HART valve positioners, the module also permits bi-directional transmission of digital communication signals so that the device can be interrogated either from the operator station or by a hand-held communicator. Process controllers with a readback facility can detect open or short circuits in the field wiring: if these occur, the current taken into the terminals drops to a preset level. The MTL5546Y(-T) is very similar to the MTL5546 except that it provides open circuit detection only (i.e. no short-circuit detection). Hazardous area Safe area Terminal Function 1 Output –ve 2 Output +ve 11 Input –ve 12 Input +ve 13 Supply –ve 14 Supply +ve Input characteristics Field wiring state MTL5546 MTL5546Y Normal <6.0V <6.0V Open-circuit <0.9mA <0.5mA Short-circuit <0.9mA N.A. Figure 6 25: Top labels for MTL5546 & MTL5546Y INM 5500 Rev 1848 6 5 2 MTL5549/ MTL5549Y - Isolating Driver Two channel, for 4/20mA HART® valve positioners with line-fault detection The MTL5549 accepts 4/20mA floating signals from safe-area controllers to drive 2 current/ pressure converters (or any other load up to 800Ω) in a hazardous area. For HART valve positioners, the module also permits bi-directional transmission of digital communication signals so that the device can be interrogated either from the operator station or by a hand-held communicator. Process controllers with a readback facility can detect open or short circuits in the field wiring: if these occur, the current taken into the terminals drops to a preset level. The MTL5549Y is very similar to the MTL5549 except that it provides open circuit detection only (i.e. no short-circuit detection). Hazardous area Safe area Terminal Function 1 Output –ve (Ch 1) 2 Output +ve (Ch 1) 4 Output –ve (Ch 2) 5 Output +ve (Ch 2) 8 Input –ve (Ch 2) 9 Input +ve (Ch 2) 11 Input –ve (Ch 1) 12 Input +ve (Ch 1) 13 Supply –ve 14 Supply +ve Input characteristics Field wiring state MTL5549 MTL5549Y Normal <6.0V <6.0V Open-circuit <0.9mA <0.5mA Short-circuit +50mV ON – NO Vin* ON – YES 16.5V. 8 3 2 Modules: MTL5541S(-T), MTL5544S & MTL5561 Figure 8 6: AI test circuit #2 “o/p sinking” Output Measurements Note: Do not connect a voltmeter in circuit to measure V1 until requested in Step 4 below, because current measurement A2 could be affected. 1. Adjust RV1 to vary the current (A1) through the range 4 to 20mA. 2. The measured current imbalance (A2) over this range for the MTL5541S and the MTL5544S should not exceed ± 20µA. For the MTL5561 the imbalance should not exceed ± 400µA. 3. Adjust RV1 for a 20mA reading on A1 4. The voltage V1, across the channel input, should typically be >16.5V. + – + – +– V1 i/p o/p RV1 10kΩ lin. A1 250Ω 24V + – I oIi A2 + – INM 5500 Rev 1863 8 3 3 Modules: MTL5541A & MTL5544A Figure 8 7: AI test circuit #3 “active i/p” Output Measurements 1. Adjust RV1 to vary the current (A1) through the range 4 to 20mA. 2. The measured current imbalance (A2) over this range should not exceed ± 20mA 8 3 4 Modules: MTL5541AS & MTL5544AS Figure 8 8: AI test circuit #4 “active i/p - o/p sinking” Output Measurements 1. Adjust RV1 to vary the current (A1) through the range 4 to 20mA. 2. The measured current imbalance (A2) over this range should not exceed ± 20mA INM 5500 Rev 1864 8 3 5 Module: MTL5581 Figure 8 9: AI test circuit #5 “mV input” Note: V1 should be capable of measurement to within 1mV. Output Measurements 1. With the LINK connected, vary output V2 between 0 and 50mV using RV1. V1 should show +50mV with the switch set to ‘+’, or 19V. Vary the potentiometer setting and check that the reading on voltmeter V varies by no more than ±100mV. + – + – A2 + – A1 o/p i/p current source +– 470Ω load I oli INM 5500 Rev 1866 8 5 2 Testing MTL5553 - Isolator/power supply for 31 25kbits/s fieldbuses Make the safe and hazardous-area connections shown in figure 10.2 and, substituting appropriate resistors at Rtest, carry out the following checks. Rtest Voltage across terminals 2 and 1 (V1) Open-circuit 17.8 < V1 < 19V 220Ω 11.5V < V1 < 13.5V 10Ω V1 < 5V 20-35V dc Vs- Vs+ -ve +ve -ve Host (31.25kbit/s) Terminator 1 2 4 5 6 3 2.6W Max 8 9 T 14 13 11 10 7 12 Link 7- 8 for Terminator Hazardous Area Safe Area V1 R test + - Top Label, MTL5553 Test circuit for MTL5553 INM 5500 Rev 1867 9 APPLICATIONS INVOLVING ZONE 2 AND/OR ZONE 22 HAZARDOUS AREAS IMPORTANT: See page iv at the front of this manual for important additional information regarding the use of these products in countries governed by the ATEX Directive. The European Community permits Category 3G equipment, such as the MTL5500 , to be installed in, or connected to, Zone 2 flammable atmospheres provided it meets the requirements of the ATEX Directive. MTL5500 Category 3 products have been designed to meet, and carry approval markings for, Ex nC and/or Ex nA. In general, meeting the relevant requirements of the appropriate European (CENELEC) standards is considered the most appropriate method of demonstrating compliance with the ATEX directive. However, Eaton often has its products approved by other national bodies, such as FM and CSA and, because national, European, and international standards are converging, it is generally possible to use other national approvals as supporting evidence for the ATEX Technical File. In the context of this document, Zone 2 (Division 2) and Zone 22 hazardous areas are those that may become potentially explosive through the presence of flammable gases, vapours and dusts for periods of up to 10 hours per year. It is recommended that the current version of the standards is consulted for detailed information on the requirements applicable to the particular installation. As a consequence of their IS approvals, MTL5500 products may also be connected into Zone 22 hazardous areas. Consult individual module approvals for further details. Unless otherwise specified, the following ambient conditions apply: Ambient Temperature range –20°C to +60°C Pollution Degree 2 (See EN 61010-1) Measurement Category II (See EN 61010-1) 9 1 Enclosure EN 60079-15 specifies the minimum required degree of protection to be IP54, but generally this is provided by the external enclosure in which the product is mounted. The user must refer to the specific certificates relating to the products being installed within the hazardous area to check that all special conditions of safe use have been complied with. INM 5500 Rev 1868 10 APPENDIX 1 10 1 MTL5000 Many modules in the MTL5000 Isolating Interface Units range have now been superceded by their equivalent in the MTL5500. For new applications the MTL5500 modules are recommended, these offer all the benefits of greater efficiency, new multichannel modules and new functionality. A number of the products in the MTL5000 will continue to provide key functionality as part of MTL DIN rail isolator range and are described within this Appendix. Important • Make sure that all installation work is carried out in accordance with all relevant local standards, codes of practice and site regulations. • When planning the installation of MTL5000 isolators it is essential to make sure that intrinsically safe and non-intrinsically safe wiring is segregated, and that units are installed as required by a nationally accepted authority or as described in EN 60079-14, ISA RP 12.6 or DIN VDE-165. • Check that the hazardous-area equipment complies with the descriptive system document. • If in doubt, refer to the certificate/catalogue for clarification of any aspects of intrinsic safety or contact Eaton's MTL product line or your local representative for assistance. • Make sure the correct hazardous-area connector (field-wiring plug) is plugged into the corresponding isolator. It is recommended that the connector is identified by the same tag number as the matching isolator. Mount all MTL5000 isolators on low-profile (7mm) or high-profile (15mm) type T35 (top-hat) DIN-rail to EN50022, BS5584, DIN46277. This is available from Eaton, in 1 metre lengths (THR2 - DIN rail). Install isolators within the safe area unless they are enclosed in approved flameproof, pressurised or purged enclosures and ensure that the local environment is clean and free of dirt and dust. Note the ambient temperature considerations of section 3.1.4. It is recommended that, in normal practice, the DIN rail should be earthed/grounded to ensure the safety of personnel in the event of a.c. mains (line) power being applied accidentally to the rail. Power connectors 104 115 110 16 16.2mm PITCH HAZ SAFE Hazardous-area connections Non-hazardous (safe) area connections INM 5500 Rev 1869 10 2 MTL5018AC single-pole, changeover relay, two-channel, switch/proximity detector with line fault detection and phase reversal The MTL5018AC modules enable each of two safe-area loads to be relay-controlled by switches or proximity detectors in a hazardous area. Line fault detection (LFD) and output phase reversal facilities are included (see section 6.1). 10 2 1 Wiring connections See figure 10.1 for wiring connections. Note: Reactive loads must be adequately suppressed. 10 2 2 Line fault detection (See section 6.1 for definition of a line fault) On each channel, input line faults (open- or short-circuit) are indicated by an LED and the de-energising of the output. LFD is enabled/disabled by switches located on the top of the module. Note: that if the LFD facility is enabled for switch inputs, the resistors shown in 10.1 and 10.2 MUST be fitted. Terminal Function 1 Input –ve (Ch 1) 2 Input +ve (Ch 1) 3 4 Input –ve (Ch 2) 5 Input +ve (Ch 2) 6 7 Normally-closed contact (Ch 2) 8 Common (Ch 2) 9 Normally-open contact (Ch 2) 10 Normally-closed contact (Ch 1) 11 Common (Ch 1) 12 Normally-open contact (Ch 1) 13 Supply N 14 Supply L Hazardous area Safe area Figure 10 1: MTL5018AC wiring diagram and connections INM 5500 Rev 1870 10 2 3 Testing Make the safe- and hazardous-area connections shown in figure 10.2, and check the status of the output contacts for each channel in turn (with a 22kΩ resistor connected to the other channel) as shown in the table 10.1. Phase reverse switch Line fault detection Input switch (SW) Output relay (11-12, 8-9) Output relay (10-11, 7-8) Channel status LED (yellow) Line fault LED (red) Normal Off a Closed Open On Off Reverse Off ISC = 7 _ 9mA Open Closed Off Off Reverse Off Open Closed Open Off Off Normal On VOC = 7.5 _ 9.5V Open Closed Off On Normal On a Open Closed Off On Normal On b Open Closed Off Off Normal On c Closed Open On Off Figure 10 2: Test circuit for MTL5018AC Table 10 1 INM 5500 Rev 1871 10 3 MTL5051 serial data comms isolator The MTL5051provides either bi-directional serial data communications from a computer system in a safe area to instrumentation in a hazardous area or data communications across a hazardous area. It is used to provide a fully floating dc supply for, and serial data communications to MTL640 text displays and MTL650 text and graphics terminals or to other IS and non-IS instrumentation and keyboards. 10 3 1 Wiring connections See the figures 10.3 and 10.4 and the terminal specifications in tables 10.2 and 10.3 for wiring connections. Figure 10.3: MTL5051 wiring diagram (to a hazardous area) Hazardous area Safe area Safe areaHazardous area Figure 10.4: MTL5051 wiring diagram (across a hazardous area) INM 5500 Rev 1872 10 3 2 Hazardous-area interfacing Displays/ terminals: For details of interfacing with MTL640 and MTL650 displays/terminals (as an alternative to the MTL696 communications interface) see the appropriate product instruction manual. Table 10 2 MTL5051 Terminals MTL640 mode MTL650 mode Comms mode Other IS devices 1 Common Common Common Common 2 V signal 12V - 5V/12V 3 I return Rx Rx - 4 - Tx Tx - 5 - - - Tx 6 - - - Rx Switch 1a On Off Off Off 1b On On On Off/On Table 10 3 Terminals RS232 mode TTL mode RS422 mode 7 - - Rx- 8 - - Rx+ 9 - Tx Tx+ 10 Tx - Tx- 11 Common Common Common 12 Rx Rx - 13 Supply -ve Supply -ve Supply -ve 14 Supply +ve Supply +ve Supply +ve Switch 2a Off On On 2b On Off Off Across hazardous areas: For communication across hazardous areas MTL5051 devices are used in pairs to transfer bi-directional full duplex data across hazardous areas, as shown in figure 10.4. Current switching is used to minimise the bandwidth-limiting effects of long cables. The maximum baud rate in this mode is the lesser of 19.2k baud or the cable-related rate produced by the following formula. Remote signalling baud rate formula, for back-to-back mode across a hazardous area: max baud rate = K/(RxCxL2) where K = 0.25 (constant) R = cable resistance (Ω/m) C = cable capacitance (F/m) L = length (m) For example, with a 2km cable of 100pF/m capacitance and 40mΩ/m resistance, the maximum baud rate = 0.25/(40mΩ x 100pFx 2km2) = 15k baud. This assumes that the cable is 2 cores plus screen, with the screen used for the 'common' connection. RS232-level devices: Communication with RS232-level interfaces, such as a suitably certified IS keyboard, mouse, etc, is achieved by using one or more MTL5051 units as required by the IS device.(TTL level interfaces are accommodated by the TTL compatibility of RS232 receivers.) The supply to IS equipment at terminal 2 can be set to either 5V or 12V, by a switch located on top of the unit, as follows: +12V mode 12.0V ±5% (load 23mA to 23mA to <50mA) Note: the normal RS232 limitations of bandwidth versus cable length are applicable. As a rule of thumb, speed (baud) x length (metres) trip setting • open closed H (high) Input trip setting closed open L (low) Input Industry Events & Webinars>Industry Automation Control Blog> mySchneider Terms of Use Privacy Policy Cookie Notice Change your cookie settings ©2025, Schneider Electric mySchneider Sustainability School: Training you for success Everything you need to know to thrive in the New Electric World Turn your climate ambition into action At Schneider Electric, we're training partners worldwide to enable sustainable practices and decarbonize the economy. Our Sustainability School provides the knowledge and tools you need to differentiate your business and win more projects! Chapter 1 courses – two levels! In our FUNDAMENTAL and ADVANCED Chapter 1 courses, discover why the low-carbon transition is key to reducing and preventing global warming. 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....7 FCC Statement
....8 Safety Precautions
....8 Technical
Data...10 System Overview
....10 Model List
....12 Overview of Configurations
....14 Overview of UPSs with 1250 kW I/O Cabinet - Single Utility/
Mains...14 Overview of UPSs with 1250 kW I/O
Cabinet - Dual Utility/Mains ....15 Overview of UPSs with 1500 kW I/O Cabinet – Single Utility/
Mains...15 Overview of UPSs with 1500 kW I/O
Cabinet – Dual Utility/Mains ....16 Parallel
System...16 Input Power Factor
....17 Input Voltage Window
....17 Inverter Short–Circuit Capabilities (Bypass not
Available) ....18 Efficiency for UPSs with 1250 kW I/O Cabinet..21
Efficiency for UPSs with 1500 kW I/O Cabinet..23 Derating Due to Load Power
Factor ....25 Batteries (VRLA)
....26 End of Discharge Voltage
....26 Battery Voltage Range
(VRLA)...26
Compliance...27 Communication and
Management ....28 EPO Connections
....28 Overview of Input Contacts and Output
Relays....................................29 Facility Planning
....31 Specifications for 500 kW UPS
....31 Specifications for 625 kW UPS
....33 Specifications for 750 kW UPS

....35 Specifications for 800 kW UPS ....37 Specifications for 1000 kW UPS ....39 Specifications for 1100 kW UPS..41 Specifications for 1250 kW UPS ....43 Specifications for 1500 kW UPS ....45 Recommended Upstream Protection and Cable Sizes – UL ....47 Recommended Bolt and Lug Sizes for Copper Cables.................................50 Recommended Bolt and Lug Sizes for Aluminium Cables ....50 Weights and Dimensions..51 UPS Shipping Weights and Dimensions ....51 Weights and Dimensions for UPSs with 1250 kW I/O Cabinet.................51 Weights and Dimensions for UPSs with 1500 kW I/O Cabinet.................52 Clearance ....53 Clearance for UPSs with 1250 kW I/O Cabinet ....53 Clearance for UPSs with 1500 kW I/O Cabinet ....53 990-5451K-001 5 480 V UPS System Guidance for Organizing Battery Cables..54 Torque Specifications..54 Environment...55 Heat Dissipation (BTU/hr) for UPSs with 1250 kW I/O Cabinet ....56 Heat Dissipation (BTU/hr) for UPSs with 1500 kW I/O Cabinet ....59 Options ....61 Configuration Options ....61 Hardware Options...62 Limited Factory Warranty...63 6 990-5451K-001 Important Safety Instructions — SAVE THESE INSTRUCTIONS Read these instructions carefully and look at the equipment to become familiar with it before trying to install, operate, service or maintain it. The following safety messages may appear throughout this manual or on the equipment to warn of potential hazards or to call attention to information that clarifies or simplifies a procedure. The addition of this symbol to a “Danger” or “Warning” safety message indicates that an electrical hazard exists which will result in personal injury if the instructions are not followed. This is the safety alert symbol. It is used to alert you to potential personal injury hazards. Obey all safety messages with this symbol to avoid possible injury or death. DANGER DANGER indicates a hazardous situation which, if not avoided, will result in death or serious injury. Failure to follow these instructions will result in death or serious injury. WARNING WARNING indicates a hazardous situation which, if not avoided, could result in death or serious injury. Failure to follow these instructions can result in death, serious injury, or equipment damage. CAUTION CAUTION indicates a hazardous situation which, if not avoided, could result in minor or moderate injury. Failure to follow these instructions can result in injury or equipment damage. NOTICE NOTICE is used to address practices not related to physical injury. The safety alert symbol shall not be used with this type of safety message. Failure to follow these instructions can result in equipment damage. Please Note Electrical equipment should only be installed, operated, serviced, and maintained by qualified personnel. No responsibility is assumed by Schneider Electric for any consequences arising out of the use of this material. A qualified person is one who has skills and knowledge related to the construction, installation, and operation of electrical equipment and has received safety training to recognize and avoid the hazards involved. 990-5451K-001 7 Important Safety Instructions — SAVE THESE INSTRUCTIONS 480 V UPS System FCC Statement NOTE: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense. Any changes or modifications not expressly approved by the party responsible for compliance could void the user’s authority to operate the equipment. Safety Precautions DANGER HAZARD OF ELECTRIC SHOCK, EXPLOSION, OR ARC FLASH • The product must be installed according to the specifications and requirements as defined by Schneider Electric. It concerns in particular the external and internal protections (upstream circuit breakers, battery circuit breakers, cabling, etc.) and environmental requirements. No responsibility is assumed by Schneider Electric if these requirements are not respected. • After the UPS system has been electrically wired, do not start up the system. Start-up must only be performed by Schneider Electric. Failure to follow these instructions will result in death or serious injury.

DANGER HAZARD OF ELECTRIC SHOCK, EXPLOSION, OR ARC FLASH The UPS System must be installed according to local and national regulations. Install the UPS according to: • IEC 60364 (including 60364–4–41- protection against electric shock, 60364– 4–42 - protection against thermal effect, and 60364–4–43 - protection against overcurrent), or • NEC NFPA 70 depending on which one of the standards apply in your local area. Failure to follow these instructions will result in death or serious injury. DANGER HAZARD OF ELECTRIC SHOCK, EXPLOSION, OR ARC FLASH • Install the UPS system in a temperature controlled area free of conductive contaminants and humidity. • Install the UPS system on a non-inflammable, level, and solid surface (e.g. concrete) that can support the weight of the system. Failure to follow these instructions will result in death or serious injury. 8 990-5451K-001 480 V UPS System Important Safety Instructions — SAVE THESE INSTRUCTIONS DANGER HAZARD OF ELECTRIC SHOCK, EXPLOSION, OR ARC FLASH The UPS is not designed for and must therefore not be installed in the following unusual operating environments: • Damaging fumes • Explosive mixtures of dust or gases, corrosive gases, or conductive or radiant heat from other sources • Moisture, abrasive dust, steam or in an excessively damp environment • Fungus, insects, vermin • Salt-laden air or contaminated cooling refrigerant • Pollution degree higher than 2 according to IEC 60664-1 • Exposure to abnormal vibrations, shocks, and tilting • Exposure to direct sunlight, heat sources, or strong electromagnetic fields Failure to follow these instructions will result in death or serious injury. NOTICE RISK OF OVERHEATING Respect the clearance requirements around the UPS system and do not cover the product's ventilation openings when the UPS system is in operation. Failure to follow these instructions can result in equipment damage. NOTICE RISK OF EQUIPMENT DAMAGE Do not connect the UPS output to regenerative load systems including photovoltaic systems and speed drives. Failure to follow these instructions can result in equipment damage. 990-5451K-001 9 Important Safety Instructions — SAVE THESE INSTRUCTIONS 480 V UPS System Technical Data System Overview Each Galaxy VX UPS consists of the following components: • An I/O cabinet for wield wiring containing the static switch, a backfeed breaker BF21, and the user interface. • A number of 250 kW power cabinets containing the power electronics. UPSs with 1250 kW I/O Cabinet The 1250 kW I/O cabinet is used for UPS systems from a minimum configuration of 500 kW with two power cabinets to a maximum configuration of 1250 kW N+1 with six power cabinets. The I/O cabinet is placed to the left and two to six power cabinets (depending on system size) are placed to the right. The image below shows the maximum configuration. UPSs with 1500 kW I/O Cabinet The 1500 kW I/O cabinet is used for UPS systems from a minimum configuration of 500 kW with two power cabinets to a maximum configuration of 1500 kW N+1 with seven power cabinets. The image below shows the maximum configuration. 10 990-5451K-001 480 V UPS System Technical Data 1. For a 1250 kW I/O cabinet, the BF2 can be installed internal in the UPS or externally in the switchgear. Maintenance Bypass Cabinet for UPSs with a Maximum Rating of 750 kW The maintenance bypass cabinet contains the following breakers to isolate the UPS during maintenance: • Static switch input breaker (SSIB) • Maintenance bypass breaker (MBB) • Unit output breaker (UOB) Maintenance Bypass Cabinet 990-5451K-001 11 Technical Data 480 V UPS System Model List UPSs with 1250 kW I/O Cabinet • Galaxy VX 500 kW, 480 V, start-up 5x8 (GVX500K500NGS) • Galaxy VX 500 kW scalable to 750 kW 480 V, start-up 5x8 (GVX500K750NGS) • Galaxy VX 500 kW scalable to 1000 kW 480 V, start-up 5x8 (GVX500K1000NGS) • Galaxy VX 500 kW scalable to 1250 kW 480 V, start-up 5x8 (GVX500K1250NGS) • Galaxy VX 625 kW, 480 V, start-up 5x8 (GVX625K625NGS) • Galaxy VX 625 kW scalable to 1000 kW 480 V, start-up 5x8 (GVX625K1000NGS) • Galaxy VX 500 kW N+1 redundant UPS 480 V, start-up 5x8 (GVX750K500NGS) • Galaxy VX 750 kW, 480 V, start-up 5x8 (GVX750K750NGS) • Galaxy VX 750 kW scalable to 1000 kW 480 V, start-up 5x8 (GVX750K1000NGS) • Galaxy VX 750 kW scalable to 1250 kW 480 V, start-up 5x8 (GVX750K1250NGS) • Galaxy VX 800 kW, 480 V, start-up 5x8 (GVX800K800NGS) • Galaxy VX 750 kW N+1 redundant UPS 480 V, start-up 5x8 (GVX1000K750NGS) • Galaxy VX 1000 kW, 480 V, start-up 5x8 (GVX1000K1000NGS) • Galaxy VX 1000 kW scalable to 1250 kW 480 V, start-up 5x8 (GVX1000K1250NGS) • Galaxy VX 1100 kW, 480 V, Start-up 5x8 (GVX1100K1100NGS) • Galaxy VX 1000 kW N+1 redundant UPS 480 V, start-up 5x8 (GVX1250K1000NGS) • Galaxy VX 1250 kW, 480 V, start-up 5x8 (GVX1250K1250NGS) • Galaxy VX 1100 kW N+1 Redundant UPS 480 V, Start up 5x8 (GVX1500K1100NGS) • Galaxy VX 1250 kW N+1 Redundant UPS 480 V, start-up 5x8 (GVX1500K1250NGS) • Galaxy VX 1250 kW I/O Cabinet without Backfeed protection on Mains 2 (GVXI1250KDNBF2)2. Requires ordering the 250 kW power cabinets separately. 12 990-5451K-001 480 V UPS System Technical Data 2. Backfeed protection can be installed internally in the 1250 kW I/O cabinet with the optional backfeed kit (GVXOPT001) (ordered separately), or installed externally upstream of the UPS in the switchgear. UPSs with 1500 kW I/O Cabinet • Galaxy VX 500 kW 480 V scalable to 1500 kW, start-up 5x8 (GVX500K1500GS) • Galaxy VX 750 kW 480 V scalable to 1500 kW, start-up 5x8

(GVX750K1500GS) • Galaxy VX 1000 kW scalable to 1500 kW 480 V, start-up 5x8 (GVX1000K1500GS) • Galaxy VX 1250 kW scalable to 1500 kW 480 V, start-up 5x8 (GVX1250K1500GS) • Galaxy VX 1500 kW 480 V, start-up 5x8 (GVX1500K1500GS) • Galaxy VX 1500 kW N+1 Redundant UPS 480 V, start-up 5x8 (GVX1750K1500GS) 990-5451K-001 13 Technical Data 480 V UPS System Overview of Configurations Breakers in the System UIB Unit input breaker SSIB Static switch input breaker BB Battery breaker MBB Maintenance bypass breaker UOB Unit output breaker BF2 Backfeed protection switch Overview of UPSs with 1250 kW I/O Cabinet - Single Utility/Mains NOTE: Depending on your chosen configuration, the backfeed breaker BF2 (marked with * in the illustration) can be preinstalled in the UPS, delivered as an optional backfeed kit GVXOPT001 to be installed in the UPS, or installed upstream of the UPS in the switchgear. The illustration shows a 750 kW UPS. The principle is the same for the other UPSs with the 1250 kW I/O cabinet. 14 990-5451K-001 480 V UPS System Technical Data Overview of UPSs with 1250 kW I/O Cabinet - Dual Utility/Mains NOTE: Depending on your chosen configuration, the backfeed breaker BF2 (marked with * in the illustration) can be preinstalled in the UPS, delivered as an optional backfeed kit GVXOPT001 to be installed in the UPS, or installed upstream of the UPS in the switchgear. The illustration shows a 750 kW UPS. The principle is the same for the other UPSs with the 1250 kW I/O cabinet. Overview of UPSs with 1500 kW I/O Cabinet – Single Utility/Mains The illustration shows a 1500 kW UPS. The principle is the same for the other UPSs with the 1500 kW I/O cabinet. Galaxy VX 1500 kW UPS 990-5451K-001 15 Technical Data 480 V UPS System Overview of UPSs with 1500 kW I/O Cabinet – Dual Utility/Mains The illustration shows a 1500 kW UPS. The principle is the same for the other UPSs with the 1500 kW I/O cabinet. Galaxy VX 1500 kW UPS Parallel System Galaxy VX can support up to 4+0 UPSs in parallel for capacity and up to 4+1 UPSs in parallel for redundancy. NOTE: Note that for systems over 4 MW it can be difficult to find appropriate breakers/switches in the correct size for the switchgear. 16 990-5451K-001 480 V UPS System Technical Data Input Power Factor 500 kW 625 kW 750 kW 800 kW 1000 kW 1100 kW 1250 kW 1500 kW 25% load 0.98 0.98 0.98 0.98 0.98 0.98 0.98 0.98 50% load 0.99 0.99 0.99 0.99 0.99 0.99 0.99 0.99 0.99 0.99 75% load 0.99 0.99 0.99 0.99 0.99 0.99 0.99 0.99 100% load 0.99 0.99 0.99 0.99 0.99 0.99 0.99 0.99 Input Voltage Window 990-5451K-001 17 Technical Data 480 V UPS System Inverter Short–Circuit Capabilities (Bypass not Available) IK1 – Short-Circuit between a Phase and Neutral 480 V IK1 S [kVA] Ik10ms [A] Normal operation /Battery operation Ik30ms [A] Normal operation /Battery operation Ik100ms [A] Normal operation /Battery operation Ik500ms [A] Normal operation /Battery operation Ik1s [A] Normal operation /Battery operation Ik5s [A] Normal operation /Battery operation I2 t total [A2s] Normal operation /Battery operation 250 – /810 – /810 – /570 – /290 – /290 – /290 – /493600 500 – /1620 – /1620 – /1140 – /580 – /580 – /580 – /1974400 750 – /2430 – /2430 – /1710 – /870 – /870 – /870 – /4442400 1000 – /3240 – /3240 – /2280 – /1160 – /1160 – /1160 – /7897600 1250 – /4050 – /4050 – /2850 – /1450 – /1450 – /1450 – /12340000 1500 – /4860 – /4860 – /3420 – /1740 – /1740 – /1740 – /17769600 18 990-5451K-001 480 V UPS System Technical Data IK2 – Short-Circuit between Two Phases 480 V IK2 S [kVA] Ik10ms [A] Normal operation /Battery operation Ik30ms [A] Normal operation /Battery operation Ik100ms [A] Normal operation /Battery operation Ik500ms [A] Normal operation /Battery operation Ik1s [A] Normal operation /Battery operation Ik5s [A] Normal operation /Battery operation I2 t total [A2s] Normal operation /Battery operation 250 790 /790 770 /770 550 /550 430 /280 430 /280 280 /280 606450 /460820 500 1580 /1580 1540 /1540 1100 /1100 860 /560 860 /560 560 /560 2425800 /1843280 750 2370 /2370 2310 /2310 1650 /1650 1290 /840 1290 /840 840 /840 5458050 /4147380 1000 3160 /3160 3080 /3080 2200 /2200 1720 /1120 1720 /1120 1120 /1120 9703200 /7373120 1250 3950 /3950 3850 /3850 2750 /2750 2150 /1400 2150 /1400 1400 /1400 15161250 /11520500 1500 4740 /4740 4620 /4620 3300 /3300 2580 /1680 2580 /1680 1680 /1680 21832200 /16589520 990-5451K-001 19 Technical Data 480 V UPS System IK3 – Short-Circuit between All Three Phases 480 V IK3 S [kVA] Ik10ms [A] Normal operation /Battery operation Ik30ms [A] Normal operation /Battery operation Ik100ms [A] Normal operation /Battery operation Ik500ms [A] Normal operation /Battery operation Ik1s [A] Normal operation /Battery operation Ik5s [A] Normal operation /Battery operation I2 t total [A2s] Normal operation /Battery operation 250 670 /660 670 /660 610 /610 440 /440 360 /440 300 /300 580600 /589380 500 1340 /1320 1340 /1320 1220 /1220 880 /880 720 /880 600 /600 2322400 /2357520 650 1742 /1716 1742 /1716 1586 /1586 1144 /1144 936 /1144 780 /780 3924856 /3984209 1000 2680 /2640 2680 /2640 2440 /2440 1760 /1760 1440 /1760 1200 /1200 9289600 /9430080 1250 3350 /3300 3350 /3300 3050 /3050 2200 /2200 1800 /2200 1500 /1500 14515000 /14734500 1500 4020 /3960 4020 /3960 3660 /3660 2640 /2640 2160 /2640 1800 /1800 20901600 /21217680 20 990-5451K-001 480 V UPS System Technical Data Efficiency for UPSs with 1250 kW I/O Cabinet Efficiency for a 500 kW UPS Normal operation ECO mode eConversion Battery operation Voltage (V) 480 480 480 480 25% load 94.9% 97.3% 96.9% 96.6% 50% load 95.9% 98.4% 98.2% 96.7% 75% load

96.0% 98.8% 98.7% 96.3% 100% load 95.9% 99.0% 98.9% 95.9% Efficiency for a 625 kW UPS Normal operation ECO mode eConversion Battery operation Voltage (V) 480 480 480 480 25% load 95.0% 97.5% 97.1% 95.8% 50% load 96.2% 98.6% 98.4% 96.2% 75% load 96.3% 98.8% 98.7% 96.3% 100% load 96.2% 99.0% 98.9% 96.2% Efficiency for a 750 kW UPS Normal operation ECO mode eConversion Battery operation Voltage (V) 480 480 480 480 25% load 95.4% 97.9% 97.7% 96.5% 50% load 96.1% 98.6% 98.5% 96.6% 75% load 96.0% 98.8% 98.7% 96.2% 100% load 95.8% 98.9% 98.9% 95.8% Efficiency for an 800 kW UPS Normal operation ECO mode eConversion Battery operation Voltage (V) 480 480 480 480 25% load 95.2% 98.7% 97.4% 96.9% 50% load 96.2% 98.9% 98.5% 96.6% 75% load 96.1% 98.9% 98.8% 96.8% 100% load 96.3% 99.0% 99.1% 96.3% 990-5451K-001 21 Technical Data 480 V UPS System Efficiency for a 1000 kW UPS Normal operation ECO mode eConversion Battery operation Voltage (V) 480 480 480 480 25% load 95.6% 98.1% 97.9% 96.6% 50% load 96.3% 98.8% 98.7% 96.7% 75% load 96.2% 99.0% 98.9% 96.3% 100% load 96.0% 99.1% 99.1% 95.9% Efficiency for a 1100 kW UPS Normal operation ECO mode eConversion Battery operation Voltage (V) 480 480 480 480 25% load 95.8% 98.3% 97.8% 96.3% 50% load 96.4% 98.9% 98.7% 96.5% 75% load 96.3% 99.0% 98.9% 96.4% 100% load 96.1% 99.1% 99.0% 96.1% Efficiency for a 1250 kW UPS Normal operation ECO mode eConversion Battery operation Voltage (V) 480 480 480 480 25% load 95.8% 98.3% 97.9% 96.6% 50% load 96.4% 98.9% 98.7% 96.6% 75% load 96.2% 99.1% 99.0% 96.3% 100% load 96.0% 99.1% 99.1% 96.1% 22 990-5451K-001 480 V UPS System Technical Data Efficiency for UPSs with 1500 kW I/O Cabinet Efficiency for a 500 kW UPS Normal operation ECO mode eConversion Battery operation Voltage (V) 480 480 480 480 25% load 95.8% 98.5% 98.2% 95.9% 50% load 96.4% 99.1% 99.1% 96.4% 75% load 96.2% 99.2% 99.2% 96.0% 100% load 96.1% 99.2% 99.2% 95.6% Efficiency for a 750 kW UPS Normal operation ECO mode eConversion Battery operation Voltage (V) 480 480 480 480 25% load 95.9% 98.5% 98.2% 95.9% 50% load 96.5% 99.1% 99.0% 96.4% 75% load 96.3% 99.2% 99.2% 96.0% 100% load 96.0% 99.2% 99.2% 95.6% Efficiency for a 1000 kW UPS Normal operation ECO mode eConversion Battery operation Voltage (V) 480 480 480 480 25% load 95.9% 98.6% 98.2% 95.9% 50% load 96.5% 99.1% 99.0% 96.4% 75% load 96.4% 99.2% 99.2% 96.0% 100% load 95.9% 99.2% 99.2% 95.6% Efficiency for a 1250 kW UPS Normal operation ECO mode eConversion Battery operation Voltage (V) 480 480 480 480 25% load 96.0% 98.7% 98.3% 95.9% 50% load 96.6% 99.2% 99.1% 96.4% 75% load 96.4% 99.3% 99.3% 96.0% 100% load 96.0% 99.3% 99.3% 95.6% 990-5451K-001 23 Technical Data 480 V UPS System Efficiency for a 1500 kW UPS Normal operation ECO mode eConversion Battery operation Voltage (V) 480 480 480 480 25% load 96.0% 98.7% 98.3% 95.9% 50% load 96.5% 99.1% 99.1% 96.4% 75% load 96.3% 99.3% 99.3% 96.1% 100% load 96.0% 99.3% 99.3% 95.7% 24 990-5451K-001 480 V UPS System Technical Data Derating Due to Load Power Factor 0.7 leading to 0.5 lagging without derating. 990-5451K-001 25 Technical Data 480 V UPS System Batteries (VRLA) End of Discharge Voltage The voltage is 1.6 to 1.75 per cell depending on discharge ratio. Battery Voltage Range (VRLA) 26 990-5451K-001 480 V UPS System Technical Data Compliance Safety UL 1778 5th edition EMC/EMI/RFI IEC 62040-2: 2016, 3rd edition Uninterruptible Power Systems (UPS) - Part 2: Electromagnetic compatibility (EMC) requirements C2 FCC 15B, class A Performance IEC 62040-3: 2011-03, 2nd edition Uninterruptible Power Systems (UPS) - Part 3: Method of specifying the performance and test requirements Environmental IEC 62040-4: 2013-04, 1st edition Uninterruptible Power Systems (UPS) - Part 4: Environmental aspects – Requirements and reporting Markings UL1778 Listing and CSA C22.2 NO.107.3 Transportation ISTA 2B IEC 60721-4-2 Level 2M2 Seismic OSHPD, IBC2012 and CBC2013 to SDS = 1.83 g Overvoltage category III Earthing system TN, TT, IT Protective class I Pollution degree 2 990-5451K-001 27 Technical Data 480 V UPS System Communication and Management Local Area Network 100 Mbps Extensions Two optional Network Management Cards MODBUS MODBUS TCP/IP Relay outputs 6 configurable Dry contact inputs 5 configurable Standard control panel 7" touch-screen display Audible alarm Yes Emergency Power Off (EPO) Options: • Normally Open (NO) • Normally Closed (NC) • External 24 VDC SELV External switchgear Option containing: • Unit Input Breaker (UIB) • Unit Output Breaker (UOB) • Static Switch Input Breaker (SSIB) • Maintenance Bypass Breaker (MBB) • System Isolation Breaker (SIB) External synchronization Yes Battery monitoring Yes — string level breaker monitoring EPO Connections 28 990-5451K-001 480 V UPS System Technical Data Overview of Input Contacts and Output Relays Input Contacts Do not connect any circuit to the input contacts unless it can be confirmed that the circuit is Class 2/SELV. All circuits connected must have the same 0 V reference. The input contacts support 24 VDC 10 mA. The switch SW5500 on 0P6548 is used to select between internal SELV supply for inputs (standard setting) and external supply3. If external supply is selected, the supply must be connected to J5530. Name Description Location IN 1 (Contact 1) Configurable input contact 0P6548 terminal J55024 IN 2 (Contact 2) Configurable input contact

0P6548 terminal J55034 IN 3 (Contact 3) Configurable input contact 0P6548 terminal J55044 IN 4 (Contact 4) Configurable input contact 0P6548 terminal J55054 IN 5 (Contact 5) Configurable input contact 0P6548 terminal J55104 IN 6 UOB redundant AUX contact 0P6548 terminal J55094 IN 7 Transformer temperature switch 0P6548 terminal J55084 IN 8 External bonding contact 0P6548 terminal J55074 IN 9 Forced external synchronization input 0P6548 terminal J55064 IN 10 External synchronization requested 0P6548 terminal J55114 IN 11 Use static bypass standby 0P6548 terminal J55124 IN 14 MegaTie 0P6552 terminal J90274 Output Relays NOTE: Maximum 250 VAC 5 A must be connected to the output relays. All external circuitry must be fused with maximum 5 A fast acting fuses. 990-5451K-001 29 Technical Data 480 V UPS System 3. An external supply is useful in parallel systems where inputs are connected between different UPSs. This is to have a common reference and to avoid cross currents. 4. Class 2/SELV wiring Name Description Location OUT 1 (Relay 1) Configurable output relay 0P6547 terminal J4939 OUT 2 (Relay 2) Configurable output relay 0P6547 terminal J4940 OUT 3 (Relay 3) Configurable output relay 0P6547 terminal J4941 OUT 4 Forced external synchronization output 0P6548 terminal J55205 OUT 5 MegaTie 0P6548 terminal J55215 OUT 6 External synchronization requested output 0P6548 terminal J55225 OUT 7 UPS in inverter ON 0P6548 terminal J55235 OUT 8 (Relay 4) Configurable output relay 0P6548 terminal J55245 OUT 9 (Relay 5) Configurable output relay 0P6548 terminal J55255 OUT 10 (Relay 6) Configurable output relay 0P6548 terminal J55285 OUT 14 Bonding contactor 0P6552 terminal J90295 NOTE: Refer to the operation manual for configuration options. 30 990-5451K-001 480 V UPS System Technical Data 5. Class 2/SELV wiring Facility Planning Specifications for 500 kW UPS Voltage (V) 380 400 415 440 480 Input Connections IEC: L1, L2, L3, PE 6 UL: L1, L2, L3 + G 7 Input voltage range (V)8 340-456 340-480 353-498 374-528 408-576 Frequency (Hz) 40-70 Nominal input current (A) 816 775 746 699 646 Maximum input current (A)9 921 885 852 798 757 Input current limitation (A) 890 832 760 Minimum short circuit rating Dependent on upstream protection. See section for 'Recommended upstream protection and cable sizes – IEC' for details. Maximum short circuit rating 100 kA RMS Total harmonic distortion (THDI) <3% at 100% load, <4% at 50% load, 40% load, 0.98 at >20% load, 0.97 at >10% load Protection Contactors Ramp-in Adaptive 1-300 seconds Bypass Connections IEC 1250 kW I/O and 1500 kW I/O: L1, L2, L3, N, PE or L1, L2, L3, PE 10 UL 1250 kW I/O: L1, L2, L3, G or L1, L2, L3, N, G UL 1500 kW I/O11: L1, L2, L3, G Bypass voltage range (V) 342-418 360-440 374-457 396-484 432-528 Frequency (Hz) 50 or 60 Frequency range (Hz) Programmable: ±0.1, ±3, ±10. Default is ±3 Nominal bypass current (A) 813 773 745 703 642 Minimum short circuit rating Dependent on upstream protection. See section for 'Recommended upstream protection and cable sizes – IEC' for details. Maximum short circuit rating 1250 kW I/O: 100 kA Icw 1500 kW I/O: 100 kA RMS (conditioned by an internal molded switch with 90 kA peak magnetic trip) Thyristor I^2t (kA^*s^2) 1250 kW I/O: 9680 1500 kW I/O: 16245 1250 kW I/O: 9165 1500 kW I/O: 16245 BF2 magnetic trip 1250 kW I/O: 39 kA 1500 kW I/O: 39 kA Protection 1250 kW I/O with preinstalled backfeed breaker BF2: Molded switch with trip for backfeed protection 1250 kW I/O with GVXOPT001 installed: Molded switch with trip for backfeed protection 1500 kW I/O with preinstalled backfeed breaker BF2: Molded switch with trip for backfeed protection 990-5451K-001 31 Facility Planning 480 V UPS System 6. TN, TT, and IT power distribution systems are supported. 7. WYE source – solid grounded and high resistance grounded sources are supported. Corner (line) grounding is not permitted. 8. The system can operate at 600 V for 1 minute. 9. At nominal input voltage and full charge. 10. TN, TT, and IT power distribution systems with no earthed line conductors are supported. 11. 4-wire connection with neutral is not compliant per FCC regulations for the 1500 kW I/O cabinet. Voltage (V) 380 400 415 440 480 Output Connections IEC 1250 kW I/O and 1500 kW I/O: L1, L2, L3, N, PE or L1, L2, L3, PE UL 1250 kw I/O: L1, L2, L3, G, GEC12 or L1, L2, L3, N, G UL 1500 kW I/O13: L1, L2, L3, G, GEC12 Overload capacity Normal operation: 150% for 1 minute, 125% for 10 minutes Battery operation: 128% for 10 seconds, 115% for 1 minute Bypass operation: 110%14 continuous, 1000% for 60 milliseconds for systems with 1250 kW I/O cabinet, and 1000% for 100 milliseconds for systems with 1500 kW I/O cabinet Output voltage tolerance Balanced load: ±1%, Unbalanced load: ±3% Dynamic load response ±5% after 2 ms, ±1% after 50 ms Output power factor 1 Nominal output current (A) 760 722 696 656 601 Minimum short circuit rating15 Dependent on upstream protection. See section for 'Recommended upstream protection and cable sizes – IEC' for details. Maximum short circuit rating16 100 kA RMS Inverter output short circuit capabilities Varies with time. See graph and table values in Inverter Short–Circuit Capabilities (Bypass not Available), page 18. Total harmonic distortion (THDU) <2% at 100% linear load, <3% at 100% non-linear load Output frequency (Hz) 50/60 (synchronized to bypass), 50/60 Hz ±0.1% (free-running) Slew rate (Hz/sec) Programmable: 0.25, 0.5, 1, 2, 4, 6 Output performance classification (according to IEC/ EN62040-3) Double-conversion: VFI-SS-111 Load crest factor Up to 3 (THDU < 5%) Load power factor 0.7 leading to 0.5 lagging without derating Battery (VRLA) Charging power in % of output power 35% at ≤ 80% load, 12% at 100% load 40% at ≤ 80% load, 15% at 100% load Maximum charging power (kW) 60 at 100% load, 175 at <80% load 75 at 100% load, 200 at 80% load Nominal battery voltage (VDC) 480 Nominal float voltage (VDC) 546 End of discharge voltage (full load) (VDC) 384 End of discharge voltage (no load) (VDC) 420 Battery current at full load and nominal battery voltage (A) 1090 Battery current at full load and minimum battery voltage (A) 1362 Maximum short circuit rating 50 kA Maximum battery backup time Unlimited Temperature compensation (per cell) -3.3 mV per °C for T ≥ 25 °C, 0 mV per °C for T < 25 °C Ripple current < 5% C20 (5-minute backup time) Battery test Manual/automatic (selectable) Deep discharge protection Yes Recharge according to battery temperature Yes 32 990-5451K-001 480 V UPS System Facility Planning 12. Per NEC 250.30. 13. 4-wire connection with neutral is not compliant per FCC regulations for the 1500 kW I/O cabinet. 14. 125% for 480 V. 15. Minimum short circuit rating for output takes backfeeding energy through the bypass of parallel UPSs into consideration. 16. Maximum short circuit rating for output takes backfeeding energy through the bypass of parallel UPSs into consideration. Specifications for 625 kW UPS Voltage (V) 380 400 415 440 480 Input Connections IEC: L1, L2, L3, PE 17 UL: L1, L2, L3 + G 18 Input voltage range (V)19 340-456 340-480 353-498 374-528 408-576 Frequency (Hz) 40-70 Nominal input current (A) 1021 969 932 870 807 Maximum input current (A)20 1151 1106 1065 994 946 Input current limitation (A) 1113 1040 950 Minimum short circuit rating Dependent on upstream protection. See section for ‘Recommended upstream protection and cable sizes – IEC’ for details. Maximum short circuit rating 100 kA RMS Total harmonic distortion (THDI) <3% at 100% load, <4% at 50% load, 40% load, 0.98 at >20% load, 0.97 at >10% load Protection Contactors Ramp-in Adaptive 1-300 seconds Bypass Connections IEC 1250 kW I/O and 1500 kW I/O: L1, L2, L3, N, PE or L1, L2, L3, PE 21 UL 1250 kW I/O: L1, L2, L3, G or L1, L2, L3, N, G UL 1500 kW I/O22: L1, L2, L3, G Bypass voltage range (V) 342-418 360-440 374-457 396-484 432-528 Frequency (Hz) 50 or 60 Frequency range (Hz) Programmable: ±0.1, ±3, ±10. Default is ±3 Nominal bypass current (A) 1017 966 931 878 802 Minimum short circuit rating Dependent on upstream protection. See section for ‘Recommended upstream protection and cable sizes – IEC’ for details. Maximum short circuit rating 1250 kW I/O: 100 kA Icw 1500 kW I/O: 100 kA RMS (conditioned by an internal molded switch with 90 kA peak magnetic trip) Thyristor I²t (kA*s²) 9680 (1250 kW I/O) 9165 (1250 kW I/O) BF2 magnetic trip 1250 kW I/O: 39 kA 1500 kW I/O: 39 kA Protection 1250 kW I/O with preinstalled backfeed breaker BF2: Molded switch with trip for backfeed protection 1250 kW I/O with GVXOPT001 installed: Molded switch with trip for backfeed protection 1500 kW I/O with preinstalled backfeed breaker BF2: Molded switch with trip for backfeed protection 990-5451K-001 33 Facility Planning 480 V UPS System 17. TN, TT, and IT power distribution systems are supported. 18. WYE source – solid grounded and high resistance grounded sources are supported. Corner (line) grounding is not permitted. 19. The system can operate at 600 V for 1 minute. 20. At nominal input voltage and full charge. 21. TN, TT, and IT power distribution systems with no earthed line conductors are supported. 22. 4-wire connection with neutral is not compliant per FCC regulations for the 1500 kW I/O cabinet. Voltage (V) 380 400 415 440 480 Output Connections IEC 1250 kW I/O and 1500 kW I/O: L1, L2, L3, N, PE or L1, L2, L3, PE UL 1250 kw I/O: L1, L2, L3, G, GEC23 or L1, L2, L3, N, G UL 1500 kW I/O24: L1, L2, L3, G, GEC23 Overload capacity Normal operation: 150% for 1 minute, 125% for 10 minutes Battery operation: 128% for 10 seconds, 115% for 1 minute Bypass operation: 110%25 continuous, 1000% for 60 milliseconds for systems with 1250 kW I/O cabinet, and 1000% for 100 milliseconds for systems with 1500 kW I/O cabinet Output voltage tolerance Balanced load: ±1%, Unbalanced load: ±3% Dynamic load response ±5% after 2 ms, ±1% after 50 ms Output power factor 1 Nominal output current (A) 950 902 870 820 752 Minimum short circuit rating26 Dependent on upstream protection. See section for ‘Recommended upstream protection and cable sizes – IEC’ for details. Maximum short circuit rating27 100 kA RMS Inverter output short circuit capabilities Varies with time. See graph and table values in Inverter Short–Circuit Capabilities (Bypass not Available), page 18. Total harmonic distortion (THDU) <2% at 100% linear load, <3% at 100% non-linear load Output frequency (Hz) 50/60 (synchronized to bypass), 50/60 Hz ±0.1% (free-running) Slew rate (Hz/sec) Programmable: 0.25, 0.5, 1, 2, 4, 6 Output performance classification (according to IEC/ EN62040-3) Double-conversion: VFI-SS-111 Load crest factor Up to 3 (THDU < 5%) Load power factor 0.7 leading to 0.5 lagging without derating Battery (VRLA) Charging power in % of output power 35% at ≤ 80% load, 12% at 100% load 40% at ≤ 80% load, 15% at 100% load Maximum charging power (kW) 75 at 100% load, 218.75 at <80% load 93.75 at 100% load, 250 at 80% load Nominal battery voltage (VDC) 480 Nominal float voltage (VDC) 546 End of discharge voltage (full load) (VDC) 384 End of discharge voltage (no load) (VDC) 420 Battery current at full load and nominal battery voltage (A) 1362 Battery current at full load and minimum battery voltage (A) 1703 Maximum short circuit rating 50 kA Maximum battery backup time Unlimited Temperature compensation (per cell) -3.3 mV per °C for T ≥ 25 °C, 0 mV per °C for T < 25 °C Ripple current < 5% C20 (5-minute backup time) Battery test Manual/automatic (selectable) Deep discharge protection Yes Recharge according to battery temperature Yes 34 990-5451K-001 480 V UPS System Facility Planning 23. Per NEC 250.30. 24. 4-wire connection with neutral is not compliant per FCC regulations for the 1500 kW I/O cabinet. 25. 125% for 480 V. 26. Minimum short circuit rating for output takes backfeeding energy through the bypass of parallel UPSs into consideration. 27. Maximum short circuit rating for output takes backfeeding energy through the bypass of parallel UPSs into consideration. Specifications for 750 kW UPS Voltage (V) 380 400 415 440 480 Input Connections IEC: L1, L2, L3, PE 28 UL: L1, L2, L3 + G 29 Input voltage range (V)30 340-456 340-480 353-498 374-528 408-576 Frequency (Hz) 40-70 Nominal input current (A) 1225 1162 1119 1050 969 Maximum input current (A)31 1381 1327 1278 1199 1136 Input current limitation (A) 1335 1248 1140 Minimum short circuit rating Dependent on upstream protection. See section for 'Recommended upstream protection and cable sizes – IEC' for details. Maximum short circuit rating 100 kA RMS Total harmonic distortion (THDI) <3% at 100% load, <4% at 50% load, 40% load, 0.98 at >20% load, 0.97 at >10% load Protection Contactors Ramp-in Adaptive 1-300 seconds Bypass Connections IEC 1250 kW I/O and 1500 kW I/O: L1, L2, L3, N, PE or L1, L2, L3, PE 32 UL 1250 kW I/O: L1, L2, L3, G or L1, L2, L3, N, G UL 1500 kW I/O33: L1, L2, L3, G Bypass voltage range (V) 342-418 360-440 374-457 396-484 432-528 Frequency (Hz) 50 or 60 Frequency range (Hz) Programmable: ±0.1, ±3, ±10. Default is ±3 Nominal bypass current (A) 1220 1159 1117 1054 964 Minimum short circuit rating Dependent on upstream protection. See section for 'Recommended upstream protection and cable sizes – IEC' for details. Maximum short circuit rating 1250 kW I/O: 100 kA Icw 1500 kW I/O: 100 kA RMS (conditioned by an internal molded switch with 90 kA peak magnetic trip) Thyristor I^2t (kA^*s^2) 1250 kW I/O: 9680 1500 kW I/O: 16245 1250 kW I/O: 9165 1500 kW I/O: 16245 BF2 magnetic trip 1250 kW I/O: 39 kA 1500 kW I/O: 39 kA Protection 1250 kW I/O with preinstalled backfeed breaker BF2: Molded switch with trip for backfeed protection 1250 kW I/O with GVXOPT001 installed: Molded switch with trip for backfeed protection 1500 kW I/O with preinstalled backfeed breaker BF2: Molded switch with trip for backfeed protection 990-5451K-001 35 Facility Planning 480 V UPS System 28. TN, TT, and IT power distribution systems are supported. 29. WYE source – solid grounded and high resistance grounded sources are supported. Corner (line) grounding is not permitted. 30. The system can operate at 600 V for 1 minute. 31. At nominal input voltage and full charge. 32. TN, TT, and IT power distribution systems with no earthed line conductors are supported. 33. 4-wire connection with neutral is not compliant per FCC regulations for the 1500 kW I/O cabinet. Voltage (V) 380 400 415 440 480 Output Connections IEC 1250 kW I/O and 1500 kW I/O: L1, L2, L3, N, PE or L1, L2, L3, PE UL 1250 kw I/O: L1, L2, L3, G, GEC34 or L1, L2, L3, N, G UL 1500 kW I/O35: L1, L2, L3, G, GEC34 Overload capacity Normal operation: 150% for 1 minute, 125% for 10 minutes Battery operation: 128% for 10 seconds, 115% for 1 minute Bypass operation: 110%36 continuous, 1000% for 60 milliseconds for systems with 1250 kW I/O cabinet, and 1000% for 100 milliseconds for systems with 1500 kW I/O cabinet Output voltage tolerance Balanced load: ±1%, Unbalanced load: ±3% Dynamic load response ±5% after 2 ms, ±1% after 50 ms Output power factor 1 Nominal output current (A) 1140 1083 1043 984 902 Minimum short circuit rating37 Dependent on upstream protection. See section for 'Recommended upstream protection and cable sizes – IEC' for details. Maximum short circuit rating38 100 kA RMS Inverter output short circuit capabilities Varies with time. See graph and table values in Inverter Short–Circuit Capabilities (Bypass not Available), page 18. Total harmonic distortion (THDU) <2% at 100% linear load, <3% at 100% non-linear load Output frequency (Hz) 50/60 (synchronized to bypass), 50/60 Hz ±0.1% (free-running) Slew rate (Hz/sec) Programmable: 0.25, 0.5, 1, 2, 4, 6 Output performance classification (according to IEC/ EN62040-3) Double-conversion: VFI-SS-111 Load crest factor Up to 3 (THDU < 5%) Load power factor 0.7 leading to 0.5 lagging without derating Battery (VRLA) Charging power in % of output power 35% at ≤ 80% load, 12% at 100% load 40% at ≤ 80% load, 15% at 100% load Maximum charging power (kW) 90 at 100% load, 262 at <80% load 112.5 at 100% load, 300 at 80% load Nominal battery voltage (VDC) 480 Nominal float voltage (VDC) 546 End of discharge voltage (full load) (VDC) 384 End of discharge voltage (no load) (VDC) 420 Battery current at full load and nominal battery voltage (A) 1634 Battery current at full load and minimum battery voltage (A) 2043 Maximum short circuit rating 50 kA Maximum battery backup time Unlimited Temperature compensation (per cell) -3.3 mV per °C for T ≥ 25 °C, 0 mV per °C for T < 25 °C Ripple current < 5% C20 (5-minute backup time) Battery test Manual/automatic (selectable) Deep discharge protection Yes Recharge according to battery temperature Yes 36 990-5451K-001 480 V UPS System Facility Planning 34. Per NEC 250.30. 35. 4-wire connection with neutral is not compliant per FCC regulations for the 1500 kW I/O cabinet. 36. 125% for 480 V. 37. Minimum short circuit rating for output takes backfeeding energy through the bypass of parallel UPSs into consideration. 38. Maximum short circuit rating for output takes backfeeding energy through the bypass of parallel UPSs into consideration. Specifications for 800 kW UPS Voltage (V) 380 400 415 440 480 Input Connections IEC: L1, L2, L3, PE 39 UL: L1, L2, L3 + G 40 Input voltage range (V)41 340-456 340-480 353-498 374-528 408-576 Frequency (Hz) 40-70 Nominal input current (A) 1307 1239 1193 1120 1033 Maximum input current (A)42 1474 1415 1363 1279 1212 Input current limitation (A) 1424 1331 1216 Minimum short circuit rating Dependent on upstream protection. See section for ‘Recommended upstream protection and cable sizes – IEC’ for details. Maximum short circuit rating 100 kA RMS Total harmonic distortion (THDI) <3% at 100% load, <4% at 50% load, 40% load, 0.98 at >20% load, 0.97 at >10% load Protection Contactors Ramp-in Adaptive 1-300 seconds Bypass Connections IEC 1250 kW I/O and 1500 kW I/O: L1, L2, L3, N, PE or L1, L2, L3, PE 43 UL 1250 kW I/O: L1, L2, L3, G or L1, L2, L3, N, G UL 1500 kW I/O44: L1, L2, L3, G Bypass voltage range (V) 342-418 360-440 374-457 396-484 432-528 Frequency (Hz) 50 or 60 Frequency range (Hz) Programmable: ±0.1, ±3, ±10. Default is ±3 Nominal bypass current (A) 1302 1236 1191 1124 1027 Minimum short circuit rating Dependent on upstream protection. See section for ‘Recommended upstream protection and cable sizes – IEC’ for details. Maximum short circuit rating 1250 kW I/O: 100 kA Icw 1500 kW I/O: 100 kA RMS (conditioned by an internal molded switch with 90 kA peak magnetic trip) Thyristor I^2t (kA^*s^2) 9680 (1250 kW I/O) 9165 (1250 kW I/O) BF2 magnetic trip 1250 kW I/O: 39 kA 1500 kW I/O: 39 kA Protection 1250 kW I/O with preinstalled backfeed breaker BF2: Molded switch with trip for backfeed protection 1250 kW I/O with GVXOPT001 installed: Molded switch with trip for backfeed protection 1500 kW I/O with preinstalled backfeed breaker BF2: Molded switch with trip for backfeed protection 990-5451K-001 37 Facility Planning 480 V UPS System 39. TN, TT, and IT power distribution systems are supported. 40. WYE source – solid grounded and high resistance grounded sources are supported. Corner (line) grounding is not permitted. 41. The system can operate at 600 V for 1 minute. 42. At nominal input voltage and full charge. 43. TN, TT, and IT power distribution systems with no earthed line conductors are supported. 44. 4-wire connection with neutral is not compliant per FCC regulations for the 1500 kW I/O cabinet. Voltage (V) 380 400 415 440 480 Output Connections IEC 1250 kW I/O and 1500 kW I/O: L1, L2, L3, N, PE or L1, L2, L3, PE UL 1250 kw I/O: L1, L2, L3, G, GEC45 or L1, L2, L3, N, G UL 1500 kW I/O46: L1, L2, L3, G, GEC45 Overload capacity Normal operation: 150% for 1 minute, 125% for 10 minutes Battery operation: 128% for 10 seconds, 115% for 1 minute Bypass operation: 110%47 continuous, 1000% for 60 milliseconds for systems with 1250 kW I/O cabinet, and 1000% for 100 milliseconds for systems with 1500 kW I/O cabinet Output voltage tolerance Balanced load: ±1%, Unbalanced load: ±3% Dynamic load response ±5% after 2 ms, ±1% after 50 ms Output power factor 1 Nominal output current (A) 1216 1155 1113 1050 962 Minimum short circuit rating48 Dependent on upstream protection. See section for ‘Recommended upstream protection and cable sizes – IEC’ for details. Maximum short circuit rating49 100 kA RMS Inverter output short circuit capabilities Varies with time. See graph and table values in Inverter Short–Circuit Capabilities (Bypass not Available), page 18. Total harmonic distortion (THDU) <2% at 100% linear load, <3% at 100% non-linear load Output frequency (Hz) 50/60 (synchronized to bypass), 50/60 Hz ±0.1% (free-running) Slew rate (Hz/sec) Programmable: 0.25, 0.5, 1, 2, 4, 6 Output performance classification (according to IEC/ EN62040-3) Double-conversion: VFI-SS-111 Load crest factor Up to 3 (THDU < 5%) Load power factor 0.7 leading to 0.5 lagging without derating Battery (VRLA) Charging power in % of output power 35% at ≤ 80% load, 12% at 100% load 40% at ≤ 80% load, 15% at 100% load Maximum charging power (kW) 96 at 100% load, 280 at <80% load 120 at 100% load, 320 at 80% load Nominal battery voltage (VDC) 480 Nominal float voltage (VDC) 546 End of discharge voltage (full load) (VDC) 384 End of discharge voltage (no load) (VDC) 420 Battery current at full load and nominal battery voltage (A) 1743 Battery current at full load and minimum battery voltage (A) 2179 Maximum short circuit rating 50 kA Maximum battery backup time Unlimited Temperature compensation (per cell) -3.3 mV per °C for T ≥ 25 °C, 0 mV per °C for T < 25 °C Ripple current < 5% C20 (5-minute backup time) Battery test Manual/automatic (selectable) Deep discharge protection Yes Recharge according to battery temperature Yes 38 990-5451K-001 480 V UPS System Facility Planning 45. Per NEC 250.30. 46. 4-wire connection with neutral is not compliant per FCC regulations for the 1500 kW I/O cabinet. 47. 125% for 480 V. 48. Minimum short circuit rating for output takes backfeeding energy through the bypass of parallel UPSs into consideration. 49. Maximum short circuit rating for output takes backfeeding energy through the bypass of parallel UPSs into consideration. Specifications for 1000 kW UPS Voltage (V) 380 400 415 440 480 Input Connections IEC: L1, L2, L3, PE 50 UL: L1, L2, L3 + G 51 Input voltage range (V)52 340-456 340-480 353-498 374-528 408-576 Frequency (Hz) 40-70 Nominal input current (A) 1633 1549 1492 1397 1291 Maximum input current (A)53 1842 1770 1704 1595 1514 Input current limitation (A) 1780 1664 1520 Minimum short circuit rating Dependent on upstream protection. See section for ‘Recommended upstream protection and cable sizes – IEC’ for details. Maximum short circuit rating 100 kA

RMS Total harmonic distortion (THDI) <3% at 100% load, <4% at 50% load, 40% load, 0.98 at >20% load, 0.97 at >10% load Protection Contactors Ramp-in Adaptive 1-300 seconds Bypass Connections IEC 1250 kW I/O and 1500 kW I/O: L1, L2, L3, N, PE or L1, L2, L3, PE 54 UL 1250 kW I/O: L1, L2, L3, G or L1, L2, L3, N, G UL 1500 kW I/O55: L1, L2, L3, G Bypass voltage range (V) 342-418 360-440 374-457 396-484 432-528 Frequency (Hz) 50 or 60 Frequency range (Hz) Programmable: ±0.1, ±3, ±10. Default is ±3 Nominal bypass current (A) 1627 1545 1489 1405 1284 Minimum short circuit rating Dependent on upstream protection. See section for 'Recommended upstream protection and cable sizes – IEC' for details. Maximum short circuit rating 1250 kW I/O: 100 kA Icw 1500 kW I/O: 100 kA RMS (conditioned by an internal molded switch with 90 kA peak magnetic trip) Thyristor I^2t (kA^*s^2) 1250 kW I/O: 9680 1500 kW I/O: 16245 1250 kW I/O: 9165 1500 kW I/O: 16245 BF2 magnetic trip 1250 kW I/O: 39 kA 1500 kW I/O: 39 kA Protection 1250 kW I/O with preinstalled backfeed breaker BF2: Molded switch with trip for backfeed protection 1250 kW I/O with GVXOPT001 installed: Molded switch with trip for backfeed protection 1500 kW I/O with preinstalled backfeed breaker BF2: Molded switch with trip for backfeed protection 990-5451K-001 39 Facility Planning 480 V UPS System 50. TN, TT, and IT power distribution systems are supported. 51. WYE source – solid grounded and high resistance grounded sources are supported. Corner (line) grounding is not permitted. 52. The system can operate at 600 V for 1 minute. 53. At nominal input voltage and full charge. 54. TN, TT, and IT power distribution systems with no earthed line conductors are supported. 55. 4-wire connection with neutral is not compliant per FCC regulations for the 1500 kW I/O cabinet. Voltage (V) 380 400 415 440 480 Output Connections IEC 1250 kW I/O and 1500 kW I/O: L1, L2, L3, N, PE or L1, L2, L3, PE UL 1250 kw I/O: L1, L2, L3, G, GEC56 or L1, L2, L3, N, G UL 1500 kW I/O57: L1, L2, L3, G, GEC56 Overload capacity Normal operation: 150% for 1 minute, 125% for 10 minutes Battery operation: 128% for 10 seconds, 115% for 1 minute Bypass operation: 110%58 continuous, 1000% for 60 milliseconds for systems with 1250 kW I/O cabinet, and 1000% for 100 milliseconds for systems with 1500 kW I/O cabinet Output voltage tolerance Balanced load: ±1%, Unbalanced load: ±3% Dynamic load response ±5% after 2 ms, ±1% after 50 ms Output power factor 1 Nominal output current (A) 1519 1443 1391 1312 1203 Minimum short circuit rating59 Dependent on upstream protection. See section for 'Recommended upstream protection and cable sizes – IEC' for details. Maximum short circuit rating60 100 kA RMS Inverter output short circuit capabilities Varies with time. See graph and table values in Inverter Short–Circuit Capabilities (Bypass not Available), page 18. Total harmonic distortion (THDU) <2% at 100% linear load, <3% at 100% non-linear load Output frequency (Hz) 50/60 (synchronized to bypass), 50/60 Hz ±0.1% (free-running) Slew rate (Hz/sec) Programmable: 0.25, 0.5, 1, 2, 4, 6 Output performance classification (according to IEC/ EN62040-3) Double-conversion: VFI-SS-111 Load crest factor Up to 3 (THDU < 5%) Load power factor 0.7 leading to 0.5 lagging without derating Battery (VRLA) Charging power in % of output power 35% at ≤ 80% load, 12% at 100% load 40% at ≤ 80% load, 15% at 100% load Maximum charging power (kW) 120 at 100% load, 350 at <80% load 150 at 100% load, 400 at <80% load Nominal battery voltage (VDC) 480 Nominal float voltage (VDC) 546 End of discharge voltage (full load) (VDC) 384 End of discharge voltage (no load) (VDC) 420 Battery current at full load and nominal battery voltage (A) 2179 Battery current at full load and minimum battery voltage (A) 2724 Maximum short circuit rating 50 kA Maximum battery backup time Unlimited Temperature compensation (per cell) -3.3 mV per °C for T ≥ 25 °C, 0 mV per °C for T < 25 °C Ripple current < 5% C20 (5-minute backup time) Battery test Manual/automatic (selectable) Deep discharge protection Yes Recharge according to battery temperature Yes 40 990-5451K-001 480 V UPS System Facility Planning 56. Per NEC 250.30. 57. 4-wire connection with neutral is not compliant per FCC regulations for the 1500 kW I/O cabinet. 58. 125% for 480 V. 59. Minimum short circuit rating for output takes backfeeding energy through the bypass of parallel UPSs into consideration. 60. Maximum short circuit rating for output takes backfeeding energy through the bypass of parallel UPSs into consideration. Specifications for 1100 kW UPS Voltage (V) 380 400 415 440 480 Input Connections IEC: L1, L2, L3, PE 61 UL: L1, L2, L3 + G 62 Input voltage range (V)63 340-456 340-480 353-498 374-528 408-576 Frequency (Hz) 40-70 Nominal input current (A) 1796 1704 1641 1540 1421 Maximum input current (A)64 2026 1947 1874 1759 1666 Input current limitation (A) 1958 1830 1672 Minimum short circuit rating Dependent on upstream protection. See section for 'Recommended upstream protection and cable sizes – IEC' for details. Maximum short circuit rating 100 kA RMS Total harmonic distortion (THDI) <3% at 100% load, <4% at 50% load, 40% load, 0.98 at >20% load, 0.97 at >10% load Protection Contactors Ramp-in Adaptive 1-300 seconds Bypass Connections IEC 1250 kW I/O and 1500 kW I/O: L1, L2, L3, N, PE or L1, L2, L3, PE 65 UL 1250 kW I/O: L1, L2, L3, G or L1, L2, L3, N, G UL 1500 kW I/O66: L1, L2, L3, G Bypass voltage range (V) 342-418 360-440 374-457 396-484 432-528 Frequency (Hz) 50 or 60 Frequency range (Hz) Programmable: ±0.1, ±3, ±10. Default is ±3 Nominal bypass current (A)

1789 1700 1639 1545 1412 Minimum short circuit rating Dependent on upstream protection. See section for ‘Recommended upstream protection and cable sizes – IEC’ for details. Maximum short circuit rating 1250 kW I/O: 100 kA Icw 1500 kW I/O: 100 kA RMS (conditioned by an internal molded switch with 90 kA peak magnetic trip) Thyristor I²t (kA*s²) 9680 (1250 kW I/O) 9165 (1250 kW I/O) BF2 magnetic trip 1250 kW I/O: 39 kA 1500 kW I/O: 39 kA Protection 1250 kW I/O with preinstalled backfeed breaker BF2: Molded switch with trip for backfeed protection 1250 kW I/O with GVXOPT001 installed: Molded switch with trip for backfeed protection 1500 kW I/O with preinstalled backfeed breaker BF2: Molded switch with trip for backfeed protection 990-5451K-001 41 Facility Planning 480 V UPS System 61. TN, TT, and IT power distribution systems are supported. 62. WYE source – solid grounded and high resistance grounded sources are supported. Corner (line) grounding is not permitted. 63. The system can operate at 600 V for 1 minute. 64. At nominal input voltage and full charge. 65. TN, TT, and IT power distribution systems with no earthed line conductors are supported. 66. 4-wire connection with neutral is not compliant per FCC regulations for the 1500 kW I/O cabinet. Voltage (V) 380 400 415 440 480 Output Connections IEC 1250 kW I/O and 1500 kW I/O: L1, L2, L3, N, PE or L1, L2, L3, PE UL 1250 kw I/O: L1, L2, L3, G, GEC67 or L1, L2, L3, N, G UL 1500 kW I/O68: L1, L2, L3, G, GEC67 Overload capacity Normal operation: 150% for 1 minute, 125% for 10 minutes Battery operation: 128% for 10 seconds, 115% for 1 minute Bypass operation: 110%69 continuous, 1000% for 60 milliseconds for systems with 1250 kW I/O cabinet, and 1000% for 100 milliseconds for systems with 1500 kW I/O cabinet Output voltage tolerance Balanced load: ±1%, Unbalanced load: ±3% Dynamic load response ±5% after 2 ms, ±1% after 50 ms Output power factor 1 Nominal output current (A) 1671 1588 1530 1443 1323 Minimum short circuit rating70 Dependent on upstream protection. See section for ‘Recommended upstream protection and cable sizes – IEC’ for details. Maximum short circuit rating71 100 kA RMS Inverter output short circuit capabilities Varies with time. See graph and table values in Inverter Short–Circuit Capabilities (Bypass not Available), page 18. Total harmonic distortion (THDU) <2% at 100% linear load, <3% at 100% non-linear load Output frequency (Hz) 50/60 (synchronized to bypass), 50/60 Hz ±0.1% (free-running) Slew rate (Hz/sec) Programmable: 0.25, 0.5, 1, 2, 4, 6 Output performance classification (according to IEC/ EN62040-3) Double-conversion: VFI-SS-111 Load crest factor Up to 3 (THDU < 5%) Load power factor 0.7 leading to 0.5 lagging without derating Battery (VRLA) Charging power in % of output power 35% at ≤ 80% load, 12% at 100% load 40% at ≤ 80% load, 15% at 100% load Maximum charging power (kW) 132 at 100% load, 385 at <80% load 165 at 100% load, 440 at <80% load Nominal battery voltage (VDC) 480 Nominal float voltage (VDC) 546 End of discharge voltage (full load) (VDC) 384 End of discharge voltage (no load) (VDC) 420 Battery current at full load and nominal battery voltage (A) 2397 Battery current at full load and minimum battery voltage (A) 2996 Maximum short circuit rating 50 kA Maximum battery backup time Unlimited Temperature compensation (per cell) -3.3 mV per °C for T ≥ 25 °C, 0 mV per °C for T < 25 °C Ripple current < 5% C20 (5-minute backup time) Battery test Manual/automatic (selectable) Deep discharge protection Yes Recharge according to battery temperature Yes 42 990-5451K-001 480 V UPS System Facility Planning 67. Per NEC 250.30. 68. 4-wire connection with neutral is not compliant per FCC regulations for the 1500 kW I/O cabinet. 69. 125% for 480 V. 70. Minimum short circuit rating for output takes backfeeding energy through the bypass of parallel UPSs into consideration. 71. Maximum short circuit rating for output takes backfeeding energy through the bypass of parallel UPSs into consideration. Specifications for 1250 kW UPS Voltage (V) 380 400 415 440 480 Input Connections IEC: L1, L2, L3, PE 72 UL: L1, L2, L3 + G 73 Input voltage range (V)74 340-456 340-480 353-498 374-528 408-576 Frequency (Hz) 40-70 Nominal input current (A) 2041 1937 1865 1750 1615 Maximum input current (A)75 2303 2212 2130 1999 1893 Input current limitation (A) 2225 2080 1900 Minimum short circuit rating Dependent on upstream protection. See section for ‘Recommended upstream protection and cable sizes – IEC’ for details. Maximum short circuit rating 100 kA RMS Total harmonic distortion (THDI) <3% at 100% load, <4% at 50% load, 40% load, 0.98 at >20% load, 0.97 at >10% load Protection Contactors Ramp-in Adaptive 1-300 seconds Bypass Connections IEC 1250 kW I/O and 1500 kW I/O: L1, L2, L3, N, PE or L1, L2, L3, PE 76 UL 1250 kW I/O: L1, L2, L3, G or L1, L2, L3, N, G UL 1500 kW I/O77: L1, L2, L3, G Bypass voltage range (V) 342-418 360-440 374-457 396-484 432-528 Frequency (Hz) 50 or 60 Frequency range (Hz) Programmable: ±0.1, ±3, ±10. Default is ±3 Nominal bypass current (A) 2033 1931 1862 1756 1605 Minimum short circuit rating Dependent on upstream protection. See section for ‘Recommended upstream protection and cable sizes – IEC’ for details. Maximum short circuit rating 1250 kW I/O: 100 kA Icw 1500 kW I/O: 100 kA RMS (conditioned by an internal molded switch with 90 kA peak magnetic trip) Thyristor I²t (kA*s²) 1250 kW I/O: 9680 1500 kW I/O: 16245 1250 kW I/O: 9165 1500 kW I/O: 16245 BF2 magnetic trip 1250 kW I/O: 39 kA 1500 kW I/O: 39 kA Protection 1250 kW I/O with preinstalled backfeed breaker BF2: Molded switch with trip for backfeed protection 1250 kW I/O with GVXOPT001 installed: Molded switch with trip for backfeed protection 1500 kW I/O with preinstalled backfeed breaker BF2: Molded switch with trip for backfeed protection 990-5451K-001 43 Facility Planning 480 V UPS System 72. TN, TT, and IT power distribution systems are supported. 73. WYE source – solid grounded and high resistance grounded sources are supported. Corner (line) grounding is not permitted. 74. The system can operate at 600 V for 1 minute. 75. At nominal input voltage and full charge. 76. TN, TT, and IT power distribution systems with no earthed line conductors are supported. 77. 4-wire connection with neutral is not compliant per FCC regulations for the 1500 kW I/O cabinet. Voltage (V) 380 400 415 440 480 Output Connections IEC 1250 kW I/O and 1500 kW I/O: L1, L2, L3, N, PE or L1, L2, L3, PE UL 1250 kw I/O: L1, L2, L3, G, GEC78 or L1, L2, L3, N, G UL 1500 kW I/O79: L1, L2, L3, G, GEC78 Overload capacity Normal operation: 150% for 1 minute, 125% for 10 minutes Battery operation: 128% for 10 seconds, 115% for 1 minute Bypass operation: 110%80 continuous, 1000% for 60 milliseconds for systems with 1250 kW I/O cabinet, and 1000% for 100 milliseconds for systems with 1500 kW I/O cabinet Output voltage tolerance Balanced load: ±1%, Unbalanced load: ±3% Dynamic load response ±5% after 2 ms, ±1% after 50 ms Output power factor 1 Nominal output current (A) 1899 1804 1739 1640 1504 Minimum short circuit rating81 Dependent on upstream protection. See section for 'Recommended upstream protection and cable sizes – IEC' for details. Maximum short circuit rating82 100 kA RMS Inverter output short circuit capabilities Varies with time. See graph and table values in Inverter Short–Circuit Capabilities (Bypass not Available), page 18. Total harmonic distortion (THDU) <2% at 100% linear load, <3% at 100% non-linear load Output frequency (Hz) 50/60 (synchronized to bypass), 50/60 Hz ±0.1% (free-running) Slew rate (Hz/sec) Programmable: 0.25, 0.5, 1, 2, 4, 6 Output performance classification (according to IEC/ EN62040-3) Double-conversion: VFI-SS-111 Load crest factor Up to 3 (THDU < 5%) Load power factor 0.7 leading to 0.5 lagging without derating Battery (VRLA) Charging power in % of output power 35% at ≤ 80% load, 12% at 100% load 40% at ≤ 80% load, 15% at 100% load Maximum charging power (kW) 150 at 100% load, 437 at <80% load 187.5 at 100% load, 500 at <80% load Nominal battery voltage (VDC) 480 Nominal float voltage (VDC) 546 End of discharge voltage (full load) (VDC) 384 End of discharge voltage (no load) (VDC) 420 Battery current at full load and nominal battery voltage (A) 2724 Battery current at full load and minimum battery voltage (A) 3405 Maximum short circuit rating 50 kA Maximum battery backup time 1 hour Temperature compensation (per cell) -3.3 mV per °C for T ≥ 25 °C, 0 mV per °C for T < 25 °C Ripple current < 5% C20 (5-minute backup time) Battery test Manual/ automatic (selectable) Deep discharge protection Yes Recharge according to battery temperature Yes 44 990-5451K-001 480 V UPS System Facility Planning 78. Per NEC 250.30. 79. 4-wire connection with neutral is not compliant per FCC regulations for the 1500 kW I/O cabinet. 80. 125% for 480 V. 81. Minimum short circuit rating for output takes backfeeding energy through the bypass of parallel UPSs into consideration. 82. Maximum short circuit rating for output takes backfeeding energy through the bypass of parallel UPSs into consideration. Specifications for 1500 kW UPS Voltage (V) 380 400 415 440 480 Input Connections IEC: L1, L2, L3, PE 83 UL: L1, L2, L3 + G 84 Input voltage range (V)85 340-456 340-480 353-498 374-528 408-576 Frequency (Hz) 40-70 Nominal input current (A) 2449 2325 2238 2100 1937 Maximum input current (A)86 2763 2654 2555 2398 2271 Input current limitation (A) 2670 2496 2280 Minimum short circuit rating Dependent on upstream protection. See section for 'Recommended upstream protection and cable sizes – IEC' for details. Maximum short circuit rating 100 kA RMS Total harmonic distortion (THDI) <3% at 100% load, <4% at 50% load, 40% load, 0.98 at >20% load, 0.97 at >10% load Protection Contactors Ramp-in Adaptive 1-300 seconds Bypass Connections IEC 1250 kW I/O and 1500 kW I/O: L1, L2, L3, N, PE or L1, L2, L3, PE 87 UL 1250 kW I/O: L1, L2, L3, G or L1, L2, L3, N, G UL 1500 kW I/O88: L1, L2, L3, G Bypass voltage range (V) 342-418 360-440 374-457 396-484 432-528 Frequency (Hz) 50 or 60 Frequency range (Hz) Programmable: ±0.1, ±3, ±10. Default is ±3 Nominal bypass current (A) 2440 2318 2234 2107 1926 Minimum short circuit rating Dependent on upstream protection. See section for 'Recommended upstream protection and cable sizes – IEC' for details. Maximum short circuit rating 1250 kW I/O: 100 kA Icw 1500 kW I/O: 100 kA RMS (conditioned by an internal molded switch with 90 kA peak magnetic trip) Thyristor I^2t (kA^*s^2) 16245 (1500 kW I/O) BF2 magnetic trip 1250 kW I/O: 39 kA 1500 kW I/O: 39 kA Protection 1250 kW I/O with preinstalled backfeed breaker BF2: Molded switch with trip for backfeed protection 1250 kW I/O with GVXOPT001 installed: Molded switch with trip for backfeed protection 1500 kW I/O with preinstalled backfeed breaker BF2: Molded switch with trip for backfeed protection 990-5451K-001 45 Facility Planning 480 V UPS System 83. TN, TT, and IT power distribution systems are supported. 84. WYE source – solid grounded and high resistance grounded sources are supported. Corner (line) grounding is not permitted. 85. The system can operate at 600 V for 1 minute. 86. At nominal input voltage and full charge. 87. TN, TT, and IT power distribution systems with no earthed line conductors are supported. 88. 4-wire connection with neutral is not compliant per FCC regulations for the 1500 kW I/O cabinet. Voltage (V) 380 400 415 440 480 Output Connections IEC 1250 kW I/O and 1500 kW I/O: L1, L2, L3, N, PE or L1, L2, L3, PE UL 1250 kw I/O: L1, L2, L3, G, GEC89 or L1, L2, L3, N, G UL 1500 kW I/O90: L1, L2, L3, G, GEC89 Overload capacity 150% for 1 minute, 125% for 10 minutes (normal operation) 115% for 1 minute (battery operation) 110% continuous,1000% for 100 milliseconds (bypass operation) Output voltage tolerance Balanced load: ±1%, Unbalanced load: ±3% Dynamic load response ±5% after 2 ms, ±1% after 50 ms Output power factor 1 Nominal output current (A) 2279 2165 2087 1968 1804 Minimum short circuit rating91 Dependent on upstream protection. See section for 'Recommended upstream protection and cable sizes – IEC' for details. Maximum short circuit rating92 100 kA RMS Inverter output short circuit capabilities Varies with time. See graph and table values in Inverter Short–Circuit Capabilities (Bypass not Available), page 18. Total harmonic distortion (THDU) <2% at 100% linear load, <3% at 100% non-linear load Output frequency (Hz) 50/60 (synchronized to bypass), 50/60 Hz ±0.1% (free-running) Slew rate (Hz/sec) Programmable: 0.25, 0.5, 1, 2, 4, 6 Output performance classification (according to IEC/ EN62040-3) Double-conversion: VFI-SS-111 Load crest factor Up to 3 (THDU < 5%) Load power factor 0.7 leading to 0.5 lagging without derating Battery (VRLA) Charging power in % of output power 35% at ≤ 80% load, 12% at 100% load 40% at ≤ 80% load, 15% at 100% load Maximum charging power (kW) 525 at < 80% load, 180 at 100% load, 600 at <80% load, 225 at 100% load Nominal battery voltage (VDC) 480 Nominal float voltage (VDC) 546 End of discharge voltage (full load) (VDC) 384 End of discharge voltage (no load) (VDC) 420 Battery current at full load and nominal battery voltage (A) 3269 Battery current at full load and minimum battery voltage (A) 4086 Maximum short circuit rating 50 kA Maximum battery backup time 1 hour Temperature compensation (per cell) -3.3 mV per °C for T ≥ 25 °C, 0 mV per °C for T < 25 °C Ripple current < 5% C20 (5-minute backup time) Battery test Manual/automatic (selectable) Deep discharge protection Yes Recharge according to battery temperature Yes 46 990-5451K-001 480 V UPS System Facility Planning 89. Per NEC 250.30. 90. 4-wire connection with neutral is not compliant per FCC regulations for the 1500 kW I/O cabinet. 91. Minimum short circuit rating for output takes backfeeding energy through the bypass of parallel UPSs into consideration. 92. Maximum short circuit rating for output takes backfeeding energy through the bypass of parallel UPSs into consideration. Recommended Upstream Protection and Cable Sizes – UL CAUTION HAZARD OF FIRE • Connect only to a circuit with the below specifications. • Connect only to a circuit provided with a maximum branch circuit overcurrent protection, as specified in the UPS rating tables below, in accordance with the National Electrical Code, ANSI/NFPA70, and the Canadian Electrical Code, Part I, C22.1. Failure to follow these instructions can result in injury or equipment damage. NOTE: Overcurrent protection is to be provided by others. NOTE: All wiring must comply with all applicable national and/or electrical code (National Electrical Code, ANSI/NFPA 70). Cable sizes in this manual are based on Table 310.15 of the National Electrical Code 2014 (NEC) with the following assertions: • 90 °C conductors (THHN) for 75 °C termination • Not more than 3 current carrying conductors in each conduit • An ambient temperature of max. 30 °C • Use of copper or aluminium conductors • 100% rated breakers • Nominal operating conditions If the ambient room temperature is greater than 30 °C, use larger or additional parallel conductors in accordance with the correction factors of the NEC. The maximum allowable conductor size is 600 kcmil. Equipment Grounding Conductors (EGC) are sized in accordance with NEC Article 250.122 and Table 250.122 Minimum size equipment conductor for grounding equipment. NOTE: Always consider the EGC size according to the complete electrical installation. NOTE: The use of aluminium conductors can limit the number of parallel Lithium-ion battery cabinets. Contact Schneider Electric for more information. NOTICE RISK OF EQUIPMENT DAMAGE To ensure correct load sharing in bypass operation in a parallel system, the following recommendations apply: • The bypass cables must be of the same length for all UPSs. • The output cables must be of the same length for all UPSs. • The input cables must be of the same length for all UPSs in a single mains system. • Cable formation recommendations must be followed. • The reactance of busbar layout in the bypass/input and output switchgear must be the same for all UPSs. If the above recommendations are not followed the result can be uneven load sharing in bypass and overload of individual UPSs. Failure to follow these instructions can result in equipment damage. 990-5451K-001 47 Facility Planning 480 V UPS System Recommended Upstream Protection and Cable Sizes for 500 kW UPS Maximum OCPD (A) Cable size per phase (AWG/kcmil) Copper / Aluminum EGC cable size (AWG/kcmil)93 Copper / Aluminum Input 800 (Ir = 1.0) 2x500 / 3x400 1x1/0 / 1x3/0 Bypass 700 (Ir = 1.0) 2x350 / 2x500 1x1/0 / 1x3/0 Output 700 (Ir = 1.0) 2x350 / 2x500 1x1/0 / 1x3/0 Battery 1600 (Ir = 0.9) 4x500 / 5x500 1x4/0 / 1x350 Recommended Upstream Protection and Cable Sizes for 625 kW UPS Maximum OCPD (A) Cable size per phase (AWG/kcmil) Copper / Aluminum EGC cable size (AWG/kcmil)93 Copper / Aluminum Input 1000 (Ir = 1.0) 3x400 / 3x600 1x2/0 / 1x4/0

Bypass 800 (Ir= 1.0) 2x600 / 3x400 1x1/0 / 1x3/0 Output 800 (Ir = 1.0) 2x600 / 3x400 1x1/0 / 1x3/0 Battery 2000 (Ir = 0.9) 5x500 / 6x500 1x250 / 1x400 Recommended Upstream Protection and Cable Sizes for 750 kW UPS Maximum OCPD (A) Cable size per phase (AWG/kcmil) Copper / Aluminum EGC cable size (AWG/kcmil)93 Copper / Aluminum Input 1200 (Ir = 1.0) 3x600 / 4x500 1x3/0 / 1x250 Bypass 1000 (Ir = 1.0) 3x400 / 3x600 1x2/0 / 1x4/0 Output 1000 (Ir = 1.0) 3x400 / 3x600 1x2/0 / 1x4/0 Battery 2500 (Ir = 0.9) 6x500 / 7x600 1x350 / 1x600 Recommended Upstream Protection and Cable Sizes for 800 kW UPS Maximum OCPD (A) Cable size per phase (AWG/kcmil) Copper / Aluminum EGC cable size (AWG/kcmil)93 Copper / Aluminum Input 1600 (Ir = 0.8) 4x400 / 4x600 1x4/0 / 1x350 Bypass 1000 3x400 / 3x600 1x2/0 / 1x4/0 Output 1000 3x400 / 3x600 1x2/0 / 1x4/0 Battery 2500 (Ir = 0.9) 6x500 / 7x600 1x350 / 1x600 48 990-5451K-001 480 V UPS System Facility Planning 93. If the conductors are run in conduits, there must be one conductor in each conduit. Recommended Upstream Protection and Cable Sizes for 1000 kW UPS Maximum OCPD (A) Cable size per phase (AWG/kcmil) Copper / Aluminum EGC cable size (AWG/kcmil)94 Copper / Aluminum Input 1600 (Ir = 1.0) 4x600 / 5x600 1x4/0 / 1x350 Bypass 1600 (Ir = 0.8) 4x400 / 4x600 1x4/0 / 1x350 Output 1600 (Ir = 0.8) 4x400 / 4x600 1x4/0 / 1x350 Battery 3000 (Ir = 1.0) 8x500 / 9x600 1x400 / 1x600 Recommended Upstream Protection and Cable Sizes for 1100 kW UPS NOTE: For a 1250 I/O cabinet, it is preferred to use flexible copper power cables with as small a diameter as possible. The number of power cables needed for this kW rating will make large and inflexible power cables more difficult to install. Maximum OCPD (A) Cable size per phase (AWG/kcmil) Copper / Aluminum EGC cable size (AWG/kcmil)94 Copper / Aluminum Input 2000 (Ir = 0.9) 5x500 / 6x500 1x250 / 1x400 Bypass 1600 (Ir = 0.9) 4x500 / 5x500 1x4/0 / 1x350 Output 1600 (Ir = 0.9) 4x500 / 5x500 1x4/0 / 1x350 Battery 3000 (Ir = 1.0) 8x500 / 9x600 1x400 / 1x600 Recommended Upstream Protection and Cable Sizes for 1250 kW UPS NOTE: For a 1250 I/O cabinet, it is preferred to use flexible copper power cables with as small a diameter as possible. The number of power cables needed for this kW rating will make large and inflexible power cables more difficult to install. Maximum OCPD (A) Cable size per phase (AWG/kcmil) Copper / Aluminum EGC cable size (AWG/kcmil)94 Copper / Aluminum Input 2000 (Ir = 1.0) 5x600 / 6x600 1x250 / 1x400 Bypass 1600 (Ir = 1.0) 4x600 / 5x600 1x4/0 / 1x350 Output 1600 (Ir = 1.0) 4x600 / 5x600 1x4/0 / 1x350 Battery 4000 (Ir = 0.9) 9x600 / 11x600 2x250 / 2x400 990-5451K-001 49 Facility Planning 480 V UPS System 94. If the conductors are run in conduits, there must be one conductor in each conduit. Recommended Upstream Protection and Cable Sizes for 1500 kW UPS Maximum OCPD (A) Cable size per phase (AWG/kcmil) Copper / Aluminum EGC cable size (AWG/kcmil)95 Copper / Aluminum Input 250096 6x600/ 8x600 1x350 / 1x400 Bypass 200096 5x600/ 6x600 1x250 / 1x350 Output 200096 5x600/ 6x600 1x250 / 1x350 Battery 500097 11x600/ 14x600 1x700 kcmil/ – Recommended Bolt and Lug Sizes for Copper Cables Cable Size Terminal Bolt Diameter Cable Lug Type Crimping Tool Die 1/0 AWG M12 x 35 mm LCCF1/0–12–X CT930 CD-920–2/0 Black P45 2/0 AWG M12 x 35 mm LCCF2/0–12–X CT930 CD-920–3/0 Orange P50 3/0 AWG M12 x 35 mm LCCF3/0–12–X CT930 CD-920–4/0 Purple P54 250 kcmil M12 x 35 mm LCCF250–12–X CT-940CH/CT-2940 CD-920–300 White P66 300 kcmil M12 x 35 mm LCCF300–12–6 CT-940CH/CT-2940 CD-920–350 Red P71 400 kcmil M12 x 35 mm LCCF400–12–6 CT-940CH/CT-2940 CD-920–500 Brown P87 500 kcmil M12 x 35 mm LCCF500–12–6 CT-940CH/CT-2940 CD-920–500A Pink P99 600 kcmil M12 x 40 mm LCCF600–12–6 CT-940CH/CT-2940 CD-920–750 Black P106 Recommended Bolt and Lug Sizes for Aluminium Cables Cable Size Terminal Bolt Diameter Cable Lug Type Crimping Tool Die 2/0 AWG M12 x 40 mm LAB2/0-12-5 CT930 Olive P54 3/0 AWG M12 x 40 mm LAB3/0-12-5 CT930 Ruby P60 250 kcmil M12 x 40 mm LAB250-12-5 CT930 Red P71 300 kcmil M12 x 40 mm LAB300-12-2 CT930 Blue P76 400 kcmil M12 x 40 mm LAB400-12-2 CT930 Green P94 500 kcmil M12 x 40 mm LAB500-12-2 CT930 Pink P99 600 kcmil M12 x 40 mm LAB600-12-2 CT930 Black P106 50 990-5451K-001 480 V UPS System Facility Planning 95. If the conductors are run in conduits, there must be one conductor in each conduit. 96. Long-time setting (Ir) = 1.0 97. Long-time setting (Ir) = 0.9 Weights and Dimensions UPS Shipping Weights and Dimensions Weight kg (lbs) Height mm (in) Width mm (in) Depth mm (in) 1250 kW I/O cabinet (GVXI1250KDNBF2 or GVXI1250KD) 800 (1764) 2140 (84.3) 1400 (55.1) 1060 (41.8) 1500 kW I/O cabinet (GVXI1500KD) 1060 (2337) 2140 (84.3) 2120 (83.5) 1060 (41.8) Galaxy VX 250 kW power cabinet (GVXP250KD) 560 (1235) 2140 (84.3) 760 (29.9) 1060 (41.8) NOTE: The Galaxy VX UPS consist of one 1250 kW I/O cabinet or one 1500 kW I/O cabinet and a minimum of two 250 kW power cabinets depending on your chosen configuration. Weights and Dimensions for UPSs with 1250 kW I/O Cabinet Commercial reference Weight kg (lbs) Height mm (in) Width mm (in) Depth mm (in) • GVX500K500NGS • GVX500K750NGS • GVX500K1000NGS • GVX500K1250NGS Total – Power cabinets – I/O cabinet 1700 (3748) 2 x 540 (2 x 1190) 620 (1367) 1970 (77.6) 2400 (94.5) 2 x 600 (2 x 23.6) 1200 (47.2) 900 (35.4) • GVX625K625NGS • GVX625K1000NGS • GVX750K500NGS • GVX750K750NGS •

GVX750K1000NGS • GVX750K1250NGS Total – Power cabinets – I/O cabinet 2240 (4938) 3 x 540 (3 x 1190) 620 (1367) 1970 (77.6) 3000 (118.1) 3 x 600 (3 x 23.6) 1200 (47.2) 900 (35.4) • GVX800K800NGS • GVX1000K750NGS • GVX1000K1000NGS • GVX1000K1250NGS Total – Power cabinets – I/O cabinet 2780 (6129) 4 x 540 (4 x 1190) 620 (1367) 1970 (77.6) 3600 (141.7) 4 x 600 (4 x 23.6) 1200 (47.2) 900 (35.4) • GVX1100K1100NGS • GVX1250K1000NGS • GVX1250K1250NGS Total – Power cabinets – I/O cabinet 3320 (7319) 5 x 540 (5 x 1190) 620 (1367) 1970 (77.6) 4200 (165.4) 5 x 600 (5 x 23.6) 1200 (47.2) 900 (35.4) • GVX1500K1100NGS • GVX1500K1250NGS Total – Power cabinets – I/O cabinet 3860 (8510) 6 x 540 (6 x 1190) 620 (1367) 1970 (77.6) 4800 (189.0) 6 x 600 (6 x 23.6) 1200 (47.2) 900 (35.4) 990-5451K-001 51 Facility Planning 480 V UPS System Weights and Dimensions for UPSs with 1500 kW I/O Cabinet Commercial reference Weight kg (lbs) Height mm (in) Width mm (in) Depth mm (in) • GVX500K1500GS Total – Power cabinets – I/O cabinet 1956 (4312) 2 x 540 (2 x 1190) 876 (1931) 1970 (77.6) 3200 (126.0) 2 x 600 (2 x 23.6) 2000 (78.7) 900 (35.4) • GVX750K1500GS Total – Power cabinets – I/O cabinet 2496 (5503) 3 x 540 (3 x 1190) 876 (1931) 1970 (77.6) 3800 (149.6) 3 x 600 (3 x 23.6) 2000 (78.7) 900 (35.4) • GVX1000K1500GS Total – Power cabinets – I/O cabinet 3036 (6693) 4 x 540 (4 x 1190) 876 (1931) 1970 (77.6) 4400 (173.2) 4 x 600 (4 x 23.6) 2000 (78.7) 900 (35.4) • GVX1250K1500GS Total – Power cabinets – I/O cabinet 3576 (7884) 5 x 540 (5 x 1190) 876 (1931) 1970 (77.6) 5000 (196.9) 5 x 600 (5 x 23.6) 2000 (78.7) 900 (35.4) • GVX1500K1500GS Total – Power cabinets – I/O cabinet 4116 (9074) 6 x 540 (6 x 1190) 876 (1931) 1970 (77.6) 5600 (220.5) 6 x 600 (6 x 23.6) 2000 (78.7) 900 (35.4) • GVX1750K1500GS Total – Power cabinets – I/O cabinet 4656 (10265) 7 x 540 (7 x 1190) 876 (1931) 1970 (77.6) 6200 (244.1) 7 x 600 (7 x 23.6) 2000 (78.7) 900 (35.4) 52 990-5451K-001 480 V UPS System Facility Planning Clearance Clearance for UPSs with 1250 kW I/O Cabinet NOTE: Clearance dimensions are published for airflow and service access only. Consult with the local safety codes and standards for additional requirements in your local area. NOTE: The UPS system can be placed up against a wall and there is no requirement for rear or side access. Clearance for UPSs with 1500 kW I/O Cabinet NOTE: Clearance dimensions are published for airflow and service access only. Consult with the local safety codes and standards for additional requirements in your local area. NOTE: The UPS system can be placed up against a wall with no requirement for rear or side access. Front View 990-5451K-001 53 Facility Planning 480 V UPS System Guidance for Organizing Battery Cables NOTE: For 3rd party batteries, use only high rate batteries for UPS applications. NOTE: When the battery bank is placed remotely, the organizing of the cables is important to reduce voltage drop and inductance. The distance between the battery bank and the UPS must not exceed 200 m (656 ft). Contact Schneider Electric for installations with a longer distance. NOTE: To minimize the risk of electromagnetic radiation, it is highly recommended to follow the below guidance and to use grounded metallic tray supports. Cable Length 200 kW Reference Guide EcoStruxure Power for Railway and Urban Transportation Public SECTION 3 – Digital Solutions and Services across the Facilities Introduction SECTION 2 – How EcoStruxure Power Can Support the Railway Industry 2- Traction Substations 3- Auxiliary Powers Systems 4- Passenger Stations eBus Depots 6- Tunnel Systems 1- Overhead Lines SECTION 1 – Introduction to the Railway and Urban Transportation Market 5- eBus Depots EcoStruxure Value Proposition Applications Overview Reference Architectures 7- Depots and Workshops 8- Control Center BIBLIOGRAPHY SECTION 4 – Design Considerations SECTION 5 – Customer Stories How does it work? Introduction to eBus Depots There are three main use cases recommended for the electrical installation, depending on the customer's needs: Use case 1: "Keep it simple, grid supply" Build and enable the electrical infrastructure to supply energy to the eBuses. Use case 2: "Self-consume, grid tied" Build and enable the electrical infrastructure while integrating the renewable energy sources. Manage energy sources for the eBuses, intended to optimize both technical and economic parameters. Use case 3: "Run off grid" Build electrical infrastructure with the ability to disconnect from the grid to help: • Increase availability (lack of supply from the grid) • Optimize energy supply prices • Enhance stability across the internal network ("microgrid") once disconnected from external energy sources. Public eBus Depot Use Cases Reference Guide EcoStruxure Power for Railway and Urban Transportation Public SECTION 3 – Digital Solutions and Services across the Facilities Introduction SECTION 2 – How EcoStruxure Power Can Support the Railway Industry 2- Traction Substations 3- Auxiliary Powers Systems 4- Passenger Stations eBus Depots 6- Tunnel Systems 1- Overhead Lines SECTION 1 – Introduction to the Railway and Urban Transportation Market 5- eBus Depots EcoStruxure Value Proposition Applications Overview Reference Architectures 7- Depots and Workshops 8- Control Center BIBLIOGRAPHY SECTION 4 – Design Considerations SECTION 5 – Customer Stories Main components of the electrical architecture Introduction to eBus Depots Public Main Components of the Electrical Architecture for eBus Depots Reference Guide EcoStruxure Power for Railway and Urban Transportation Public SECTION 3 – Digital Solutions and Services across the Facilities

5- eBus Depots Introduction EcoStruxure Value Proposition Applications Overview Reference Architectures SECTION 2 – How EcoStruxure Power Can Support the Railway Industry 2- Traction Substations 3- Auxiliary Powers Systems eBus Depots 6- Tunnel Systems 1- Overhead Lines SECTION 1 – Introduction to the Railway and Urban Transportation Market 7- Depots and Workshops 8- Control Center BIBLIOGRAPHY 4- Passenger Stations SECTION 4 – Design Considerations SECTION 5 – Customer Stories EcoStruxure Power Value Proposition Apps, analytics, and services Edge Control Connected products Fleet Management (Third party) for eBus Depots EV charger Circuit breaker Cloud-Based Advisor Services for Asset Management, EV Charging and distributed energy resources (renewables) Uninterruptible power supply Power meter Power quality solutions Panel server 2. Operational Management • Real-time monitoring and control of power system status and identification of abnormal temperature, insulation faults or power disturbances • EV Charging Expert to optimize the use of energy between every charging point • Microgrid Automation to manage Distributed Energy Resources (DERs) and improve real-time grid stability and reliability 3. Analysis & Optimization • Cloud-based predictive power asset maintenance with expert recommendation provided by our Schneider Electric service experts • Consulting services including network audits, microgrid sizing services, power systems engineering and sustainable energy procurement • Microgrid optimization using a cloud-based platform with necessary algorithms to get the most out of the local energy resources • EV advisor for advanced management of the charging process, connected to a route-planning application (third-party) 1. Primary Equipment • MV/LV range of power Connected Products for protection, power correction and monitoring • Battery Energy Storage Systems (BESSs) to improve grid flexibility and stability • High powered DC electric vehicle charging units AVEVA System Platform EcoStruxure Power Operation / Power Monitoring Expert EcoStruxure EV Charging Expert Simulation Engine EcoStruxure Microgrid Operation Our solution to control and supply energy to eBus depots Reference Guide EcoStruxure Power for Railway and Urban Transportation Public SECTION 3 – Digital Solutions and Services across the Facilities 5- eBus Depots Introduction EcoStruxure Value Proposition Applications Overview Reference Architectures SECTION 2 – How EcoStruxure Power Can Support the Railway Industry 2- Traction Substations 3- Auxiliary Powers Systems eBus Depots 6- Tunnel Systems 1- Overhead Lines SECTION 1 – Introduction to the Railway and Urban Transportation Market 7- Depots and Workshops 8- Control Center BIBLIOGRAPHY 4- Passenger Stations SECTION 4 – Design Considerations SECTION 5 – Customer Stories Specific pillars for eBus depots EcoStruxure Power Value Proposition EcoStruxure Power provides applications to support the challenges of eBus depots for Railway and Urban Transportation, with the following pillars: Reliable Electrification Electrical Distribution Monitoring and Alarming Capacity Management Power Event Analysis Power Quality Monitoring, Correction, and Compliance Power Source and Load Control Safety and Comfort Enhance safety and comfort in passenger stations and tunnels Continuous Thermal Monitoring Guided Procedures Through Extended Reality Digitalization Operate centrally and maintain infrastructure efficiently Backup Power Testing Circuit Breaker Settings Monitoring Asset Performance Decarbonization Reduce energy consumption and carbon footprint Basic Energy Awareness Advanced Energy Performance Effective Energy Accounting Energy and Environmental Compliance Electrification (eBus Depot) Advanced Microgrid Improve reliability of electrical infrastructure Reference Guide EcoStruxure Power for Railway and Urban Transportation Public SECTION 3 – Digital Solutions and Services across the Facilities 5- eBus Depots Introduction EcoStruxure Value Proposition Applications Overview Reference Architectures SECTION 2 – How EcoStruxure Power Can Support the Railway Industry 2- Traction Substations 3- Auxiliary Powers Systems eBus Depots 6- Tunnel Systems 1- Overhead Lines SECTION 1 – Introduction to the Railway and Urban Transportation Market 7- Depots and Workshops 8- Control Center BIBLIOGRAPHY 4- Passenger Stations SECTION 4 – Design Considerations SECTION 5 – Customer Stories Our Digital Solutions and Services: Applications Overview ■■■ Essential ■■ Recommended ■ Desirable Click on the blue links to have more information Capacity Management è Visualize real-time or historical power system capacity è Monitor and trend circuit or equipment loading è Provide information for capacity planning Reliable Electrification Power Event Analysis è Provide a user-friendly graphical tool to simplify and save time in event analysis è Provide an aggregated view of events in the same dashboard è Enable root cause analysis Reliable Electrification Power Quality Monitoring, Correction, and Compliance è Power Quality Monitoring and Compliance: Monitor persistent steady state and event- based disturbances to better understand and analyze power quality disturbances è Power Quality Correction: Correct over/under voltages, harmonics, etc. Reliable Electrification Power Source and Load Control è Help isolate faults with relay automation and circuit breaker coordination è Help preserve critical loads by automatically transferring to alternate power è Help restore power quickly è Get real-time visibility, automation and control of the entire electrical infrastructure Reliable Electrification ■■■

■■■ ■■■ ■■■ è Provide real-time status of the electrical distribution system è Help identify anomalies and notify the right personnel è Aggregate onboard alarm data in an easy-to-understand way è Take advantage of native integration of intelligent electrical devices Reliable Electrification Electrical Distribution Monitoring and Alarming ■■■ Reference Guide EcoStruxure Power for Railway and Urban Transportation Public SECTION 3 – Digital Solutions and Services across the Facilities 5- eBus Depots Introduction EcoStruxure Value Proposition Applications Overview Reference Architectures SECTION 2 – How EcoStruxure Power Can Support the Railway Industry 2- Traction Substations 3- Auxiliary Powers Systems eBus Depots 6- Tunnel Systems 1- Overhead Lines SECTION 1 – Introduction to the Railway and Urban Transportation Market 7- Depots and Workshops 8- Control Center BIBLIOGRAPHY 4- Passenger Stations SECTION 4 – Design Considerations SECTION 5 – Customer Stories Our Digital Solutions and Services: Applications Overview ■■■ Essential ■■ Recommended ■ Desirable Click on the blue links to have more information Continuous Thermal Monitoring è Monitor the temperature of busbar, cable, transformer, and withdrawable circuit breaker connections è Help detect poor connections at an early stage è Provide temperature alarming and reporting for fast response Guided Procedures Through XR è Use Extended Reality to perform step-by-step guidance è Benefit from “X-ray” vision and virtually overlaid contextual asset and site information, live data, events and alarms è Take advantage of remote collaboration Safety and Comfort Safety and Comfort Backup Power Testing è Automatically record key backup power test parameters such as run time, engine loading, exhaust and engine temperatures è Perform automated backup power test reporting Digitalization Circuit Breaker Settings Monitoring è Compare current circuit breaker settings with commissioned settings è Help detect inappropriate setting modifications periodically è Provide information for capacity planning Digitalization Asset Performance è Make asset health visible across the entire system è Streamline inspections using continuous asset health monitoring è Optimize maintenance planning with analytics and expert advice Digitalization ■■■ ■■ ■■ ■ ■■■ Reference Guide EcoStruxure Power for Railway and Urban Transportation Public SECTION 3 – Digital Solutions and Services across the Facilities 5- eBus Depots Introduction EcoStruxure Value Proposition Applications Overview Reference Architectures SECTION 2 – How EcoStruxure Power Can Support the Railway Industry 2- Traction Substations 3- Auxiliary Powers Systems eBus Depots 6- Tunnel Systems 1- Overhead Lines SECTION 1 – Introduction to the Railway and Urban Transportation Market 7- Depots and Workshops 8- Control Center BIBLIOGRAPHY 4- Passenger Stations SECTION 4 – Design Considerations SECTION 5 – Customer Stories Our Digital Solutions and Services: Applications Overview ■■■ Essential ■■ Recommended ■ Desirable Click on the blue links to have more information Effective Energy Accounting Identify areas for possible energy conservation measures: è Utility Bill Verification: Identify billing errors by comparison with a shadow bill è Cost Allocation: Allocate energy costs to terminals or departments for accurate billing è Power Factor correction: Mitigate harmonic effects and power quality issues Decarbonization Basic Energy Awareness è Energy Monitoring: Increase awareness of energy usage by creating easy-to- understand graphical dashboards and reports from data è Cost Allocation: Identify "quick-win" opportunities for energy savings Decarbonization è Energy Efficiency Compliance: Report effectively about local/global energy and environmental building code compliance è Greenhouse Gas Reporting: Track and report emissions effectively to help cut carbon emissions Decarbonization Energy and Environmental Compliance ■■ ■ ■ Advanced Microgrid è Enhance power system reliability, despite grid instability often resulting from powerful storms and grid unavailability è Reduce carbon emissions and optimize cost efficiency by leveraging Distributed Energy Resources (DERs) Decarbonization ■■ Advanced Energy Performance è Energy Performance: Normalize energy data (e.g. with respect to building area) to give context. Analyze energy performance in context using KPIs è Energy Benchmarking: Compare energy usage with respect to other comparable facilities è Energy Modeling and Verification: Model the energy usage versus energy drivers Decarbonization ■ Reference Guide EcoStruxure Power for Railway and Urban Transportation Public SECTION 3 – Digital Solutions and Services across the Facilities 5- eBus Depots Introduction EcoStruxure Value Proposition Applications Overview Reference Architectures SECTION 2 – How EcoStruxure Power Can Support the Railway Industry 2- Traction Substations 3- Auxiliary Powers Systems eBus Depots 6- Tunnel Systems 1- Overhead Lines SECTION 1 – Introduction to the Railway and Urban Transportation Market 7- Depots and Workshops 8- Control Center BIBLIOGRAPHY 4- Passenger Stations SECTION 4 – Design Considerations SECTION 5 – Customer Stories Our Digital Solutions and Services: Applications Overview ■■■ Essential ■■ Recommended ■ Desirable è Power the bus depot with an end-to-end electrical distribution solution for charging your electrical buses è Integrate and manage local power generation and batteries for self-consumption of renewable energy or for resiliency purposes Decarbonization Electrification (EV Charging for eBus Depot) ■■■ Reference Guide EcoStruxure Power for Railway and Urban

Transportation Public SECTION 3 – Digital Solutions and Services across the Facilities 5- eBus Depots Introduction EcoStruxure Value Proposition Applications Overview Reference Architectures SECTION 2 – How EcoStruxure Power Can Support the Railway Industry 2- Traction Substations 3- Auxiliary Powers Systems eBus Depots 6- Tunnel Systems 1- Overhead Lines SECTION 1 – Introduction to the Railway and Urban Transportation Market 7- Depots and Workshops 8- Control Center BIBLIOGRAPHY 4- Passenger Stations SECTION 4 – Design Considerations SECTION 5 – Customer Stories Reference Electrical and Digital Architectures Typical electrical architecture Reference digital architecture Find the Schneider Electric products necessary to implement the selected applications. Then find their location in the electrical architecture. Find how the products, software solutions and cloud services are connected in the digital architecture. Public Typical Electrical Architecture for e-Bus Depots Public Reference Digital Architecture for e-Bus Depots Reference Guide EcoStruxure Power for Railway and Urban Transportation Public SECTION 3 – Digital Solutions and Services across the Facilities WHY READ THIS SECTION? SECTION 3 SECTION 2 – How EcoStruxure Power Can Support the Railway Industry 2- Traction Substations 3- Auxiliary Powers Systems 4- Passenger Stations 5- eBus Depots 6- Tunnel Systems Introduction EcoStruxure Value Proposition Applications Overview Reference Architectures 1- Overhead Lines SECTION 1 – Introduction to the Railway and Urban Transportation Market 7- Depots and Workshops 8- Control Center BIBLIOGRAPHY SECTION 4 – Design Considerations SECTION 5 – Customer Stories The objective of this section is to: • Introduce tunnel systems • Review EcoStruxure Power value propositions and the associated applications for tunnel systems • Provide reference electrical and digital architectures EcoStruxure Power Digital Solutions and Services for: à Tunnel Systems Reference Guide EcoStruxure Power for Railway and Urban Transportation Public SECTION 3 – Digital Solutions and Services across the Facilities SECTION 2 – How EcoStruxure Power Can Support the Railway Industry 2- Traction Substations 3- Auxiliary Powers Systems 5- eBus Depots 6- Tunnel Systems 7- Depots and Workshops 8- Control Center Introduction EcoStruxure Value Proposition Applications Overview Reference Architectures Tunnel Systems BIBLIOGRAPHY 1- Overhead Lines SECTION 1 – Introduction to the Railway and Urban Transportation Market 4- Passenger Stations SECTION 4 – Design Considerations SECTION 5 – Customer Stories What is it? Introduction to Tunnel Systems Railway tunnels allow crossing of geographical landforms while respecting the layout limitations of the railway lines. They involve major civil engineering works and the supply of systems to improve the safe use of the infrastructure. Reference Guide EcoStruxure Power for Railway and Urban Transportation Public SECTION 3 – Digital Solutions and Services across the Facilities SECTION 2 – How EcoStruxure Power Can Support the Railway Industry 2- Traction Substations 3- Auxiliary Powers Systems 5- eBus Depots 6- Tunnel Systems 7- Depots and Workshops 8- Control Center Introduction EcoStruxure Value Proposition Applications Overview Reference Architectures Tunnel Systems BIBLIOGRAPHY 1- Overhead Lines SECTION 1 – Introduction to the Railway and Urban Transportation Market 4- Passenger Stations SECTION 4 – Design Considerations SECTION 5 – Customer Stories Access ControlVentilation How does it work? Introduction to Tunnel Systems A typical tunnel system consists of multiple technical systems that work in coordination in order to fulfill the operational plan. These include: Telecom Fire Detection Power Supply Drainage Lighting Weather Forecasting Signaling Reference Guide EcoStruxure Power for Railway and Urban Transportation Public SECTION 3 – Digital Solutions and Services across the Facilities SECTION 2 – How EcoStruxure Power Can Support the Railway Industry 2- Traction Substations 3- Auxiliary Powers Systems 5- eBus Depots 6- Tunnel Systems 7- Depots and Workshops 8- Control Center Introduction EcoStruxure Value Proposition Applications Overview Reference Architectures Tunnel Systems BIBLIOGRAPHY 1- Overhead Lines SECTION 1 – Introduction to the Railway and Urban Transportation Market 4- Passenger Stations SECTION 4 – Design Considerations SECTION 5 – Customer Stories Main components of the electrical architecture Introduction Public Main Components of the Electrical Architecture for Tunnel Systems Reference Guide EcoStruxure Power for Railway and Urban Transportation Public SECTION 3 – Digital Solutions and Services across the Facilities SECTION 2 – How EcoStruxure Power Can Support the Railway Industry 2- Traction Substations 3- Auxiliary Powers Systems 5- eBus Depots Introduction EcoStruxure Value Proposition Applications Overview Reference Architectures Tunnel Systems 6- Tunnel Systems 1- Overhead Lines SECTION 1 – Introduction to the Railway and Urban Transportation Market 7- Depots and Workshops 8- Control Center BIBLIOGRAPHY 4- Passenger Stations SECTION 4 – Design Considerations SECTION 5 – Customer Stories EcoStruxure Power Value Proposition Apps, analytics, and services Edge Control Connected products for Tunnel Systems Cloud-Based Advisor Services for asset management, data integrity, and workforce empowerment with extended reality guidance AVEVA System Platform Protection relay Remote terminal unit Circuit breaker Safety control unit RIO drop Control unit Power quality meter Protection device UPS Power quality solutions

Automatic transfer switch Variable speed drive Energy meter Panel server 2. Operational Management Edge Control for all systems such as elevators, escalators, lighting, HVAC, drainage, ventilation, etc. These systems can be: • Option 1: centrally controlled (from the Control Center) using Supervisory Control and Data Acquisition (SCADA) • Option 2: locally controlled using onsite HMIs or mobile apps A software interface is used to exchange the control perimeter between the local tunnel system and the Control Center. 3. Analysis & Optimization • Cloud-based predictive power asset maintenance with expert recommendation provided by our Schneider Electric service experts • Consulting Services including network and power quality audits • Augmented reality guidance for complicated or rarely performed procedures AVEVA System Platform EcoStruxure Power Operation / Power Monitoring Expert Cooling Local HMI Our solution to control and supply energy to tunnel systems 1. Primary Equipment Connected products include protective and electrical network automation devices, power meters, power conditioning units (UPS and power quality solution), and building automation. 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BIBLIOGRAPHY 1- Overhead Lines SECTION 1 – Introduction to the Railway and Urban Transportation Market Introduction EcoStruxure Value Proposition Applications Overview Reference Architectures SECTION 4 – Design Considerations SECTION 5 – Customer Stories What is it? Introduction to Depots and Workshops A depot or workshop is a railway facility where preventive and corrective maintenance tasks are carried out on rolling stock. The difference between the two is not totally clear, but the former is usually more focused on train storage and their periodic maintenance, while the latter is more focused on major repairs. However, it is common for both types of services to be carried out within the same building. Main line Stabling Area Yard Area Pway & Infrastructure Building Workshop Building Car Delivery Test Track Depot Control Center Administrative Building 1 4 5 A train depot/workshop has the following main areas: 1. Train yard 2. Train workshop building 3. Train wash plant 4. Test track 5. Depot control center Wash Plant Wheel Lathe Store 2 3 Reference Guide EcoStruxure Power for Railway and Urban Transportation Public 7- Depots and Workshops Depots and Workshops SECTION 3 – Digital Solutions and Services across the Facilities SECTION 2 – How EcoStruxure Power Can Support the Railway Industry 2- Traction Substations 3- Auxiliary Powers Systems 4- Passenger Stations 5- eBus Depots 6- Tunnel Systems 8- Control Center BIBLIOGRAPHY 1- Overhead Lines SECTION 1 – Introduction to the Railway and Urban Transportation Market Introduction EcoStruxure Value Proposition Applications Overview Reference Architectures SECTION 4 – Design Considerations SECTION 5 – Customer Stories Drainage Traction Power How does it work? Introduction to Depots and Workshops Typical depots and workshops consist of multiple technical systems that work in coordination in order to fulfill the operational plan. 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Proposition Applications Overview Reference Architectures SECTION 4 – Design Considerations SECTION 5 – Customer Stories Specific pillars for depots and workshops EcoStruxure Power Value Proposition EcoStruxure Power provides applications to support the challenges of depots and workshops for Railway and Urban Transportation, with the following pillars: Reliable Electrification Safety and Comfort Enhance safety and comfort in passenger stations and tunnels Digitalization Operate centrally and maintain infrastructure efficiently Decarbonization Reduce energy consumption and carbon footprint Capacity Management Guided Procedures Through Extended Reality Circuit Breaker Settings Monitoring Basic Energy Awareness Power Event Analysis Asset Performance Advanced Energy Performance Power Quality Monitoring, Correction, and Compliance Advanced Microgrid Electrical Distribution Monitoring and Alarming Continuous Thermal Monitoring Backup Power Testing Effective Energy Accounting Improve 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and Services: Applications Overview ■■■ Essential ■■ Recommended ■ Desirable Click on the blue links to have more information Continuous Thermal Monitoring è Monitor the temperature of busbar, cable, transformer, and withdrawable circuit breaker connections è Help detect poor connections at an early stage è Provide temperature alarming and reporting for fast response Guided Procedures Through XR è Use Extended Reality to perform step-by-step guidance è Benefit from "X-ray" vision and virtually overlaid contextual asset and site information, live data, events and alarms è Take advantage of remote collaboration Safety and Comfort Safety and Comfort Backup Power Testing è Automatically record key backup power test parameters such as run time, engine loading, exhaust and engine temperatures è Perform automated backup power test reporting Digitalization Circuit Breaker Settings Monitoring è Compare current circuit breaker settings with commissioned settings è Help detect inappropriate setting modifications periodically è Provide information for capacity planning Digitalization ■■■ ■■ ■■ ■ è Provide distributed control and supervision of overhead (catenary) line disconnectors Reliable Electrification Overhead Line Protection and Automation ■■■ Reference Guide EcoStruxure Power for Railway and Urban Transportation Public 7- Depots and Workshops Depots and Workshops SECTION 3 – Digital Solutions and Services across the Facilities SECTION 2 – How EcoStruxure Power Can Support the Railway Industry 2- Traction Substations 3- Auxiliary Powers Systems 4- Passenger Stations 5- eBus Depots 6- Tunnel Systems 8- Control Center

BIBLIOGRAPHY 1- Overhead Lines SECTION 1 – Introduction to the Railway and Urban Transportation Market Introduction EcoStruxure Value Proposition Applications Overview Reference Architectures SECTION 4 – Design Considerations SECTION 5 – Customer Stories Our Digital Solutions and Services: Applications Overview ■■■ Essential ■■ Recommended ■ Desirable Click on the blue links to have more information Effective Energy Accounting Identify areas for possible energy conservation measures: è Utility Bill Verification: Identify billing errors by comparison with a shadow bill è Cost Allocation: Allocate energy costs to terminals or departments for accurate billing è Power Factor correction: Mitigate harmonic effects and power quality issues Decarbonization Basic Energy Awareness è Energy Monitoring: Increase awareness of energy usage by creating easy-to- understand graphical dashboards and reports from data è Cost Allocation: Identify "quick-win" opportunities for energy savings Decarbonization ■■■ ■■ Advanced Microgrid è Enhance power system reliability, despite grid instability often resulting from powerful storms and grid unavailability è Reduce carbon emissions and optimize cost efficiency by leveraging Distributed Energy Resources (DERs) Decarbonization ■■ Asset Performance è Make asset health visible across the entire system è Streamline inspections using continuous asset health monitoring è Optimize maintenance planning with analytics and expert advice Digitalization ■■ Advanced Energy Performance è Energy Performance: Normalize energy data (e.g. with respect to building area) to give context. Analyze energy performance in context using KPIs è Energy Benchmarking: Compare energy usage with respect to other comparable facilities è Energy Modeling and Verification: Model the energy usage versus energy drivers Decarbonization ■■ Reference Guide EcoStruxure Power for Railway and Urban Transportation Public 7- Depots and Workshops Depots and Workshops SECTION 3 – Digital Solutions and Services across the Facilities SECTION 2 – How EcoStruxure Power Can Support the Railway Industry 2- Traction Substations 3- Auxiliary Powers Systems 4- Passenger Stations 5- eBus Depots 6- Tunnel Systems 8- Control Center BIBLIOGRAPHY 1- Overhead Lines SECTION 1 – Introduction to the Railway and Urban Transportation Market Introduction EcoStruxure Value Proposition Applications Overview Reference Architectures SECTION 4 – Design Considerations SECTION 5 – Customer Stories Our Digital Solutions and Services: Applications Overview ■■■ Essential ■■ Recommended ■ Desirable Click on the blue links to have more information è Energy Efficiency Compliance: Report effectively about local/global energy and environmental building code compliance è Greenhouse Gas Reporting: Track and report emissions effectively to help cut carbon emissions Decarbonization Energy and Environmental Compliance ■■ Reference Guide EcoStruxure Power for Railway and Urban Transportation Public 7- Depots and Workshops Depots and Workshops SECTION 3 – Digital Solutions and Services across the Facilities SECTION 2 – How EcoStruxure Power Can Support the Railway Industry 2- Traction Substations 3- Auxiliary Powers Systems 4- Passenger Stations 5- eBus Depots 6- Tunnel Systems 8- Control Center BIBLIOGRAPHY 1- Overhead Lines SECTION 1 – Introduction to the Railway and Urban Transportation Market Introduction EcoStruxure Value Proposition Applications Overview Reference Architectures SECTION 4 – Design Considerations SECTION 5 – Customer Stories Reference Electrical and Digital Architectures Typical electrical architecture Typical digital architecture Find the Schneider Electric products necessary to implement the selected applications. Then find their location in the electrical architecture. Find how the products, software solutions and cloud services are connected in the digital architecture. Public Typical Electrical Architecture for for Depots and Workshops Public Typical Digital Architecture for Depots and Workshops Reference Guide EcoStruxure Power for Railway and Urban Transportation Public SECTION 3 – Digital Solutions and Services across the Facilities WHY READ THIS SECTION? SECTION 3 SECTION 2 – How EcoStruxure Power Can Support the Railway Industry 2- Traction Substations 3- Auxiliary Powers Systems 4- Passenger Stations 5- eBus Depots 6- Tunnel Systems 7- Depots and Workshops 8- Control Center Introduction EcoStruxure Value Proposition Applications Overview Reference Architectures BIBLIOGRAPHY SECTION 4 – Design Considerations SECTION 5 – Customer Stories 1- Overhead Lines SECTION 1 – Introduction to the Railway and Urban Transportation Market The objective of this section is to: • Introduce the control center • Review EcoStruxure Power value propositions and the associated applications for the control center • Provide reference architectures EcoStruxure Power Digital Solutions and Services for: à Control Center Reference Guide EcoStruxure Power for Railway and Urban Transportation Public SECTION 3 – Digital Solutions and Services across the Facilities SECTION 2 – How EcoStruxure Power Can Support the Railway Industry 2- Traction Substations 3- Auxiliary Powers Systems 4- Passenger Stations 5- eBus Depots 6- Tunnel Systems 8- Control Center Introduction EcoStruxure Value Proposition Applications Overview Reference Architectures Control Center BIBLIOGRAPHY 1- Overhead Lines SECTION 1 – Introduction to the Railway and Urban Transportation Market 7- Depots and Workshops BIBLIOGRAPHY SECTION 4 – Design Considerations SECTION 5 – Customer Stories What is it? Introduction to the Control

Center The Control Center is a central location from which the following facilities (described in the previous sections) are operated: • Traction Substations • Overhead Lines • Auxiliary Power System • Passenger Stations • Tunnel Systems • Datacenters Its purpose is to achieve compliance with the operational plan, with the minimum necessary resources. Comment: • Initially, the responsibility was located at the local levels of the facilities. • Now, process automation makes it possible to delegate responsibility to a higher hierarchy facility and increase the operational efficiency. Reference Guide EcoStruxure Power for Railway and Urban Transportation Public SECTION 3 – Digital Solutions and Services across the Facilities SECTION 2 – How EcoStruxure Power Can Support the Railway Industry 2- Traction Substations 3- Auxiliary Powers Systems 4- Passenger Stations 5- eBus Depots 6- Tunnel Systems 8- Control Center Introduction EcoStruxure Value Proposition Applications Overview Reference Architectures Control Center BIBLIOGRAPHY 1- Overhead Lines SECTION 1 – Introduction to the Railway and Urban Transportation Market 7- Depots and Workshops BIBLIOGRAPHY SECTION 4 – Design Considerations SECTION 5 – Customer Stories Real-time Operation Asset Management Objective Add advanced facility maintenance strategies to traditional corrective and preventive maintenance. This helps optimize asset availability without increasing maintenance costs. Objective Optimize operations with the analytics applied to data acquired from the field devices. This helps to empower the workforce. Operational Efficiency How does it work? (1/2) Introduction to the Control Center The control center is the facility that centrally manages the railway installations. The most relevant element of this facility is the control room, from which the system operators are mandated to perform the following functions: How • Monitor and control the facilities including the implementation of automated systems that facilitate any changes in the configuration of the tasks. • Manage operations for all the facilities (full delegation, exceptions for abnormal situations). • Manage emergency scenarios for passenger stations and tunnel systems. Objective Manage the operational plan of the facilities remotely and centrally. This helps to optimize the state of operation under various situations. How Collect data from field devices to monitor asset health and perform: • Condition-based maintenance: Proactive monitoring depending on the condition of the asset. Maintenance is triggered when critical parameters vary beyond their “normal” range. • Predictive maintenance: a maintenance task is performed when measured variables of an asset deviate from those indicated as normal by a digital model of the asset. How Use data collected at operational level to implement advanced functionalities such as: • Electrical simulation: commonly used for operator training or operation support, and during the facility electrical design phase. • Basic and advanced reporting: advanced representation of information and generation of new data, using data processing techniques and AI models. Reference Guide EcoStruxure Power for Railway and Urban Transportation Public SECTION 3 – Digital Solutions and Services across the Facilities SECTION 2 – How EcoStruxure Power Can Support the Railway Industry 2- Traction Substations 3- Auxiliary Powers Systems 4- Passenger Stations 5- eBus Depots 6- Tunnel Systems 8- Control Center Introduction EcoStruxure Value Proposition Applications Overview Reference Architectures Control Center BIBLIOGRAPHY 1- Overhead Lines SECTION 1 – Introduction to the Railway and Urban Transportation Market 7- Depots and Workshops BIBLIOGRAPHY SECTION 4 – Design Considerations SECTION 5 – Customer Stories A Redundancy-based Strategy The Control Center is responsible for the operations of all the facilities (except in abnormal situations mainly related to maintenance and telecom network issues). Therefore, it has a huge responsibility, and its availability is critical. To improve availability of the control center, essential services are usually implemented with redundancy: • Redundancy of the components inside the control center • Redundancy of the control center in other locations (emergency control center). How does it work? (2/2) Introduction to the Control Center In case of failure of a component or of unavailability of the control center, the redundant component / control center takes over the function/service until repair/availability. Reference Guide EcoStruxure Power for Railway and Urban Transportation Public SECTION 3 – Digital Solutions and Services across the Facilities SECTION 2 – How EcoStruxure Power Can Support the Railway Industry 2- Traction Substations 3- Auxiliary Powers Systems 5- eBus Depots 6- Tunnel Systems 8- Control Center Introduction EcoStruxure Value Proposition Applications Overview Reference Architectures Control Center BIBLIOGRAPHY 1- Overhead Lines SECTION 1 – Introduction to the Railway and Urban Transportation Market 7- Depots and Workshops BIBLIOGRAPHY 4- Passenger Stations SECTION 4 – Design Considerations SECTION 5 – Customer Stories EcoStruxure Power Value Proposition Apps, analytics, and services Edge Control Connected products for Control Centers Cloud-Based Advisor Services for asset management, data integrity and workforce empowerment with extended reality guidance AVEVA Insight EcoStruxure XR Operator Advisor EcoStruxure EV Advisor EcoStruxure Microgrid Advisor EcoStruxure Building Advisor AVEVA System Platform EcoStruxure Power Operation / Power Monitoring Expert EcoStruxure Building Operation Simulation Engine EcoCare Membership * EcoStruxure Cybersecurity

Admin Expert 2. Operational Management Among the usual tasks to be carried out by the operators of the control center, we can highlight the following: • Assurance of power supply to trains and rail consumers • Mitigation of the impact of electrical faults in the railway traction scope. • Implementation of the different operational / emergency scenarios defined for passenger stations and tunnels. • Central management of the cybersecurity for the full architecture. 3. Analysis & Optimization Applications for advanced asset management, analysis and optimization of operations: • Predictive and condition-based maintenance for electrical assets • Integration, contextualization, analysis, and representation of information • Advanced management of microgrids and electric chargers, including technical and economic aspects. • Consulting Services, including network and power quality audits • Augmented reality guidance for complicated or rarely performed procedures 1. Primary Equipment Data provided by connected products from the different facilities Energy control of traction, non-traction and catenary systems Passenger Stations Tunnels Our solution to control and supply energy to control centers Reference Guide EcoStruxure Power for Railway and Urban Transportation Public SECTION 3 – Digital Solutions and Services across the Facilities SECTION 2 – How EcoStruxure Power Can Support the Railway Industry 2- Traction Substations 3- Auxiliary Powers Systems 5- eBus Depots 6- Tunnel Systems 8- Control Center Introduction EcoStruxure Value Proposition Applications Overview Reference Architectures Control Center BIBLIOGRAPHY 1- Overhead Lines SECTION 1 – Introduction to the Railway and Urban Transportation Market 7- Depots and Workshops BIBLIOGRAPHY 4- Passenger Stations SECTION 4 – Design Considerations SECTION 5 – Customer Stories Specific pillars for control centers EcoStruxure Power Value Proposition EcoStruxure Power provides applications to support the challenges of control centers for Railway and Urban Transportation, with the following pillars: Reliable Electrification Improve reliability of electrical infrastructure Electrical Distribution Monitoring and Alarming Capacity Management Power Event Analysis Power Quality Monitoring, Correction, and Compliance Overhead Line Protection and Automation Safety and Comfort Enhance safety and comfort in passenger stations and tunnels Continuous Thermal Monitoring Guided Procedures Through Extended Reality Digitalization Operate centrally and maintain infrastructure efficiently Circuit Breaker Settings Monitoring Asset Performance Operator Training Simulation Simulate Before Operate Cybersecurity Central Management Asset Preventive Maintenance Asset analytics Massive Data Archive and Contextualization Rail Power Design Decarbonization Reduce energy consumption and carbon footprint Basic Energy Awareness Advanced Energy Performance Energy and Environmental Compliance Electrification (EV Charging for eBus Depot) Building Automation Effective Energy Accounting Advanced Microgrid Reference Guide EcoStruxure Power for Railway and Urban Transportation Public SECTION 3 – Digital Solutions and Services across the Facilities SECTION 2 – How EcoStruxure Power Can Support the Railway Industry 2- Traction Substations 3- Auxiliary Powers Systems 5- eBus Depots 6- Tunnel Systems 8- Control Center Introduction EcoStruxure Value Proposition Applications Overview Reference Architectures Control Center BIBLIOGRAPHY 1- Overhead Lines SECTION 1 – Introduction to the Railway and Urban Transportation Market 7- Depots and Workshops BIBLIOGRAPHY 4- Passenger Stations SECTION 4 – Design Considerations SECTION 5 – Customer Stories Our Digital Solutions and Services: Applications Overview ■■■ Essential ■■ Recommended ■ Desirable Click on the blue links to have more information Capacity Management è Visualize real-time or historical power system capacity è Monitor and trend circuit or equipment loading è Provide information for capacity planning Reliable Electrification Power Event Analysis è Provide a user-friendly graphical tool to simplify and save time in event analysis è Provide an aggregated view of events in the same dashboard è Enable root cause analysis Reliable Electrification Power Quality Monitoring, Correction, and Compliance è Power Quality Monitoring and Compliance: Monitor persistent steady state and event- based disturbances to better understand and analyze power quality disturbances è Power Quality Correction: Correct over/under voltages, harmonics, etc. Reliable Electrification ■■■ ■■■ ■■ è Provide real-time status of the electrical distribution system è Help identify anomalies and notify the right personnel è Aggregate onboard alarm data in an easy-to-understand way è Take advantage of native integration of intelligent electrical devices Reliable Electrification Electrical Distribution Monitoring and Alarming ■■■ è Provide distributed control and supervision of overhead (catenary) line disconnectors Reliable Electrification Overhead Line Protection and Automation ■■■ Reference Guide EcoStruxure Power for Railway and Urban Transportation Public SECTION 3 – Digital Solutions and Services across the Facilities SECTION 2 – How EcoStruxure Power Can Support the Railway Industry 2- Traction Substations 3- Auxiliary Powers Systems 5- eBus Depots 6- Tunnel Systems 8- Control Center Introduction EcoStruxure Value Proposition Applications Overview Reference Architectures Control Center BIBLIOGRAPHY 1- Overhead Lines SECTION 1 – Introduction to the Railway and Urban Transportation Market 7- Depots and Workshops BIBLIOGRAPHY 4- Passenger Stations SECTION 4 –

Design Considerations SECTION 5 – Customer Stories Our Digital Solutions and Services: Applications Overview ■■■ Essential ■■ Recommended ■ Desirable Click on the blue links to have more information Continuous Thermal Monitoring è Monitor the temperature of busbar, cable, transformer, and withdrawable circuit breaker connections è Help detect poor connections at an early stage è Provide temperature alarming and reporting for fast response Guided Procedures Through XR è Use Extended Reality to perform step-by-step guidance è Benefit from “X-ray” vision and virtually overlaid contextual asset and site information, live data, events and alarms è Take advantage of remote collaboration Safety and Comfort Safety and Comfort Circuit Breaker Settings Monitoring è Compare current circuit breaker settings with commissioned settings è Help detect inappropriate setting modifications periodically è Provide information for capacity planning Digitalization Asset Performance è Make asset health visible across the entire system è Streamline inspections using continuous asset health monitoring è Optimize maintenance planning with analytics and expert advice Digitalization ■■■ ■ ■ ■■ Operator Training Simulation è Train new employees and build confidence on new systems è Practice operation within a simulated but highly realistic environment to enhance safety and operational efficiency è Track and review trainee actions to analyze and challenge them Digitalization ■■ Reference Guide EcoStruxure Power for Railway and Urban Transportation Public SECTION 3 – Digital Solutions and Services across the Facilities SECTION 2 – How EcoStruxure Power Can Support the Railway Industry 2- Traction Substations 3- Auxiliary Powers Systems 5- eBus Depots 6- Tunnel Systems 8- Control Center Introduction EcoStruxure Value Proposition Applications Overview Reference Architectures Control Center BIBLIOGRAPHY 1- Overhead Lines SECTION 1 – Introduction to the Railway and Urban Transportation Market 7- Depots and Workshops BIBLIOGRAPHY 4- Passenger Stations SECTION 4 – Design Considerations SECTION 5 – Customer Stories Our Digital Solutions and Services: Applications Overview ■■■ Essential ■■ Recommended ■ Desirable Click on the blue links to have more information Simulate Before Operate è Provide operators with a list of potential side effects, prior to executing a command è Empower employees to feel more confident when operating their facilities by providing real-time guidance è Reduce human error that could lead to outages or safety concerns Digitalization Cybersecurity Central Management è Integrate cybersecurity solutions allowing the operations team to have visibility of key cybersecurity data è Help manage/maintain cybersecurity control points è Align to cybersecurity standards and best practices to strengthen OT security Digitalization Asset Preventive Maintenance è Minimize inventory costs and improve spare part availability è Manage mobile work for more accurate and timely data collection è Receive proactive maintenance information by identifying labor/material/tools/drawings on work order Digitalization Asset Analytics è Analyze utilization, efficiency, and condition-management of assets. Receive alerts and notifications è Provide automated analytics using supervised or unsupervised machine learning è Create dynamic data visualizations and asset frameworks for contextual data viewing Digitalization Massive Data Archive and Contextualization è Collect and store in one single place real-time data from operating assets with sub- second granularity è Contextualize and visualize data Digitalization ■■ ■■■ ■■ ■■ ■■ Reference Guide EcoStruxure Power for Railway and Urban Transportation Public SECTION 3 – Digital Solutions and Services across the Facilities SECTION 2 – How EcoStruxure Power Can Support the Railway Industry 2- Traction Substations 3- Auxiliary Powers Systems 5- eBus Depots 6- Tunnel Systems 8- Control Center Introduction EcoStruxure Value Proposition Applications Overview Reference Architectures Control Center BIBLIOGRAPHY 1- Overhead Lines SECTION 1 – Introduction to the Railway and Urban Transportation Market 7- Depots and Workshops BIBLIOGRAPHY 4- Passenger Stations SECTION 4 – Design Considerations SECTION 5 – Customer Stories Our Digital Solutions and Services: Applications Overview ■■■ Essential ■■ Recommended ■ Desirable Click on the blue links to have more information Rail Power Design è Visualize and analyze traction power systems using synchronized geospatial and schematic views è Simulate and analyze operation of combined DC and AC power supply networks è Model traction power-specific devices with built-in components and engineering libraries Digitalization Effective Energy Accounting Identify areas for possible energy conservation measures: è Utility Bill Verification: Identify billing errors by comparison with a shadow bill è Cost Allocation: Allocate energy costs to terminals or departments for accurate billing è Power Factor correction: Mitigate harmonic effects and power quality issues Decarbonization Basic Energy Awareness è Energy Monitoring: Increase awareness of energy usage by creating easy-to- understand graphical dashboards and reports from data è Cost Allocation: Identify "quick-win" opportunities for energy savings Decarbonization Advanced Microgrid è Enhance power system reliability, despite grid instability often resulting from powerful storms and grid unavailability è Reduce carbon emissions and optimize cost efficiency by leveraging Distributed Energy Resources (DERs) Decarbonization ■■■ ■■ ■■ ■■ Advanced Energy Performance è Energy Performance: Normalize energy data (e.g. with respect to building area) to give context. 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Then find their location in the reference architecture. Find how the products, software solutions and cloud services are connected in the digital architecture. Public Typical Reference Architecture for the Control Center Public Reference Digital Architecture for the Control Center Reference Guide EcoStruxure Power for Railway and Urban Transportation Public SECTION 4 SECTION 2 – How EcoStruxure Power Can Support the Railway Industry SECTION 3 – Digital Solutions and Services across the Facilities SECTION 4 – Design Considerations SECTION 1 – Introduction to the Railway and Urban Transportation Market Control Center Solutions Control Strategies for Passenger Stations Control Strategies for Traction Substations Communications Protocols Time Synchronization Integration with BMS Cybersecurity Environmental Data Program BIBLIOGRAPHY SECTION 5 – Customer Stories WHY READ THIS SECTION? Design Considerations à Control Center Solutions à Communication Protocols à Time Synchronization à Integration with BMS à Cybersecurity à Environmental Data Program The objective of this section is to: • Provide the details of the critical system design components to be considered while designing digital architecture • Addresses design considerations of the electrical installation in the context of communications, data, time and cybersecurity à Control Strategies for Passenger Stations à Control Strategies for Traction substations Reference Guide EcoStruxure Power for Railway and Urban Transportation Public SECTION 4 – Design Considerations SECTION 2 – How EcoStruxure Power Can Support the Railway Industry SECTION 3 – Digital Solutions and Services across the Facilities SECTION 1 – Introduction to the Railway and Urban Transportation Market Control Center Solutions Control Strategies for Passenger Stations Control Strategies for Traction Substations Communications Protocols Cybersecurity BIBLIOGRAPHY SECTION 5 – Customer Stories Integration with BMS Time Synchronization Environmental Data Program The control center centralizes the operation of railway facilities. Schneider Electric offers the following solutions for effective management and control: How to Choose a Solution for Operation Control Centers Management of Energy Management of Passenger Stations Control of Railway Tunnels Control of Datacenters AVEVA System Platform EcoStruxure Power Monitoring Expert EcoStruxure Building Operation EcoStruxure IT Expert AVEVA System Platform AVEVA System Platform Basic functionalities EcoStruxure Power Operation Complex systems Building approach Industrial approach Additional analysis EcoStruxure Power Monitoring Expert • Continuous thermal monitoring • Power event analysis • Power quality monitoring • Energy usage analysis • Energy efficiency & power quality compliance • Good capabilities for integration with external systems •

Industrial interoperability protocols • Management of power supply • Monitoring of environmental conditions • Railways • Building element integration • Building management • Interoperability protocols • Urban Transportation • Higher integration needs of external systems • Industrial interoperability protocols • Basic operation and monitoring • Alarm management • Access control • Automatism and interlocks • Basic reporting • Continuous thermal monitoring • Power event analysis • Power quality monitoring • Energy usage analysis • Energy efficiency & power quality compliance • Advanced alarm management • Advanced reporting & data analytics tools • Emergency control center • Graphical event replay • Scalability Additional analysis EcoStruxure Power Monitoring Expert • Continuous thermal monitoring • Power event analysis • Power quality monitoring • Energy usage analysis • Energy efficiency & power quality compliance Tunnel Management Additional analysis EcoStruxure Power Monitoring Expert • Continuous thermal monitoring • Power event analysis • Power quality monitoring • Energy usage analysis • Energy efficiency & power quality compliance Datacenter Management Reference Guide EcoStruxure Power for Railway and Urban Transportation Public SECTION 4 – Design Considerations SECTION 2 – How EcoStruxure Power Can Support the Railway Industry SECTION 3 – Digital Solutions and Services across the Facilities SECTION 1 – Introduction to the Railway and Urban Transportation Market Control Center Solutions Control Strategies for Passenger Stations Control Strategies for Traction Substations Cybersecurity BIBLIOGRAPHY SECTION 5 – Customer Stories Integration with BMS Time Synchronization Environmental Data Program Communications Protocols Control Strategies for Passenger Stations Passenger stations can be conceptualized in various ways, depending on the approach to automation and the perception of the facility. Surface-installed passenger station Underground passenger station Application • Mainlines or in high-speed rail systems Control strategy • Considered as a specialized type of building • Alignment with building management system Typical equipment • Floor controllers (AS-P) • Room controllers (RP-C) • Building Operation & Building Advisor for centralizing station information. Telecommunication Protocols • KNX • DALI • Other standard telecontrol protocols. Application • Urban transportation Control strategy • Considered as an industrial facility • Use of industrial automation for critical components like ventilation Typical equipment • PLCs based solutions (M580 and M340) • AVEVA System Platform for centralizing information Telecommunication Protocols • OPC (for advanced data modeling and cybersecurity features). • Modbus (for interconnexion with legacy systems) Reference Guide EcoStruxure Power for Railway and Urban Transportation Public SECTION 4 – Design Considerations SECTION 2 – How EcoStruxure Power Can Support the Railway Industry SECTION 3 – Digital Solutions and Services across the Facilities SECTION 1 – Introduction to the Railway and Urban Transportation Market Control Center Solutions Control Strategies for Passenger Stations Control Strategies for Traction Substations Cybersecurity BIBLIOGRAPHY SECTION 5 – Customer Stories Integration with BMS Time Synchronization Environmental Data Program Communications Protocols Control Strategies for Traction Substations Alternating Current (AC) Direct Current (DC) Application Mainly in high performance systems such as mainlines or in high- speed rail systems • Railway systems with very high energy demand • High-speed travel • Railway systems with a very high frequency of train movements Control Strategy • Use elements borrowed from electrical distribution Typical equipment • Specialized controllers for managing electrical devices with a native implementation of most of the necessary functions for substation automation Interoperability standard • IEC 61850: describes the implementation of the functions present in a substation from both a constructive and functional perspective Advantage • Fully adapted to control an electrical process • Analysis of electrical events • Excellent performance • Maintenance management & engineering tools • Good interoperability due to the use of IEC 61850 • Cybersecurity requirements Drawback • Higher price Application Mainly urban transportation • Systems with lower energy demand (tramways) • Networks with a strong tradition in this technology (metros) Control Strategy • Choose a general-purpose programmable logic controller (PLC) as the main element for their automation Typical equipment • Use general-purpose programmable logic controllers (PLCs) for automation Interoperability standard • Modbus (and variants) Advantage • Simple configuration • Price competitive Drawback • Limitation in meeting usual standards of the electrical world • Limited performance • Limitations due to Modbus: deficiencies in electrical object modeling, event dating, and cybersecurity. Can be addressed using non-standard versions of the protocol or OPC UA protocol (widely used in industrial environments). Control strategy is different whether the system is supplied with alternating or direct current: Reference Guide EcoStruxure Power for Railway and Urban Transportation Public SECTION 4 – Design Considerations SECTION 2 – How EcoStruxure Power Can Support the Railway Industry SECTION 3 – Digital Solutions and Services across the Facilities SECTION 1 – Introduction to the Railway and Urban Transportation Market Control Center Solutions Control Strategies for Passenger Stations Control Strategies for Traction Substations Communications Protocols Cybersecurity

BIBLIOGRAPHY SECTION 5 – Customer Stories Integration with BMS Time Synchronization Environmental Data Program Communications Protocols Modern electrical distribution systems, especially in critical infrastructure like railways and urban transportation, use various industrial protocols for data communication from devices such as circuit breakers, relays, controllers, and sensors. Key protocols include: Commonly used for high-speed medium voltage automation. Provides: • Consistent measurement naming • Fast device-to-device communication (GOOSE messaging) • Communication to a SCADA system IEC 61850 Modbus RTU and Modbus TCP/IP Common in low voltage systems for metering, protection, and control. Can convert serial Modbus to Modbus TCP/ IP for data integration with a power monitoring or SCADA software . Wireless (IEC 802.15-4, e.g. Zigbee) Enables low-powered simple data communication for energy and condition monitoring sensors. Can be aggregated and converted to Modbus TCP/IP for integration with a power monitoring or SCADA software (using a data concentrator and protocol converter device) EcoStruxure Power natively integrates with Schneider Electric devices to obtain real-time, historical event and data logs, as well as waveforms. However, it is common for 3rd party devices to store event logs and waveform data in proprietary formats. The EcoStruxure Power platform can acquire data from any device using the open protocols mentioned above, provided the data is available in non-vendor-proprietary formats. • Communications Learn more about: Reference Guide EcoStruxure Power for Railway and Urban Transportation Public SECTION 4 – Design Considerations SECTION 2 – How EcoStruxure Power Can Support the Railway Industry SECTION 3 – Digital Solutions and Services across the Facilities SECTION 1 – Introduction to the Railway and Urban Transportation Market Control Center Solutions Control Strategies for Passenger Stations Control Strategies for Traction Substations Time Synchronization Cybersecurity BIBLIOGRAPHY SECTION 5 – Customer Stories Integration with BMS Environmental Data Program Communications Protocols Time Synchronization Why consider time synchronization of connected products? To operate, EcoStruxure Power applications collect data from the connected products of the electrical installation (such as relays, trip units, power meter, sensors). When applications analyze and correlate timestamped data from multiple connected products, it is crucial to make sure that their internal clocks are accurate relative to other devices and local time. The setting of devices to a single time reference is called time synchronization. The choice of the time synchronization solution must be defined during the system design phase. It depends on the time criticality of the applications deployed to monitor and control the different parts of the installation. Refer to next page for further explanations about time criticality. • "How to Optimize Time-Synchronization and Data Recording for EcoStruxure Power Digital Applications" Technical Guide For a detailed coverage of time synchronization, refer to: • Data recording and Timestamping section in the EcoStruxure Power Design Guide Reference Guide EcoStruxure Power for Railway and Urban Transportation Public SECTION 4 – Design Considerations SECTION 2 – How EcoStruxure Power Can Support the Railway Industry SECTION 3 – Digital Solutions and Services across the Facilities SECTION 1 – Introduction to the Railway and Urban Transportation Market Control Center Solutions Control Strategies for Passenger Stations Control Strategies for Traction Substations Time Synchronization Cybersecurity BIBLIOGRAPHY SECTION 5 – Customer Stories Integration with BMS Environmental Data Program Communications Protocols What is the time criticality of an application? Time Synchronization The time criticality of an application defines the level of time accuracy required for data timestamping to enable the proper operation of the application. EcoStruxure Power categorizes applications into three levels of time criticality: Example of time criticality: • Continuous Thermal Monitoring: This application monitors the progressive rise in busbar connection temperature to help prevent fires. It has a low time criticality. • Power Event Analysis: This application reconstructs the sequence of events among multiple electrical equipment to help understand the cause(s) of an incident. It has a high time criticality. Refer to next page to learn how to select the appropriate time synchronization solution based on the time criticality. • Time criticality of applications Learn more about: Digital Application Time Critical Time Accuracy Upper Limit Time Accuracy Lower Limit High ± 1 ms ± 10 ms Medium ± 10 ms ± 1 s Low ± 1 s ± 10 s Reference Guide EcoStruxure Power for Railway and Urban Transportation Public SECTION 4 – Design Considerations SECTION 2 – How EcoStruxure Power Can Support the Railway Industry SECTION 3 – Digital Solutions and Services across the Facilities SECTION 1 – Introduction to the Railway and Urban Transportation Market Control Center Solutions Control Strategies for Passenger Stations Control Strategies for Traction Substations Time Synchronization Cybersecurity BIBLIOGRAPHY SECTION 5 – Customer Stories Integration with BMS Environmental Data Program Communications Protocols How to select the time synchronization solution based on time criticality? Time Synchronization There are many options available for time synchronization protocols, which can make it challenging to develop a cohesive strategy for all connected devices. To achieve optimal performance while minimizing costs, it is common to enforce the most accurate protocols only in the sensitive areas of electrical distribution (e.g., the electrical supply of core industrial processes) and use less accurate solutions in areas with lower sensitivity (e.g., utilities). The table below provides an overview of the solutions based on achieved time criticality and related costs: To summarize the table : • PTP provides the best performance versus cost option available today for highly time-critical applications, but is not available on all devices • IRIG-B offers similar performance to PTP but comes with a much higher installation cost. • NTP is the next best alternative for medium time-criticality needs. • SNTP or Modbus are adequate for low time-critical applications. Application Time Critical Typical Time Accuracy Protocol Media Protocol Typical Cost High ± 1 ms Ethernet PTP (IEEE 1588) $ $ High ± 1 ms Serial IRIG-B $ $ $ Medium ± 10 ms to 100 ms Ethernet NTP $ Medium ± 100 ms Serial DCF77 $ $ Low ± 1 s Ethernet SNTP $ Low ± 1 s Ethernet Over Modbus / ION from Edge Control $ Low ± 1 s Serial 1 per 10 $ $ Reference Guide EcoStruxure Power for Railway and Urban Transportation Public SECTION 4 – Design Considerations SECTION 2 – How EcoStruxure Power Can Support the Railway Industry SECTION 3 – Digital Solutions and Services across the Facilities SECTION 1 – Introduction to the Railway and Urban Transportation Market Control Center Solutions Control Strategies for Passenger Stations Control Strategies for Traction Substations Integration with BMS Cybersecurity BIBLIOGRAPHY SECTION 5 – Customer Stories Time Synchronization Environmental Data Program Communications Protocols Why integrate mechanical and electrical systems? Integration with Building Automation Systems (BMS) • Data Integration and Interoperability between Systems Learn more about: Need for data aggregation Facility infrastructure is experiencing a convergence of information and operational systems. This is particularly true for Railway and Urban Transportation applications, where mechanical and electrical systems are essential infrastructure. These systems are rapidly generating increasing amounts of data, with the addition of new sensors, meters, and other smart equipment. It is crucial to have robust software system with proper data aggregation from these devices. Examples of mechanical and electrical systems integration in Railway • Energy performance monitoring : Track and model facility energy usage; • Asset management: View mechanical and electrical asset performance in one place; • Fault management: Detect faults and respond through an integrated interface. Benefits of systems integration Integrating the systems: • Creates a unified interface for visualizing, analyzing, and reporting data, simplifying daily tasks for operations and maintenance staff; • Enables applications to utilize context from both systems to optimize the decision-making processes; • Enhances overall Operational efficiency Reference Guide EcoStruxure Power for Railway and Urban Transportation Public SECTION 4 – Design Considerations SECTION 2 – How EcoStruxure Power Can Support the Railway Industry SECTION 3 – Digital Solutions and Services across the Facilities SECTION 1 – Introduction to the Railway and Urban Transportation Market Control Center Solutions Control Strategies for Passenger Stations Control Strategies for Traction Substations Integration with BMS Cybersecurity BIBLIOGRAPHY SECTION 5 – Customer Stories Time Synchronization Environmental Data Program Communications Protocols Why plan the integration at the design phase? Integration with Building Automation Systems (BMS) • Data Integration and Interoperability between Systems Learn more about: Costly retrofit of existing installations Traditionally, Power Management Systems (electrical systems) and Building Management Systems (including mechanical systems) are designed in silos. The consequence is that it leaves the end user with little to no electrical data in operational systems. Retrofitting this into an existing system can be quite costly. Therefore, it is essential to design the proper IoT electrical systems far in advance. Advantages of early system integration Enabling the BMS and PMS to integrate directly to relevant data allows the systems to perform as designed. Additionally, it also: • Reduces cost and complexity by minimizing excessive wiring of electrical devices to mechanical control systems. • Helps system integrators by enabling a seamless interface to manage facility operations and maintenance; Reference Guide EcoStruxure Power for Railway and Urban Transportation Public SECTION 4 – Design Considerations SECTION 2 – How EcoStruxure Power Can Support the Railway Industry SECTION 3 – Digital Solutions and Services across the Facilities SECTION 1 – Introduction to the Railway and Urban Transportation Market Control Center Solutions Control Strategies for Passenger Stations Control Strategies for Traction Substations Integration with BMS Cybersecurity BIBLIOGRAPHY SECTION 5 – Customer Stories Time Synchronization Environmental Data Program Communications Protocols How is data acquired and integrated within the architecture? (1/2) Integration with Building Automation Systems (BMS) Data acquisition Digital electrical monitoring and control software acquires data from intelligent electrical devices via open communication protocols. This includes: • Real-time information • Historical power events • Data logs • Electrical signal waveforms • Service diagnostics. By default, BMS (Building Management Systems) cannot retrieve certain data from the electrical distribution, such as event logs, waveforms, and diagnostic data. Trying to do this directly with the BMS would require a tremendous amount of engineering. It is more efficient and native to let a PMS (Power Management System) collect the data from the electrical distribution and then integrate the PMS with the BMS. • Data Integration and Interoperability between Systems Learn more about: Reference Guide EcoStruxure Power for Railway and Urban Transportation Public SECTION 4 – Design Considerations SECTION 2 – How EcoStruxure Power Can Support the Railway Industry SECTION 3 – Digital Solutions and Services across the Facilities SECTION 1 – Introduction to the Railway and Urban Transportation Market Control Center Solutions Control Strategies for Passenger Stations Control Strategies for Traction Substations Integration with BMS Cybersecurity BIBLIOGRAPHY SECTION 5 – Customer Stories Time Synchronization Environmental Data Program Communications Protocols How is data acquired and integrated within the architecture? (2/2) Integration with Building Automation Systems (BMS) Data Integration The method/tool to integrate the data depends on the data type, and on the direction of the transfer: The integration is performed through: • An Extract Transform Load functions Used for historical building management data to enable energy data correlation. The integration is performed through: • EcoStruxure Web Services Used for real-time data, alarms, and historical data • Web interface integration (Single Sign On) Used for power and energy dashboards, graphical diagrams, trends, reports, and configuration pages EcoStruxure Building Operation (EBO) EcoStruxure Power Operation (EPO) with Advanced Reporting and Dashboards EcoStruxure Building Operation (EBO) EcoStruxure Power Operation (EPO) with Advanced Reporting and Dashboards PublicExample of Combined Solution with EcoStruxure Building Operation and EcoStruxure Power Operation with Advanced Reporting and Dashboards Reference Guide EcoStruxure Power for Railway and Urban Transportation Public SECTION 4 – Design Considerations SECTION 2 – How EcoStruxure Power Can Support the Railway Industry SECTION 3 – Digital Solutions and Services across the Facilities SECTION 1 – Introduction to the Railway and Urban Transportation Market Control Center Solutions Control Strategies for Passenger Stations Control Strategies for Traction Substations Cybersecurity BIBLIOGRAPHY 1 2 3 5 4 6 7 SECTION 5 – Customer Stories Integration with BMS Time Synchronization Environmental Data Program Communications Protocols ACCESS CONTROL Seven pillars to strengthen cybersecurity Cybersecurity Protect electrical components by verifying the identity of any user requesting access to a component before activating the communication with that component. When used in conjunction with security event logging, this will include ensuring 'non-repudiation,' for example, a person cannot deny that they performed a particular action. Access Control DATA CONFIDENTIALITY USE CONTROL DATA INTEGRITY DATA FLOW TIMELY RESPONSE TO EVENTS RESOURCE AVAILABILITY Cybersecurity is no longer a question of competitive advantage or even minimizing damage. It is a fundamental requirement for doing business today. Here are the seven essential pillars for improving it: Reference Guide EcoStruxure Power for Railway and Urban Transportation Public SECTION 4 – Design Considerations SECTION 2 – How EcoStruxure Power Can Support the Railway Industry SECTION 3 – Digital Solutions and Services across the Facilities SECTION 1 – Introduction to the Railway and Urban Transportation Market Control Center Solutions Control Strategies for Passenger Stations Control Strategies for Traction Substations Cybersecurity BIBLIOGRAPHY 1 2 3 5 4 6 7 SECTION 5 – Customer Stories Integration with BMS Time Synchronization Environmental Data Program Communications Protocols Seven pillars to strengthen cybersecurity Cybersecurity Protect against unauthorized actions on component resources by verifying that the necessary privileges have been granted before allowing a user to perform the actions. This must address what a hacker can potentially do if they access the system and counteract that by only giving the minimum level of access necessary for that user to perform their role. Use Control USE CONTROL DATA CONFIDENTIALITY DATA INTEGRITY DATA FLOW TIMELY RESPONSE TO EVENTS RESOURCE AVAILABILITY ACCESS CONTROL Cybersecurity is no longer a question of competitive advantage or even minimizing damage. It is a fundamental requirement for doing business today. 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Consider a Circuit Breaker that is detecting potential issues in its operation: if the SCADA system is hacked and is forced to indicate everything is okay, that could cause an unexpected and dangerous event. Data Integrity DATA INTEGRITY DATA CONFIDENTIALITY USE CONTROL DATA FLOW TIMELY RESPONSE TO EVENTS RESOURCE AVAILABILITY ACCESS CONTROL Cybersecurity is no longer a question of competitive advantage or even minimizing damage. It is a fundamental requirement for doing business today. 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Data Confidentiality DATA CONFIDENTIALITY USE CONTROL DATA INTEGRITY DATA FLOW TIMELY RESPONSE TO EVENTS RESOURCE AVAILABILITY ACCESS CONTROL Cybersecurity is no longer a question of competitive advantage or even minimizing damage. It is a fundamental requirement for doing business today. 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Here are the seven essential pillars for improving it: Ensure the connection of the device to a segmented network where disconnection strategy, unidirectional gateway, firewall, and demilitarized zones are defined to avoid unnecessary data flow. Network segmentation is a strategy that can stop a cyberattack from going from one connected system to another (for example, from the electrical communication network to the business network). Data Flow DATA FLOW DATA CONFIDENTIALITY USE CONTROL DATA INTEGRITY TIMELY RESPONSE TO EVENTS RESOURCE AVAILABILITY ACCESS CONTROL Reference Guide EcoStruxure Power for Railway and Urban Transportation Public SECTION 4 – Design Considerations SECTION 2 – How EcoStruxure Power Can Support the Railway Industry SECTION 3 – Digital Solutions and Services across the Facilities SECTION 1 – Introduction to the Railway and Urban Transportation Market Control Center Solutions Control Strategies for Passenger Stations Control Strategies for Traction Substations Cybersecurity BIBLIOGRAPHY 1 2 3 5 4 6 7 SECTION 5 – Customer Stories Integration with BMS Time Synchronization Environmental Data Program Communications Protocols Seven pillars to strengthen cybersecurity Cybersecurity Detect, identify and respond to security violations by notifying the proper authority, reporting needed evidence of the violation, and taking timely corrective action when incidents are discovered in mission- critical or safety-critical situations. Timely Response to Events TIMELY RESPONSE TO EVENTS DATA CONFIDENTIALITY USE CONTROL DATA INTEGRITY DATA FLOW RESOURCE AVAILABILITY ACCESS CONTROL Cybersecurity is no longer a question of competitive advantage or even minimizing damage. It is a fundamental requirement for doing business today. 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Resource Availability RESOURCE AVAILABILITY DATA CONFIDENTIALITY USE CONTROL DATA INTEGRITY DATA FLOW TIMELY RESPONSE TO EVENTS ACCESS CONTROL Cybersecurity is no longer a question of competitive advantage or even minimizing damage. It is a fundamental requirement for doing business today. Here are the seven essential pillars for improving it: Reference Guide EcoStruxure Power for Railway and Urban Transportation Public SECTION 4 – Design Considerations SECTION 2 – How EcoStruxure

Power Can Support the Railway Industry SECTION 3 – Digital Solutions and Services across the Facilities SECTION 1 – Introduction to the Railway and Urban Transportation Market Control Center Solutions Control Strategies for Passenger Stations Control Strategies for Traction Substations Cybersecurity BIBLIOGRAPHY SECTION 5 – Customer Stories Integration with BMS Time Synchronization Environmental Data Program Communications Protocols Recommendations for selecting your partners for an optimal cybersecurity journey Cybersecurity The IEC 62443 standard provides essential guidelines for enhancing the security of connected electrical distribution systems, including network, control, and safety solutions. When selecting partners, it is important that they understand the standard well and implement it effectively. It's crucial to choose a partner with robust internal processes who can certify that products and solutions are developed according to well-defined procedures. At Schneider Electric, we have dedicated services to support throughout the cybersecurity journey. SOLUTION PROVIDERS SERVICE PROVIDERS CONSULTANT Find an electrical power distribution specialist with a deep understanding of cybersecurity requirements. They should: • Help you with the risk assessment; • Define the levels of security you require, compliant with IEC 62443; • Provide guidance on implementing best practices for cybersecurity. Reference Guide EcoStruxure Power for Railway and Urban Transportation Public SECTION 4 – Design Considerations SECTION 2 – How EcoStruxure Power Can Support the Railway Industry SECTION 3 – Digital Solutions and Services across the Facilities SECTION 1 – Introduction to the Railway and Urban Transportation Market Control Center Solutions Control Strategies for Passenger Stations Control Strategies for Traction Substations Cybersecurity BIBLIOGRAPHY SECTION 5 – Customer Stories Integration with BMS Time Synchronization Environmental Data Program Communications Protocols Recommendations for selecting your partners for an optimal cybersecurity journey Cybersecurity The IEC 62443 standard provides essential guidelines for enhancing the security of connected electrical distribution systems, including network, control, and safety solutions. When selecting partners, it is important that they understand the standard well and implement it effectively. It's crucial to choose a partner with robust internal processes who can certify that products and solutions are developed according to well-defined procedures. At Schneider Electric, we have dedicated services to support throughout the cybersecurity journey. CONSULTANT SERVICE PROVIDERS SOLUTION PROVIDERS Choose an electrical system technology provider that has adopted the IEC 62443 standard and has a secure development lifecycle process in place that: • Ensures systems are resilient in case of cyberattack; • Provides a formal process to inform and assist customers if any security vulnerabilities are discovered; • Fully tests and validates the security of all components and systems; • Demonstrates third-party cybersecurity certification; • Delivers customized and flexible solutions that align with your business requirements. Reference Guide EcoStruxure Power for Railway and Urban Transportation Public SECTION 4 – Design Considerations SECTION 2 – How EcoStruxure Power Can Support the Railway Industry SECTION 3 – Digital Solutions and Services across the Facilities SECTION 1 – Introduction to the Railway and Urban Transportation Market Control Center Solutions Control Strategies for Passenger Stations Control Strategies for Traction Substations Cybersecurity BIBLIOGRAPHY SECTION 5 – Customer Stories Integration with BMS Time Synchronization Environmental Data Program Communications Protocols Recommendations for selecting your partners for an optimal cybersecurity journey Cybersecurity The IEC 62443 standard provides essential guidelines for enhancing the security of connected electrical distribution systems, including network, control, and safety solutions. When selecting partners, it is important that they understand the standard well and implement it effectively. It's crucial to choose a partner with robust internal processes who can certify that products and solutions are developed according to well-defined procedures. At Schneider Electric, we have dedicated services to support throughout the cybersecurity journey. CONSULTANT SOLUTION PROVIDERS SERVICE PROVIDERS Choose partners with the required capabilities: • A system integrator with deep IT and OT experience including cybersecurity within the context of critical operational systems • Cybersecurity services that can deliver quick response to help assess and recover from a cyberattack. Reference Guide EcoStruxure Power for Railway and Urban Transportation Public SECTION 4 – Design Considerations SECTION 2 – How EcoStruxure Power Can Support the Railway Industry SECTION 3 – Digital Solutions and Services across the Facilities SECTION 1 – Introduction to the Railway and Urban Transportation Market Control Center Solutions Control Strategies for Passenger Stations Control Strategies for Traction Substations Cybersecurity BIBLIOGRAPHY SECTION 5 – Customer Stories Integration with BMS Time Synchronization Environmental Data Program Communications Protocols Certified secure system architecture according to IEC 62443-3-3 with documented processes and solutions for a secure system. Cybersecurity system configuration software for consistent security policy deployment. Consulting services from design, implementation, operations and maintenance to tailor your security solutions to your strategy and budget. Our solutions to support cybersecurity journey Cybersecurity At Schneider Electric, we can: • Provide a selection of cybersecurity certified products • Provide certified system architectures and solutions • Deliver lifecycle services Lifecycle servicesCertified products Certified systems & solutions • Cybersecurity Learn more about: Certified products developed according to IEC 62443 functional requirements with Secure Development Lifecycle processes. Reference Guide EcoStruxure Power for Railway and Urban Transportation Public SECTION 4 – Design Considerations SECTION 2 – How EcoStruxure Power Can Support the Railway Industry SECTION 3 – Digital Solutions and Services across the Facilities SECTION 1 – Introduction to the Railway and Urban Transportation Market Control Center Solutions Control Strategies for Passenger Stations Control Strategies for Traction Substations Time Synchronization Cybersecurity Environmental Data Program BIBLIOGRAPHY SECTION 5 – Customer Stories Integration with BMS Communications Protocols Environmental Data Program Governments are committing to carbon neutrality by 2050, leading to new regulations promoting sustainability: ESG reporting is becoming crucial. The Corporate Sustainability Reporting Directive (CSRD) expands disclosure requirements to nearly 50,000 companies, including those outside the EU. This enhances transparency and accountability. Consumers demand sustainable practices, with a rise in repairing, reselling, and reusing products. However, greenwashing remains a challenge, as some companies make unsubstantiated sustainability claims. Regulators are cracking down on false claims, emphasizing the need for credible and verifiable environmental data. Consumer Expectations and Greenwashing Risks The need to address ESG regulations (ESG = Environmental, Social, and Governance) At Schneider Electric, we have deployed an Environmental Data Program to address this need. Discover more next page Reference Guide EcoStruxure Power for Railway and Urban Transportation Public SECTION 4 – Design Considerations SECTION 2 – How EcoStruxure Power Can Support the Railway Industry SECTION 3 – Digital Solutions and Services across the Facilities SECTION 1 – Introduction to the Railway and Urban Transportation Market Control Center Solutions Control Strategies for Passenger Stations Control Strategies for Traction Substations Time Synchronization Cybersecurity Environmental Data Program BIBLIOGRAPHY SECTION 5 – Customer Stories Integration with BMS Communications Protocols Next-level transparency for better-informed product choices Environmental Data Program The Environmental Data Program is a framework for how we, at Schneider Electric, measure, categorize, and compare the environmental attributes and footprint of our products. Using a rigorous, fact-based methodology, the program provides environmental data from across the product lifecycle. Use Better: How sustainable a product is, including environmental footprint, materials and substances, packaging, and energy efficiency. Use Longer: How a product's lifetime can be effectively extended in terms of repairability and updatability. Use Again: How a product can be reused, from dismantling and remanufacturing to recyclability and manufacturer take back. With this transparent, fact-based data, customers and partners are empowered to make conscious environmental choices and accurately evaluate and report on sustainability performance. All our hardware offers have an associated environmental data available on se.com product pages. • Schneider Electric Environmental Program Learn more about: Reference Guide EcoStruxure Power for Railway and Urban Transportation Public SECTION 5 – Customer Stories Railway: Europe Urban Transportation: US SECTION 3 – Digital Solutions and Services across the Facilities SECTION 5 SECTION 2 – How EcoStruxure Power Can Support the Railway Industry 2- Traction Substations 3- Auxiliary Powers Systems 4- Passenger Stations 5- eBus Depots 6- Tunnel Systems 7- Depots and Workshops 8- Control Center SECTION 4 – Design Considerations 1- Overhead Lines SECTION 1 – Introduction to the Railway and Urban Transportation Market WHY READ THIS SECTION? BIBLIOGRAPHY Urban Transportation: Europe Customer Stories The objective of this section is to: • Showcase our solutions provided across globe in the Railway and Urban Transportation sectors, addressing our customers' challenges and key needs. Reference Guide EcoStruxure Power for Railway and Urban Transportation Public SECTION 5 – Customer Stories SECTION 4 – Design Considerations Railway: Europe Urban Transportation: US SECTION 3 – Digital Solutions and Services across the Facilities SECTION 2 – How EcoStruxure Power Can Support the Railway Industry 2- Traction Substations 3- Auxiliary Powers Systems 4- Passenger Stations 5- eBus Depots 6- Tunnel Systems 7- Depots and Workshops 8- Control Center 1- Overhead Lines SECTION 1 – Introduction to the Railway and Urban Transportation Market BIBLIOGRAPHY Urban Transportation: Europe Solution Provided Railway: A Leading Railway Operator in Europe Manage and operate efficiently a country-wide network: • Nearly 6.000 km mainlines railway network with almost 340 electrical substations; • Nearly 4.000 km of reliable high speed national rail network with almost 175 traction electrical facilities. Services • Maintenance services: corrective and preventive • Engineering and electrical substation design • Cybersecurity Edge Control • AVEVA System Platform for energy and building management at Control Center level • EcoStruxure Power

Automation System as the substation automation solution • EcoStruxure Power Monitoring Expert for power management with Power Quality improvements Connected products • AC MV Panels for traction network: 25 kV AC high speed and 3.3 kV DC mainlines • Cabinets for auxiliary power line • Overhead line disconnectors (OHL): 25 kV AC high speed and 3.3 kV DC mainlines • PowerLogic T500 (formerly Saitel) for data acquisition and concentration • Building Management System for Passenger Stations • Tunnel Automation System Customer Challenges • Real-time single view of the national rail network, through integrated main and back-up control centers • Optimized energy through integrated monitoring and energy management systems Customer Benefits Public Solution Provided for a Leading Railway Operator in Europe Apps, analytics, and services Edge Control Connected products AVEVA System Platform EcoStruxure Power Monitoring Expert EcoStruxure Power Automation System Cybersecurity Consulting Digitalization Consulting Electrical Engineering Maintenance Services Commissioning and Training MV switchgear, control units, protection relays, power meters, overhead line controllers Note: Pictures displayed here may not represent the actual product available on site. 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Customer Challenges • Improvement of operational efficiency with new extended remote operation capabilities. • Open platform integrating multiple external systems with many certified system integrators. • Enhanced modeling, design, analysis, operation planning, predictive simulation and automation services enabled by ETAP real-time solution. Customer Benefits Public Solution Provided for Leading Metro Operator in Europe Apps, analytics, and services Edge Control Connected products Simulation Engine Modicon M580 SM AirSeT RM6 (SeT series) LV Switchgear EcoStruxure Power Automation System PowerLogic P5 Modicon M340 Note: Pictures displayed here may not represent the actual product available on site. They are used for pictorial demonstration only. Reference Guide EcoStruxure Power for Railway and Urban Transportation Public SECTION 3 – Digital Solutions and Services across the Facilities BIBLIOGRAPHY Reference Document Useful Links BIBLIOGRAPHY SECTION 2 – How EcoStruxure Power Can Support the Railway Industry 2- Traction Substations 3- Auxiliary Powers Systems 4- Passenger Stations 5- eBus Depots 6- Tunnel Systems 7- Depots and Workshops 8- Control Center SECTION 4 – Design Considerations SECTION 5 – Customer Stories 1- Overhead Lines SECTION 1 – Introduction to the Railway and Urban Transportation Market Reference Guide EcoStruxure Power for Railway and Urban Transportation Public SECTION 3 – Digital Solutions and Services across the Facilities Reference Document BIBLIOGRAPHY SECTION 2 – How EcoStruxure Power Can Support the Railway Industry 2- Traction Substations 3- Auxiliary Powers Systems 4- Passenger Stations 5- eBus Depots 6- Tunnel Systems 7- Depots and Workshops 8- Control Center SECTION 4 – Design Considerations SECTION 5 – Customer Stories 1- Overhead Lines SECTION 1 – Introduction to the Railway and Urban Transportation Market Useful Links Design Guide Reference Documents Digital Applications for Large Buildings and Critical Facilities The Digital Applications Design Guide provides comprehensive details on the building blocks of EcoStruxure Power: the IoT applications are driven by a software layer to control the traditional electrical distribution infrastructure. Developed to help engineering consultants and designers, this guide is an invaluable resource for specifying, designing and prescribing EcoStruxure Power architectures capable of performing one or more of the business-driven applications described within. Access the Design Guide online from the Landing page (IEC/NEMA) Download the PDF View online Download IEC Download NEMA Reference Guide EcoStruxure Power for Railway and Urban Transportation Public SECTION 3 – Digital Solutions and Services across the Facilities Reference Document Useful Links BIBLIOGRAPHY SECTION 2 – How EcoStruxure Power Can Support the Railway Industry 2- Traction Substations 3- Auxiliary Powers Systems 4- Passenger Stations 5- eBus Depots 6- Tunnel Systems 7- Depots and Workshops 8- Control Center SECTION 4 – Design Considerations SECTION 5 – Customer Stories 1- Overhead Lines SECTION 1 – Introduction to the Railway and Urban Transportation Market Transportation landing page on se.com Useful links Landing page Public Schneider Electric Industries SAS 35, rue Joseph Monier CS 30323 92506 Rueil Malmaison Cedex France www.se.com © 2025 Schneider Electric. All Rights Reserved. All trademarks are owned by Schneider Electric SE, its subsidiaries and affiliated companies. All other brands are trademarks of their respective owners 2025/01/23 ESXP2RG004EN eConversion Premium protection and sustainability for highly critical applications A unique high-efficiency mode available for Galaxy V-series UPSs se.com The next step in your sustainability journey eConversion mode: the unbeatable combination of power quality and efficiency Protect power to your load, reduce your electricity consumption, and meet your sustainability goals with up to 99% efficient, Class 1-compliant eConversion mode for Galaxy V-series UPSs. This patented high-efficiency mode achieves Class 1 categorization (the highest protection class), equaling Double Conversion, the legacy default operating mode of 3-phase UPSs. In eConversion mode, the inverter operates continuously, ensuring that if power fluctuates, your UPS can protect the load with no transfer time. eConversion mode also recharges batteries and provides power factor correction and harmonics compensation, making it a versatile solution for protecting both IT and non-IT loads. Operating at up to 99% efficiency isn't just good for the environment, it's good for your balance sheet. Within 10 years, the electricity savings of operating your UPS in eConversion typically equals up to 3x the price of the UPS. Delivering premium power protection and optimized total cost of ownership, eConversion is both the recommended operating mode for your Galaxy V-series UPS and an effortless step toward a more profitable business and a more sustainable world. 2 eConversion Third-party certified performance eConversion is the first UL-verified high efficiency mode. It has passed the rigorous testing of this 3rd-party, industry-leading certification agency. Class 1 protection Choose eConversion mode with confidence; its performance has been certified Class 1 per IEC ® 62040-3, the same class as Double Conversion. Excellent load protection, including patented zero-break transfer design The UPS continues to deliver input power factor correction, harmonic filtering, and no-break transfer to Double Conversion mode or battery operation. Maximum availability, third-party certified Enjoy the highest energy efficiency available today without sacrificing load protection. Every Galaxy V-series UPS includes eConversion mode and delivers these benefits: eConversion meets Class 1 of IEC 62040-3: zero-break transfer during power outage. 1000.11 10 Nominal Value (Voltage %) 100% 80% 60% 40% 20% 0% -20% -40% -60% -80% -100% 1,000 Overvoltage transient limit Undervoltage transient limit +10% -10% Transient duration in milliseconds (ms) eConversion

Over 10 years of field deployment Since its launch in 2014, eConversion has been successfully deployed all over the world. Join thousands of customers who use it daily to protect their critical loads. Continuously charging batteries With eConversion mode, your batteries are ready when you need runtime. Ideal for IT and non-IT applications • Data centers • Factories • Commercial offices • Transportation • Hospitals Sustainably reduce your operating costs Using eConversion mode achieves 99% efficiency, which provides significant savings every year on your electricity bill. Compared to Double Conversion, the savings are typically equivalent to up to 3 times the UPS acquisition price after 10 years. Optimize your energy consumption eConversion power savings accrue fast. For example, Galaxy VL with eConversion mode conserves every year as much power as the electricity generated by 30 rooftop solar installations, equivalent to the electricity required to recharge 50 electric cars. Up to 3x reduction in electricity use 4 = = 1x 31x 53x Galaxy VL in eConversion Rooftop solar installations Cars powered $$$$ UPS Price + Electricity Electricity savings = up to 3x UPS price $$$ $$ $ 0 Year 1 Year 5 Year 10 eConversion 99% efficiency Double Conversion eConversion Double Conversion 97% efficiency Total Cost of Ownership, optimized UPS eConversion savings over 10 years UPS kW rating Electricity savings* Carbon emissions (metric tons) savings Equivalent solar rooftop production Cars powered Galaxy VS 150 kW $41,000 135 10 16 Galaxy VM 225 kW $73,000 243 17 28 Galaxy VL 500 kW $146,000 484 31 53 Galaxy VXL 1250 kW $394,200 1314 88 150 Galaxy VX 1500 kW $684,000 2300 154 263 *Model dependent; based on a market electricity price: $0.15 /kWh and CO2 emissions factor of 0.5 kg/kWh. The annual electricity and carbon emissions savings are done by comparing the UPS efficiency in Double Conversion mode to its efficiency in eConversion mode. Carbon emissions are calculated based on the world average reported by the International Energy Agency (IEA): https://www.iea.org/reports/global-energy-co2-status-report-2019/ emissions Calculate your efficiency and carbon emissions savings using the eConversion vs Double Conversion calculator, using this link or the QR code on page 6: https://www.se.com/ww/en/work/solutions/ system/s1/data-center-and-network-systems/ trade-off-tools/econversion-vs-double-conversion-calculator/ eConversion A unique combination eConversion, Double Conversion, or ECO mode? A comparative study For decades, Double Conversion has been used as the default mode in 3-phase UPSs. The main disadvantage is the very high amount of electricity used 24 hours a day, 365 days a year to permanently regulate the output with a very tight +/-1% voltage tolerance. The cost of electricity used to perform permanent regulation typically represents up to 3x the UPS price over 10 years, while permanently re-creating a perfect sinewave has no extra benefit to the load as even the most critical loads are insensitive to a +/-10% voltage. Legacy 3-phase 'Default' mode Legacy 'High-efficiency' mode Most important for the availability of critical loads is the no-break transfer, certified by Class 1 protection (the highest category). In eConversion, the load is powered by the grid as long as it is within tolerance, but the inverter is kept operating in parallel. This ensures a no-break transfer in case of an outage, surge, or short circuit, and ensures third-party certified, Class 1 output, which denotes the highest availability. In comparison, using ECO mode (the legacy high-efficiency mode) reduces load availability and is therefore not a preferred mode of operation for applications requiring maximum protection. Double Conversion eConversion ECO mode Voltage fluctuation ««« Frequency fluctuation ««« Recharge batteries ««« No transfer time ««« PF Correction ««« Protection class Class 1 Efficiency 96-97% Voltage fluctuation «« Frequency fluctuation «« Recharge batteries ««« No transfer time ««« PF Correction ««« Protection class Class 1 Efficiency 99% Voltage fluctuation «« Frequency fluctuation «« Recharge batteries Option No transfer time No PF Correction No Protection class Class 3 Efficiency 99% Bypass switch Bypass switch Bypass switch Battery Battery Battery DC/DC DC/DC DC/DC AC in AC in AC in M2 M2 M2 M1 M1 M1 AC in AC in AC inLoad Load Load Inverter Inverter InverterPFC rectifier PFC rectifier PFC rectifier May be on to allow battery recharge Calculate your savings 6 Use our eConversion vs Double Conversion Calculator to quickly assess your potential energy savings, operating cost optimization, and CO2 emissions reduction by comparing the cost of running your Galaxy V-series UPS in eConversion mode vs Double Conversion mode. Scan this QR code with your phone camera, or access the calculator from the Schneider Electric Data Center Trade Off ToolsTM Web page: https://www.se.com/ww/en/work/solutions/system/s1/data-center-and-network-systems/trade-off-tools/econversion-vs-double-conversion-calculator/ If you have site-specific questions, our trained Field Service Representatives can perform a technical assessment of your site before you activate eConversion mode. To learn more, contact your Schneider Electric representative. On-screen savings meter If you already have a Galaxy V-series UPS, start using eConversion mode and watch the savings add up! eConversion Schneider Electric Industries SAS 35 rue Joseph Monier 92500 Rueil-Malmaison, France Tel : +33 (0)1 41 29 70 00

998-22187559 To learn more about eConversion mode, contact your Schneider Electric representative or visit https://www.se.com/ww/en/work/solutions/eConversion- high-efficiency-UPS-mode About Schneider Electric: At Schneider Electric, we believe access to energy and digital is a basic human right. We empower all to make the most of their energy and resources, ensuring Life Is On everywhere, for everyone, at every moment. We provide energy and automation digital solutions for efficiency and sustainability. We combine world-leading energy technologies, real-time automation, software and services into integrated solutions for Homes, Buildings, Data Centers, Infrastructure, and Industries. We are committed to unleash the infinite possibilities of an open, global, innovative community that is passionate about our Meaningful Purpose, Inclusive and Empowered values. www.se.com 3-Phase Uninterruptible Power Supply (UPS) Secure Power Portfolio www.se.com Public 2 Contents I. Overview 3 II. Our Portfolio 4 III. Products 3-Phase UPSs 5 Galaxy VS (10-150 kW) 6 Galaxy VM (160-225 kVA) 7 Galaxy VL (200-500 kW) 8 Galaxy VX (500-1500 kW) 9 Galaxy VXL (500-1250 kW) 10 Easy UPS 3S (10-40 kVA) 11 Easy UPS 3M (60-200 kVA) 12 Easy UPS 3M Advanced (100-250 kW) 13 Easy UPS 3L (250-600 kVA) 14 Galaxy 3L (250-600 kVA) 15 Easy UPS 3-Phase Modular (50-250 kW) 16 Galaxy PX (100-250 kW) 17 Symmetra PX (10-500 kVA) 18 Galaxy PW 2nd Gen (10-200 kVA) 19 3-Phase Lithium-ion Battery Cabinets 20 Galaxy Lithium-ion Battery Cabinets 21 3-Phase IT Power Distribution 22 Galaxy Power Distribution Units (PDUs) 23 Galaxy RPP 24 Configurable and Modular Power Distribution Units 25 Upsilon Static Transfer Switches 26 IV. Key Applications and Segments by Product 28 2 Schneider's purpose is to empower all to make the most of our energy and resources, bridging progress and sustainability for all. We call this Life Is On. Our mission is to be your digital partner for Sustainability and Efficiency. Schneider Electric is a world leader in power protection, solving today's energy challenges while setting the standard for quality and innovation with fully integrated solutions, enterprise-wide networks, data centers, mission-critical systems, and industrial/ manufacturing processes. Overview Empowering all to make the most of our energy and resources, bridging progress and sustainability for all. 3 Public 4 Our Portfolio Fully integrated, end-to-end 3-phase UPS solutions help maintain your enterprise-wide networks, data centers, mission-critical systems, and industrial manufacturing processes. Our global portfolio of world-class products and services uniquely combines to offer end- to-end critical power solutions, providing customers with robust power protection, anytime/anywhere visibility, and peace of mind with EcoStruxure IT software and flexible service plans throughout the life cycle of their installations. Galaxy V Series UPSs Maximize your availability and sustainability and optimize your total cost of ownership. Our modular Galaxy V Series UPSs deliver superior performance in a compact footprint, with up to 99% efficiency in eConversion mode, scalability and internal redundancy options, and Galaxy Lithium-ion battery solutions, making them ideal for the data center or business-critical applications. Easy UPS 3-phase UPSs Quickly deploy power protection that optimizes your capital expenses. Easy UPS 3-phase range UPSs feature robust electrical specifications, ruggedizing features, and a compact, lightweight footprint that are ideal for commercial or industrial applications. Modular Data Centers Schneider Electric 3-phase UPSs are ideal for Modular Data Center applications. Contact your Schneider Electric representative to learn how you can increase your infrastructure capacity while shrinking your infrastructure footprint. 5 Products 3-phase UPSs Galaxy VS For external batteries: 10-75 kW (208V), 20-150 kW (400V/480V) With internal smart battery modules: 10-50 kW (208V), 10-100 kW (400V), 20-100 kW (480V) Sold: Worldwide 6 SE.com Features Applications & Segments • IT • Small and medium data centers • Business-critical applications • Edge • Commercial and industrial facilities • Marine • Healthcare, Oil & Gas, Transportation, Minerals, Metals, Mining, Power, Grid • High efficiency in eConversion mode (up to 99%) • Maximum availability with modular architecture • Innovative Live Swap of power modules • Parallel for capacity or redundancy—up to 4 UPSs • Internal redundancy with N+1 power modules • Flexible modular, classic, & Lithium-ion battery solutions • Compact design with optimized footprint • Touchscreen display with NMC • NMC with Secure Subscription License • EcoStruxure connected • Green Premium solution • Start-up service included Options • Battery flexibility, including Lithium-ion batteries • Single and parallel wallmount maintenance bypass panel • Classic and Modular Battery Cabinets • Battery Breaker Box and Battery Breaker Kit • IP52/NEMA 12 Kit • Seismic kits (OSHPD) • Network management card embedded with ethernet (NMP) and Modbus • Galaxy VS 20 kW (480V in, 400V out) up to 80 kW Internal Input Transformer for NAM Overview Galaxy VS is a highly efficient, modular, simple-to-deploy 3-phase UPS that delivers top performance to edge, small, and medium data centers, as well as critical infrastructure in commercial and industrial facilities. It offers increased availability, reduced operating costs, and first-class power protection for critical infrastructure. Galaxy VM For external batteries: 160-200 kVA (400V), 160-225 kVA (480V) Sold: Worldwide (except Japan) Features Applications & Segments • Mission-critical environments • Medium data centers • Industrial plants and applications • Facility infrastructure • Healthcare • Telecommunications • Highly efficient eConversion mode (up to 98.5%) • Integrated backfeed protection • Single-cabinet top and bottom cable entry • Full front-service access • Flexible modular, classic, and Lithium-ion battery solutions • Large color touch-screen display with built-in NMC • 65 kAIC rating standard • Compact footprint • Smart Power Test (SPoT) mode • OSHPD certified cabinets • Integrated casters for ease of mobility • EcoStruxure connected • Start-up service included Options • Classic and Modular Battery Cabinets • Management cards • Fuse kits • Wall-mounted battery breaker boxes • Parallel system bypass cabinets • Dust filter kits • System bypass cabinets • 208V transformers • Flywheel and Lithium-ion battery compatible • Network Management Card (AP9640 / AP9641) with Secure NMC Subscription License 7 Overview Galaxy VM is a highly efficient, modular 3-phase UPS that seamlessly integrates into medium data centers, industrial, or facilities applications. SE.com Public 8 Galaxy VL Applications & Segments • Mission-critical environments • Medium and large data centers • Colocation facilities • Computer rooms • Edge computing, Internet DC, Cloud computing • Light industry and commercial buildings • Infrastructure and transportation 8 For external batteries: 200-500 kW (400V/480V) Sold: Worldwide Overview Galaxy VL is a highly efficient, scalable 3-phase UPS featuring a modular, redundant design and low TCO for medium and large data centers and mission-critical environments. Minimize your total cost of ownership while expanding your business and maximizing your availability, reliability, and sustainability. With up to 99% efficiency in eConversion mode and fast power expansion with Live Swap, Galaxy VL is the most compact galaxy in the UPS universe. Make your data center or co-location facility more sustainable today. SE.com Features • Highly efficient eConversion mode (up to 99%) • Compact design, optimized footprint • Innovative Live Swap • Lithium-ion battery option • Parallel for capacity or redundancy—up to 6 UPSs • Scalable, modular design enables N+1 internal redundancy • Smart Power Test (SPoT) mode • Fault-tolerant design • Touchscreen display with NMC • Secure NMC Subscription License • Full front-service access • EcoStruxure connected • Green Premium solution • Startup service included Options • Classic battery cabinets • SKRU kit • Remote Centralized Display Box • Bottom Entry Cabinet 65kAIC Kit • Seismic (with option kit) • Replaceable dust filters • Backfeed protection options • Battery Breaker Box/Kit • NMC embedded with ethernet (NMP) and Modbus • Maintenance bypass cabinets Galaxy VX Features Applications & Segments • Mission-critical environments • Large/extra-large data centers • Industrial applications • Facility infrastructure • Cloud and Service providers • Colocation facilities • Finance, semiconductor, and manufacturing environments • Telecommunications, Healthcare • Highly efficient eConversion mode (up to 99%) • Cabinet-level scalability for capacity or redundancy • Dual mains input, top and bottom cable entry • Parallel for capacity or redundancy — up to 4 UPSs • Flywheel and Lithium-ion battery compatible • Internal redundancy with N+1 power cabinets • Smart Power Test (SPoT) mode • Touchscreen display with NMC • EcoStruxure connected • Startup service included Options • Battery pull box • Network Management Card (AP9640 / AP9641 / AP9643) with Secure NMC Subscription License • SmartSlot cards • Replaceable dust filters • Single feed kit 9 For external batteries: 500 scalable to 1500 kW N+1 (400V/480V) Sold: Worldwide Overview Galaxy VX is a highly efficient, modular 3-phase UPS scalable from 500 to 1500 kW in a single unit with high performance and flexible operating modes. Its scalability accommodates the changing needs of your rapidly expanding business, and its exceptional performance and abundance of cost-saving features reduce your energy costs and total cost of ownership. Galaxy VX is the ideal UPS for today's large data centers, cloud and colocation facilities, as well as mission-critical applications. SE.com • Parallel cable kit • Maintenance bypass cabinets • Classical battery cabinets Public 10 Galaxy VXL 10 For external batteries: 500-1250 kW (400V) Sold: All IEC countries worldwide SE.com Features Applications & Segments • Large and extra-large data centers • Colocation facilities • Computer rooms • Light industry & commercial buildings • Cloud & Service Provider facilities • Semiconductor industry • Manufacturing critical line • Energy and Chemicals • Bank, Finance, Insurance • Pre-fabricated systems • High efficiency eConversion mode (up to 99%) • Compact design, optimized footprint only 1.2m2 • Innovative Live Swap • Lithium-ion battery integration • EcoStruxure connected • Scalable, modular design enables N+1 internal redundancy • Reliable and fault-tolerant design • Sustainable solution • Full front access • Unity power factor @40°C, kVA=kW • Touchscreen display with NMC • High short circuit level 100kA • Secure NMC Subscription License • Smart Power Test (SPoT) mode • Startup service included Options • Battery Breaker Box/Kit • Empty Battery Cabinet Overview Galaxy VXL is a highly efficient, compact, and modular 3-phase UPS with Live Swap. With its industry-leading compact design, high-density technology, and fault-tolerant architecture, Galaxy VXL maximizes availability, operational efficiency, and critical load protection while minimizing TCO. This UPS delivers up to 97.5% efficiency in double conversion mode and up to 99% in eConversion mode, reducing the UPS Carbon emissions by a factor of two. Galaxy VXL offers proactive asset management services to give you peace of mind anytime, anywhere. Start-up service is included. • Galaxy Lithium-ion Battery Cabinets • Air filter kit • Parallel Communications Kit • Seismic kit, and other options Public 11 Easy UPS 3S For external batteries: 10-40 kVA (400V) With and/or for internal batteries: 10-40 kVA (208V/400V) Sold: US, Canada, Mexico, and all IEC countries worldwide, except Japan Features Applications & Segments • Small data centers • Commercial buildings & light industrial applications • Business-critical applications • Healthcare, Telecommunication, Transportation, Manufacturing facilities • Non-IT • Easy to install and start up; minimal footprint • Delivers up to 96% efficiency • Wide operating temperature range and strong overload protection • Replaceable dust filters • Strong protection against harsh environments with robust electrical specifications • Conformal coating • Easy Loop Test to verify UPS performance before you connect your load • Parallel for capacity or redundancy—up to 4 UPSs • Easy to manage with mimic panel • EcoStruxure connected • Long life battery string ready Options • Cold Start kit • Parallel maintenance bypass, up to 2 units for 400V or 3 units for 208V • Battery Breaker Box and Battery Breaker Kit • Empty battery cabinets • Standard 7Ah or 9Ah battery modules • NMC with Secure Subscription License • Start-up service 11 Overview Easy UPS 3S (400V) is an easy to install, use, and service 3-Phase UPS available for external batteries or with and/or for internal batteries designed for small data centers and other business critical applications. Easy UPS 3S (208V) is an easy to install, use, and service 3-Phase UPS for internal batteries designed for small data centers, commercial buildings, non-IT, and light industrial applications. SE.com: 400V / 208V Public 12 Easy UPS 3M For external batteries: 60-200 kVA (400V) and 50-100 kVA (208V) With internal batteries: 60-80 kVA (400V) Sold: 208V countries of South America and Caribbean Islands, and all IEC countries worldwide, except Japan 12 SE.com Features Applications & Segments • Small and medium data centers and computer rooms • Electrical rooms • Business-critical applications • Commercial buildings • Healthcare, Telecommunication, Transportation, Manufacturing facilities • Start-up included • Easy deployment and compact footprint • Delivers up to 95.5% efficiency • Wide operating temperature range and strong overload protection • Strong protection against harsh environments with robust electrical specifications • Easy Loop Test to verify UPS performance before you connect your load • IP20 protection (extra protection with IP30, IP40, and/or IPX2 Option Kits) • Replaceable dust filters • Parallel for capacity or redundancy— up to 6 UPSs • Front and rear access service • Easy to manage with touchscreen display • Embedded NMC with Subscription License • EcoStruxure connected Options • Parallel and unitary maintenance bypass panel • Modular Battery cabinet • Classic Battery Cabinets with batteries • Empty battery cabinets • Battery Breaker Box and Battery Breaker Kit • Battery string or high-capacity battery string • Lithium-ion battery option Overview Easy UPS 3M 60-200 kVA (400V) and 50-100 kVA (208V) for external batteries, and 60-80 kVA (400V) with internal batteries is an easy to install, connect, use, and service 3-Phase UPS for small and medium data centers, electrical rooms, and other business-critical applications. Public 13 Easy UPS 3M Advanced For external batteries: 100-250 kW (400V) Sold: India Features Applications & Segments • Small and medium data centers • Commercial buildings • Light industrial applications • Government & Public Sector Units • Healthcare, Telecommunication, Transportation, Retail, Process Automation • Start-up included to optimizes your system's performance, quality, and safety • Scalable 100 kW to 250 kW for pay as you grow • Modular design, enabling easy serviceability • Easy deployment and compact footprint • Delivers up to 96% efficiency • Single frame capable up to 250 kW in capacity with Internal N+1 redundancy for up to 200 kW N+1 • Wide operating temperature range and strong overload protection • Pluggable Draw In/Out type power module • kVA = kW up to 40°C • Replaceable dust filters • Front and rear access service • Easy to manage with 7" touchscreen display • EcoStruxure connected • Made in India enables direct sales to Government, Public Sector Units, and Infrastructure Projects Options • Power module • Maintenance Bypass Panel • Battery Breaker Box and Battery Breaker Kit 13 Overview Easy UPS 3M Advanced—part of the Easy UPS 3-phase range—is an easy-to-install, connect, use, service, and scale 100-250 kW (400V) 3-Phase UPS made in India that is ideal for small and medium businesses, data centers, and other mission-critical applications in India. SE.com • Battery Temperature Sensors • Network Management Card (AP9640 / AP9641) with Secure NMC Subscription License Public 14 Easy UPS 3L For external batteries: 250-600 kW (400V) Sold: All IEC countries worldwide, except Japan and China Applications & Segments • Medium and large commercial buildings • Light industrial applications • Computer room and regional data centers • Healthcare, Telecommunication, Transportation, Financial, Government • Non-IT 14 Overview Easy UPS 3L 250-600 kVA (400V) is an easy to configure, use, and service 3-Phase UPS that delivers high availability and predictability to medium and large commercial buildings and light industrial applications. SE.com Features • Easy deployment and compact footprint • Delivers up to 96% efficiency • Power Module for fault-tolerant design • Streamlined installation and service • Protection against harsh environments with robust electrical specifications and ruggedizing features, including conformal coating • Replaceable dust filter • 1+1 redundant UPSs can share a common battery bank, reducing battery costs • IP20 (extra protection with IP31 option kit) • Smart Test mode optimizes site acceptance testing costs without requiring a load bank • Parallel up to 5 UPSs for capacity or 5+1 UPSs for redundancy • Supports 4+4 redundant configurations • Top cable entry • EcoStruxure connected • Embedded NMC with Secure NMC Subscription License • Start-up service included Options • Maintenance Bypass Panel • Classic Battery Cabinets • Empty battery cabinets • Battery Breaker Box and Battery Breaker Kit • Cold Start kit • Lithium-ion battery option Public 15 Galaxy 3L For external batteries: 250-600 kW (400V) Sold: China Features Applications & Segments • Medium and large data centers, and colocation facilities • Commercial and light industrial applications • Edge applications and computer rooms • Telecommunication, Healthcare, Government Transportation, Manufacturing, Finance • Easy deployment and compact footprint • Delivers up to 96% efficiency • Fault-tolerant design • Protection against harsh environments with robust electrical specifications and ruggedizing features • 1+1 redundant UPSs can share a common battery bank, reducing battery costs • Top cable entry • Replaceable dust filter • Embedded Network Management Card • IP20 (extra protection with IP31 option kit) • Smart Test mode optimizes site acceptance testing costs without requiring a load bank • Parallel up to 5 UPSs for capacity or 5+1 UPSs for redundancy • Supports 4+4 redundant configurations • 7-inch display • EcoStruxure connected • Start-up included Options • Maintenance Bypass Panel • Battery Breaker Box and Battery Breaker Kit • Classic Battery Cabinets • Empty battery cabinets • Cold Start kit 15 Overview Galaxy 3L 250-600 kVA (400V) is an easy to configure, use, and service 3-Phase UPS that delivers high availability and predictability to medium and large data centers, commercial buildings, and light industrial applications in China. SE.com • Bottom entry Cabinet • Lithium-ion battery option Public 16 Easy UPS 3-Phase Modular For external batteries: 50-250 kW (400V) Sold: All IEC countries worldwide, except Japan and China 16 Overview Easy UPS 3-Phase Modular 50-250 kW (400V) delivers robust power protection and availability in a capital- expenditure-friendly package. It is easy to select, quote, install, and maintain, with modular, redundant, scalable options and Live Swap modules in a compact footprint. SE.com Features Applications & Segments • Easy to select, configure, start up, use, and service • Up to 96% efficiency in double conversion mode • Third-party verified Live Swap functionality for fast MTTR and expansion with no scheduled downtime • Add Live Swap power modules as demand grows • Modular design with 50 kW power module enables N+1 redundancy to increase availability • Scalable design: pay as you grow • Up to 250 kW N+1 in a black one-rack design to conserve valuable real estate • Unity power factor @40°C • EcoStruxure connected for peace of mind anytime, anywhere • Parallel 4+0, increasing power capacity to 1 MW • Neutral Lithium-ion Function • Start-up service included • Bottom Entry Cabinet • Empty Battery Cabinet • Battery Breaker Box and Battery Breaker Kit • Maintenance Bypass Panel • Parallel Communications Kit • Redundant Intelligence Module • Lithium-ion battery option • Classic Battery Cabinet • Network Management Card (AP9640 / AP9641) with Secure NMC Subscription License • Other options: Depth Adapter, Backfeed Kit, Wide Seismic Kit, Battery Temperature Sensor • Small and medium data centers • Telecommunication • Transportation • Healthcare • Process Automation Options • Commercial buildings • Retail Public 17 Galaxy PX UPS 100-250 kW (400V) Sold: China Features Applications & Segments • Simple to select, configure, start up, use, and service • Up to 96% efficiency in double conversion mode • Third-party verified Live Swap functionality for fast MTTR and expansion with no scheduled downtime • Compact footprint with 10-inch touchscreen display • Modular design with 50 kW power module enables N+1 redundancy to increase availability • Parallel 4+0, increasing power capacity to 1 MW • Up to 250 kW N+1 in a black one-rack design to conserve valuable real estate • Scalable design: optimize capex, pay as you grow • Unity power factor @40°C • EcoStruxure connected for peace of mind anytime, anywhere • Neutral Lithium-ion Function • Start-up service included Options • Bottom Entry Cabinet • Depth Adapter • Neutral Disconnection Kit for 250 KW • Battery Temperature Sensor • Parallel Communications Kit • Lithium-ion battery option • 600mm wide Seismic Kit for 250 kW • Backfeed Kit 250 kW • Network Management Card • Redundant Intelligence Module 17 Overview Galaxy PX 100-250 kW (400V) UPS delivers robust power protection and availability in a capital-expenditure- friendly package. It is simple to select, quote, install, and maintain, with modular, redundant, scalable options, and Live Swap modules in a compact footprint. SE.com • Small & medium data centers • Telecommunication • Transportation • Healthcare • Process Automation• Commercial buildings • Retail Symmetra PX 400V: 16-500 kW with Symmetra PX 48 All-in-One, 96/160, & 250/500 208V: 10-100 kW with Symmetra PX 20, 40, & 100 480V: 100-500 kW with Symmetra PX 100 & 250/500 Sold: Worldwide 250/500 20 40 48 AIO 96/160 100 250/500 18 SE.com Features Applications & Segments • Data closet • Small, medium, and large data centers • Line up and match NetShelter form factor • Configurable for N+1 internal redundancy •

Redundant intelligent modules • Scalable power capacity • Modular power, battery, bypass, and intelligent control modules • Parallel up to 4 UPSs (Symmetra PX 250/500 only) • Dual mains input, top or bottom feed • Embedded power distribution (PX20, 48) • EcoStruxure connected • Network Management Card with Secure NMC Subscription Licenses • Start-up service included Options • Secondary network management card (HTTP/Telnet/SNMP) • Seismic kits (OSHPD) • Battery breaker enclosure Overview Symmetra PX is a high performance, right-sized, modular, scalable, 3-phase UPS that offers power protection with high availability and efficiency for small, medium, and large data centers and mission-critical environments. Made up of dedicated and redundant modules, this architecture can scale power and runtime as demand grows or as higher levels of availability are required. • Extended runtime battery frames • Classic battery cabinets: PX100, 96/160, 250/500 • Lithium-ion battery option for Symmetra PX 250/500 • High-density zones of large data centers • Mission-critical environments • Maintenance bypass cabinets with distribution: PX40, 100, 96/160, 250/500 • Configurable power distribution: PX20, 40, 100 • Modular power distribution: PX48, 96/160, 100 Public 19 Galaxy PW 2nd Gen Features Applications & Segments • Petroleum Petrochemical Gas • Metallurgy • Power Plant • Medical • Semiconductor • Transportation • Food & Beverage • Mining • Manufacturing • Supports dual input • Overload capacity: 125% 10 min; 150% 1 min • Parallel up to 3+1 (4+0) • ISTA 2B • Robust design for harsh environments • Phase rotation check • Standard protection class: IP31 • Operating temperature: 0-40°C • Supports DC cold start • Designed for easy service • Start-up service included Options • AP9547 Network Management Card with Secure NMC Subscription License • Replaceable dust filters • Parallel Communications Kit • Backfeed Kits 19 10-200 kVA (400V) transformer-based UPS Sold: Europe, Middle East & Africa, Pacific, and Greater China Overview Galaxy PW 2nd Gen is a 10-200 kVA (400V) transformer-based UPS for industrial applications. The DC busbar voltage covers 220VDC and 384VDC, and uses a reliable 6-pulse or 12-pulse SCR rectifier. SE.com • Cable Adapter Kits for Galaxy Pwi • IP42 Kit (ETO) Products 3-phase UPSs Products 3-phase Lithium-ion Battery Cabinets 20 Public 21 Galaxy Lithium-ion Battery Cabinets Features Applications & Segments • Data centers, colocation, computer rooms • Edge computing, Internet DC, cloud computing • Computer rooms • Light industrial and commercial buildings • Infrastructure and transportation • Telecommunications and networking • Critical power infrastructures • Emergency lighting • UP9540A fire tested compliance • 67Ah LMO/NCM battery system • Double your battery life vs. VRLA solutions • Up to 70% more compact footprint frees up floor space for revenue-generating equipment • Boost availability with 2-3x faster recharge rates than VRLA solutions • Built-in 3-level battery management system (BMS) • Green Premium solution • Aesthetic match with Galaxy V Series UPSs • Self feeding SMPS simplifies installation • Fast, simple installation — cabinet ships pre- assembled, except battery modules, and rolls quickly into place • Enhance employee protection with modular touch- safe design, breaker covers, and built-in fuse protection at the battery cell and cabinet level • Seismic kit • EcoStruxure connected • Start-up service options available 21 For Galaxy VS, VM, VL, VX, VXL; Symmetra PX 250/500; Symmetra MW; Easy UPS 3M; Easy UPS 3L/Galaxy 3L; Easy UPS 3-Phase Modular; and Galaxy PX Sold: Worldwide Overview A Galaxy Lithium-ion Battery Cabinet are compact, lightweight, long-lasting, and sophisticated energy storage solution for Galaxy V series and Easy 3-phase UPSs in data centers, industrial processes, and critical infrastructures. This UL9540A-compliant battery solution reduces battery footprint and weight by up to 70%, allowing more effective use of space. Lithium-ion batteries reduce total cost of ownership, both by doubling battery life and by operating at higher temperatures, reducing cooling requirements. SE.com 22 Products 3-phase IT Power Distribution Public 23 Power Distribution Units (PDUs) Features Applications • Small, medium, and large data centers • Colocation facilities • Compartmental design simplifies asset access allocation • Meets the demanding scalability needs of any data center of any size • Factory installed and tested Square D breaker panel configured to meet the unique needs of your site • Easy to install and service with top and bottom cable entry • Low total cost of ownership • Seismic cabinet (OSHPD) • 7-inch display interface • EcoStruxure connected 23 Overview Power Distribution Units are reliable, scalable, and intelligent high-density power distribution solutions ideal for installation in the electrical rooms of data centers. SE.com 400 & 500 kVA (480V) Sold: US, Central America Options • Copper or aluminum transformers • Main input switch or breaker • Main output breaker • Advanced metering • Wide range of 250 Amp, 400 Amp, and 600 Amp branch breaker options from Schneider Electric’s PowerPact J- and L-frame breaker series • EPO • Cloud service providers • Industrial applications 400 & 500 kVA (Aluminum) and 400 kVA (Copper) 500 kVA (Copper) Public 24 Galaxy RPP Features Applications • Data centers • Colocation facilities • Cloud service providers • Compact footprint and easy front-access design • Supports installation against walls, back-to-back, or in your EcoStruxure Pod Data Center • Flexible configuration, with factory installed and tested Square D breaker panels configured to your site requirements • Meets the demanding scalability needs of any large data center • PowerLogic Branch Circuit Power Meter monitors single or dual feed installations • Compartmental design simplifies asset access allocation • Top and bottom cable entry • Compatible with all Schneider Electric Power Distribution Units • 7-inch touchscreen display • EcoStruxure connected 24 Overview Galaxy RPP (Remote Power Panels) 250 and 400 Amp (120V/208V) offers highly configurable, highly modular, high-density row-level power distribution for data centers and colocation facilities. SE.com 250 & 400 Amp (120V/208V) Sold: US, Canada, Central America Options • L-frame or J-frame main input breakers • NP, NQ, or IP2X panelboard • QO, QOB, or EDB distribution breakers • Surge protection devices • Start-up service options available Configurable and Modular Power Distribution Units • Top or bottom cable entry (60/150 kW PDU) • Flexible configure-to-order options • Factory assembled and tested • Scalable • Modbus supported • Integrated monitoring • Network enabled • No side access required • Preconfigured cord sets • Compatible with StruxureWare Data Center Expert • Branch circuit monitoring • Power distribution modules with locking connectors (Modular) 25 Features Applications • Small, medium, or large data centers Overview Modular Power Distribution Units (PDUs) mitigate the need to predict the future requirements and configurations of your data center. Configurable Power Distribution Units bring agility, availability, and speed of deployment to your data center. Our factory-tested power distribution units are built to your exact specifications, support overhead or underfloor distribution, and feature a convenient, portable rack form factor. Options 120/208/230/400/480/600V: 72-277 kW (Modular) 208V/480V/600V: 40-150 kW (Configurable) Sold: Worldwide; product availability varies by region Modular Configurable • Shielding troughs Startup service SE.com: Configurable and Modular Upsilon Static Transfer Switches 30-630A standard; 800-1250A on request Sold: All IEC regions worldwide • Industrial applications • Data centers • Telecommunication centers • Infrastructure • Simplifies installation and maintenance while minimizing space requirements • Independent control boards, dual cooling systems, and power supplies ensure high reliability performance • Small footprint reduces required floor space • Text and mimic diagrams display modes of operation, system parameters, and alarms • Allows isolation of a source for maintenance without interrupting power to the protected loads Options • Communication: JBus/Modbus card (supplied as standard), status information card (supplied as standard) • Open frame version Overview Upsilon Static Transfer Switches (STS) provides true redundance and exceptional high reliability for automatic power supply transfer to a range of equipment from two independent and redundant power sources. Static Transfer Switches automatically transfer power to a stable alternate source in less than 4ms under normal operating conditions. Even under extreme conditions, such as 180 degrees out of phase, the STS will have detection and automatic transfer times that are up to 10 times faster than many other switches. 26 SE.com • PDU (36 16A circuit breakers incorporated in the H = 1900 cell, up to 100 A) • Connection at the top of the unit Features Applications & Segments 27 Key Applications and Segments by Product 28 IT Small data centers Medium data centers Large data centers Colocation facilities Cloud computing Commercial facilities Industrial facilities Healthcare Transportation Telecommunications Energy & Chemical Metal, Minerals, and Mining Consumer Packaged Goods Semi Conductor Galaxy VS Galaxy VM Galaxy VL Galaxy VX Galaxy VXL Easy UPS 3S Easy UPS 3M Easy UPS 3M Advanced Easy UPS 3L Galaxy 3L Easy UPS 3-Phase Modular Galaxy PX Symmetra PX Galaxy PW 2nd Gen Galaxy Lithium-ion Battery Cabinets Power Distribution Units (PDUs) Galaxy RPP Configurable and Modular PDUs Upsilon Static Transfer Switches ü Key Applications and Segments by Product To learn more about Schneider Electric 3-Phase UPS products and solutions, contact your Schneider Electric representative or visit www.se.com. Schneider Electric 35 rue Joseph Monier 92500 Rueil Malmaison France Product specifications are subject to change without notice and are provided “as is” without warranty of any kind, express or implied. See apc.com for the most up to date product specifications. • 998-19858418_GMA-US 28 3-Phase Uninterruptible Power Supply (UPS) Secure Power Portfolio www.se.com Public 2 Contents I. Overview 3 II. Our Portfolio 4 III. Products 3-Phase UPSs 5 Galaxy VS (10-150 kW) 6 Galaxy VM (160-225 kVA) 7 Galaxy VL (200-500 kW) 8 Galaxy VX (500-1500 kW) 9 Galaxy VXL (500-1250 kW) 10 Easy UPS 3S (10-40 kVA) 11 Easy UPS 3M (60-200 kVA) 12 Easy UPS 3M Advanced (100-250 kW) 13 Easy UPS 3L (250-600 kVA) 14 Galaxy 3L (250-600 kVA) 15 Easy UPS 3-Phase Modular (50-250 kW) 16 Galaxy PX (100-250 kW) 17 Symmetra PX (10-500 kVA) 18 Galaxy PW 2nd Gen (10-200 kVA) 19 3-Phase Lithium-ion Battery Cabinets 20 Galaxy Lithium-ion

Battery Cabinets 21 3-Phase IT Power Distribution 22 Galaxy Power Distribution Units (PDUs) 23 Galaxy RPP 24 Configurable and Modular Power Distribution Units 25 Upsilon Static Transfer Switches 26 IV. Key Applications and Segments by Product 28 2 Schneider's purpose is to empower all to make the most of our energy and resources, bridging progress and sustainability for all. We call this Life Is On. Our mission is to be your digital partner for Sustainability and Efficiency. Schneider Electric is a world leader in power protection, solving today's energy challenges while setting the standard for quality and innovation with fully integrated solutions, enterprise-wide networks, data centers, mission-critical systems, and industrial/ manufacturing processes. Overview Empowering all to make the most of our energy and resources, bridging progress and sustainability for all. 3 Public 4 Our Portfolio Fully integrated, end-to-end 3-phase UPS solutions help maintain your enterprise-wide networks, data centers, mission-critical systems, and industrial manufacturing processes. Our global portfolio of world-class products and services uniquely combines to offer end- to-end critical power solutions, providing customers with robust power protection, anytime/anywhere visibility, and peace of mind with EcoStruxure IT software and flexible service plans throughout the life cycle of their installations. Galaxy V Series UPSs Maximize your availability and sustainability and optimize your total cost of ownership. Our modular Galaxy V Series UPSs deliver superior performance in a compact footprint, with up to 99% efficiency in eConversion mode, scalability and internal redundancy options, and Galaxy Lithium-ion battery solutions, making them ideal for the data center or business-critical applications. Easy UPS 3-phase UPSs Quickly deploy power protection that optimizes your capital expenses. Easy UPS 3-phase range UPSs feature robust electrical specifications, ruggedizing features, and a compact, lightweight footprint that are ideal for commercial or industrial applications. Modular Data Centers Schneider Electric 3-phase UPSs are ideal for Modular Data Center applications. Contact your Schneider Electric representative to learn how you can increase your infrastructure capacity while shrinking your infrastructure footprint. 5 Products 3-phase UPSs Galaxy VS For external batteries: 10-75 kW (208V), 20-150 kW (400V/480V) With internal smart battery modules: 10-50 kW (208V), 10-100 kW (400V), 20-100 kW (480V) Sold: Worldwide 6 SE.com Features Applications & Segments • IT • Small and medium data centers • Business-critical applications • Edge • Commercial and industrial facilities • Marine • Healthcare, Oil & Gas, Transportation, Minerals, Metals, Mining, Power, Grid • High efficiency in eConversion mode (up to 99%) • Maximum availability with modular architecture • Innovative Live Swap of power modules • Parallel for capacity or redundancy—up to 4 UPSs • Internal redundancy with N+1 power modules • Flexible modular, classic, & Lithium-ion battery solutions • Compact design with optimized footprint • Touchscreen display with NMC • NMC with Secure Subscription License • EcoStruxure connected • Green Premium solution • Start-up service included Options • Battery flexibility, including Lithium-ion batteries • Single and parallel wallmount maintenance bypass panel • Classic and Modular Battery Cabinets • Battery Breaker Box and Battery Breaker Kit • IP52/NEMA 12 Kit • Seismic kits (OSHPD) • Network management card embedded with ethernet (NMP) and Modbus • Galaxy VS 20 kW (480V in, 400V out) up to 80 kW Internal Input Transformer for NAM Overview Galaxy VS is a highly efficient, modular, simple-to-deploy 3-phase UPS that delivers top performance to edge, small, and medium data centers, as well as critical infrastructure in commercial and industrial facilities. It offers increased availability, reduced operating costs, and first-class power protection for critical infrastructure. Galaxy VM For external batteries: 160-200 kVA (400V), 160-225 kVA (480V) Sold: Worldwide (except Japan) Features Applications & Segments • Mission-critical environments • Medium data centers • Industrial plants and applications • Facility infrastructure • Healthcare • Telecommunications • Highly efficient eConversion mode (up to 98.5%) • Integrated backfeed protection • Single-cabinet top and bottom cable entry • Full front-service access • Flexible modular, classic, and Lithium-ion battery solutions • Large color touch-screen display with built-in NMC • 65 kAIC rating standard • Compact footprint • Smart Power Test (SPoT) mode • OSHPD certified cabinets • Integrated casters for ease of mobility • EcoStruxure connected • Start-up service included Options • Classic and Modular Battery Cabinets • Management cards • Fuse kits • Wall-mounted battery breaker boxes • Parallel system bypass cabinets • Dust filter kits • System bypass cabinets • 208V transformers • Flywheel and Lithium-ion battery compatible • Network Management Card (AP9640 / AP9641) with Secure NMC Subscription License 7 Overview Galaxy VM is a highly efficient, modular 3-phase UPS that seamlessly integrates into medium data centers, industrial, or facilities applications. SE.com Public 8 Galaxy VL Applications & Segments • Mission-critical environments • Medium and large data centers • Colocation facilities • Computer rooms • Edge computing, Internet DC, Cloud computing • Light industry and commercial buildings • Infrastructure and transportation 8 For external batteries: 200-500 kW (400V/480V) Sold: Worldwide Overview Galaxy VL is a highly efficient, scalable 3-phase UPS featuring a modular, redundant design and low TCO for medium and large data centers and mission-critical environments. Minimize your total cost of ownership while expanding your business and maximizing your availability, reliability, and sustainability. With up to 99% efficiency in eConversion mode and fast power expansion with Live Swap, Galaxy VL is the most compact galaxy in the UPS universe. Make your data center or co-location facility more sustainable today. SE.com Features • Highly efficient eConversion mode (up to 99%) • Compact design, optimized footprint • Innovative Live Swap • Lithium-ion battery option • Parallel for capacity or redundancy—up to 6 UPSs • Scalable, modular design enables N+1 internal redundancy • Smart Power Test (SPoT) mode • Fault-tolerant design • Touchscreen display with NMC • Secure NMC Subscription License • Full front-service access • EcoStruxure connected • Green Premium solution • Startup service included Options • Classic battery cabinets • SKRU kit • Remote Centralized Display Box • Bottom Entry Cabinet 65kAIC Kit • Seismic (with option kit) • Replaceable dust filters • Backfeed protection options • Battery Breaker Box/Kit • NMC embedded with ethernet (NMP) and Modbus • Maintenance bypass cabinets Galaxy VX Features Applications & Segments • Mission-critical environments • Large/extra-large data centers • Industrial applications • Facility infrastructure • Cloud and Service providers • Colocation facilities • Finance, semiconductor, and manufacturing environments • Telecommunications, Healthcare • Highly efficient eConversion mode (up to 99%) • Cabinet-level scalability for capacity or redundancy • Dual mains input, top and bottom cable entry • Parallel for capacity or redundancy — up to 4 UPSs • Flywheel and Lithium-ion battery compatible • Internal redundancy with N+1 power cabinets • Smart Power Test (SPoT) mode • Touchscreen display with NMC • EcoStruxure connected • Startup service included Options • Battery pull box • Network Management Card (AP9640 / AP9641 / AP9643) with Secure NMC Subscription License • SmartSlot cards • Replaceable dust filters • Single feed kit 9 For external batteries: 500 scalable to 1500 kW N+1 (400V/480V) Sold: Worldwide Overview Galaxy VX is a highly efficient, modular 3-phase UPS scalable from 500 to 1500 kW in a single unit with high performance and flexible operating modes. Its scalability accommodates the changing needs of your rapidly expanding business, and its exceptional performance and abundance of cost-saving features reduce your energy costs and total cost of ownership. Galaxy VX is the ideal UPS for today's large data centers, cloud and colocation facilities, as well as mission-critical applications. SE.com • Parallel cable kit • Maintenance bypass cabinets • Classical battery cabinets Public 10 Galaxy VXL 10 For external batteries: 500-1250 kW (400V) Sold: All IEC countries worldwide SE.com Features Applications & Segments • Large and extra-large data centers • Colocation facilities • Computer rooms • Light industry & commercial buildings • Cloud & Service Provider facilities • Semiconductor industry • Manufacturing critical line • Energy and Chemicals • Bank, Finance, Insurance • Pre-fabricated systems • High efficiency eConversion mode (up to 99%) • Compact design, optimized footprint only 1.2m2 • Innovative Live Swap • Lithium-ion battery integration • EcoStruxure connected • Scalable, modular design enables N+1 internal redundancy • Reliable and fault-tolerant design • Sustainable solution • Full front access • Unity power factor @40°C, kVA=kW • Touchscreen display with NMC • High short circuit level 100kA • Secure NMC Subscription License • Smart Power Test (SPoT) mode • Startup service included Options • Battery Breaker Box/Kit • Empty Battery Cabinet Overview Galaxy VXL is a highly efficient, compact, and modular 3-phase UPS with Live Swap. With its industry-leading compact design, high-density technology, and fault-tolerant architecture, Galaxy VXL maximizes availability, operational efficiency, and critical load protection while minimizing TCO. This UPS delivers up to 97.5% efficiency in double conversion mode and up to 99% in eConversion mode, reducing the UPS Carbon emissions by a factor of two. Galaxy VXL offers proactive asset management services to give you peace of mind anytime, anywhere. Start-up service is included. • Galaxy Lithium-ion Battery Cabinets • Air filter kit • Parallel Communications Kit • Seismic kit, and other options Public 11 Easy UPS 3S For external batteries: 10-40 kVA (400V) With and/or for internal batteries: 10-40 kVA (208V/400V) Sold: US, Canada, Mexico, and all IEC countries worldwide, except Japan Features Applications & Segments • Small data centers • Commercial buildings & light industrial applications • Business-critical applications • Healthcare, Telecommunication, Transportation, Manufacturing facilities • Non-IT • Easy to install and start up; minimal footprint • Delivers up to 96% efficiency • Wide operating temperature range and strong overload protection • Replaceable dust filters • Strong protection against harsh environments with robust electrical specifications • Conformal coating • Easy Loop Test to verify UPS performance before you connect your load • Parallel for capacity or redundancy—up to 4 UPSs • Easy to manage with mimic panel • EcoStruxure connected • Long life battery string ready Options • Cold Start kit • Parallel maintenance bypass, up to 2 units for 400V or 3 units for 208V • Battery Breaker Box and Battery Breaker Kit • Empty battery cabinets • Standard 7Ah or 9Ah battery modules • NMC with Secure Subscription License • Start-up service 11 Overview Easy UPS 3S (400V) is an easy to install, use, and service 3-Phase UPS available for external batteries or with and/or for internal batteries designed for small data centers and other business critical applications. Easy UPS 3S (208V) is an easy to install, use, and service 3-Phase UPS for internal batteries designed for small data centers, commercial buildings, non-IT, and light industrial applications. SE.com: 400V / 208V Public 12 Easy UPS 3M For external batteries: 60-200 kVA (400V) and 50-100 kVA (208V) With internal batteries: 60-80 kVA (400V) Sold: 208V countries of South America and Caribbean Islands, and all IEC countries worldwide, except Japan 12 SE.com Features Applications & Segments • Small and medium data centers and computer rooms • Electrical rooms • Business-critical applications • Commercial buildings • Healthcare, Telecommunication, Transportation, Manufacturing facilities • Start-up included • Easy deployment and compact footprint • Delivers up to 95.5% efficiency • Wide operating temperature range and strong overload protection • Strong protection against harsh environments with robust electrical specifications • Easy Loop Test to verify UPS performance before you connect your load • IP20 protection (extra protection with IP30, IP40, and/or IPX2 Option Kits) • Replaceable dust filters • Parallel for capacity or redundancy— up to 6 UPSs • Front and rear access service • Easy to manage with touchscreen display • Embedded NMC with Subscription License • EcoStruxure connected Options • Parallel and unitary maintenance bypass panel • Modular Battery cabinet • Classic Battery Cabinets with batteries • Empty battery cabinets • Battery Breaker Box and Battery Breaker Kit • Battery string or high-capacity battery string • Lithium-ion battery option Overview Easy UPS 3M 60-200 kVA (400V) and 50-100 kVA (208V) for external batteries, and 60-80 kVA (400V) with internal batteries is an easy to install, connect, use, and service 3-Phase UPS for small and medium data centers, electrical rooms, and other business-critical applications. Public 13 Easy UPS 3M Advanced For external batteries: 100-250 kW (400V) Sold: India Features Applications & Segments • Small and medium data centers • Commercial buildings • Light industrial applications • Government & Public Sector Units • Healthcare, Telecommunication, Transportation, Retail, Process Automation • Start-up included to optimizes your system's performance, quality, and safety • Scalable 100 kW to 250 kW for pay as you grow • Modular design, enabling easy serviceability • Easy deployment and compact footprint • Delivers up to 96% efficiency • Single frame capable up to 250 kW in capacity with Internal N+1 redundancy for up to 200 kW N+1 • Wide operating temperature range and strong overload protection • Pluggable Draw In/Out type power module • kVA = kW up to 40°C • Replaceable dust filters • Front and rear access service • Easy to manage with 7" touchscreen display • EcoStruxure connected • Made in India enables direct sales to Government, Public Sector Units, and Infrastructure Projects Options • Power module • Maintenance Bypass Panel • Battery Breaker Box and Battery Breaker Kit 13 Overview Easy UPS 3M Advanced—part of the Easy UPS 3-phase range—is an easy-to-install, connect, use, service, and scale 100-250 kW (400V) 3-Phase UPS made in India that is ideal for small and medium businesses, data centers, and other mission-critical applications in India. SE.com • Battery Temperature Sensors • Network Management Card (AP9640 / AP9641) with Secure NMC Subscription License Public 14 Easy UPS 3L For external batteries: 250-600 kW (400V) Sold: All IEC countries worldwide, except Japan and China Applications & Segments • Medium and large commercial buildings • Light industrial applications • Computer room and regional data centers • Healthcare, Telecommunication, Transportation, Financial, Government • Non-IT 14 Overview Easy UPS 3L 250-600 kVA (400V) is an easy to configure, use, and service 3-Phase UPS that delivers high availability and predictability to medium and large commercial buildings and light industrial applications. SE.com Features • Easy deployment and compact footprint • Delivers up to 96% efficiency • Power Module for fault-tolerant design • Streamlined installation and service • Protection against harsh environments with robust electrical specifications and ruggedizing features, including conformal coating • Replaceable dust filter • 1+1 redundant UPSs can share a common battery bank, reducing battery costs • IP20 (extra protection with IP31 option kit) • Smart Test mode optimizes site acceptance testing costs without requiring a load bank • Parallel up to 5 UPSs for capacity or 5+1 UPSs for redundancy • Supports 4+4 redundant configurations • Top cable entry • EcoStruxure connected • Embedded NMC with Secure NMC Subscription License • Start-up service included Options • Maintenance Bypass Panel • Classic Battery Cabinets • Empty battery cabinets • Battery Breaker Box and Battery Breaker Kit • Cold Start kit • Lithium-ion battery option Public 15 Galaxy 3L For external batteries: 250-600 kW (400V) Sold: China Features Applications & Segments • Medium and large data centers, and colocation facilities • Commercial and light industrial applications • Edge applications and computer rooms • Telecommunication, Healthcare, Government Transportation, Manufacturing, Finance • Easy deployment and compact footprint • Delivers up to 96% efficiency • Fault-tolerant design • Protection against harsh environments with robust electrical specifications and ruggedizing features • 1+1 redundant UPSs can share a common battery bank, reducing battery costs • Top cable entry • Replaceable dust filter • Embedded Network Management Card • IP20 (extra protection with IP31 option kit) • Smart Test mode optimizes site acceptance testing costs without requiring a load bank • Parallel up to

5 UPSs for capacity or 5+1 UPSs for redundancy • Supports 4+4 redundant configurations • 7-inch display • EcoStruxure connected • Start-up included Options • Maintenance Bypass Panel • Battery Breaker Box and Battery Breaker Kit • Classic Battery Cabinets • Empty battery cabinets • Cold Start kit 15 Overview Galaxy 3L 250-600 kVA (400V) is an easy to configure, use, and service 3-Phase UPS that delivers high availability and predictability to medium and large data centers, commercial buildings, and light industrial applications in China. SE.com • Bottom entry Cabinet • Lithium-ion battery option Public 16 Easy UPS 3-Phase Modular For external batteries: 50-250 kW (400V) Sold: All IEC countries worldwide, except Japan and China 16 Overview Easy UPS 3-Phase Modular 50-250 kW (400V) delivers robust power protection and availability in a capital- expenditure-friendly package. It is easy to select, quote, install, and maintain, with modular, redundant, scalable options and Live Swap modules in a compact footprint. SE.com Features Applications & Segments • Easy to select, configure, start up, use, and service • Up to 96% efficiency in double conversion mode • Third-party verified Live Swap functionality for fast MTTR and expansion with no scheduled downtime • Add Live Swap power modules as demand grows • Modular design with 50 kW power module enables N+1 redundancy to increase availability • Scalable design: pay as you grow • Up to 250 kW N+1 in a black one-rack design to conserve valuable real estate • Unity power factor @40°C • EcoStruxure connected for peace of mind anytime, anywhere • Parallel 4+0, increasing power capacity to 1 MW • Neutral Lithium-ion Function • Start-up service included • Bottom Entry Cabinet • Empty Battery Cabinet • Battery Breaker Box and Battery Breaker Kit • Maintenance Bypass Panel • Parallel Communications Kit • Redundant Intelligence Module • Lithium-ion battery option • Classic Battery Cabinet • Network Management Card (AP9640 / AP9641) with Secure NMC Subscription License • Other options: Depth Adapter, Backfeed Kit, Wide Seismic Kit, Battery Temperature Sensor • Small and medium data centers • Telecommunication • Transportation • Healthcare • Process Automation Options • Commercial buildings • Retail Public 17 Galaxy PX UPS 100-250 kW (400V) Sold: China Features Applications & Segments • Simple to select, configure, start up, use, and service • Up to 96% efficiency in double conversion mode • Third-party verified Live Swap functionality for fast MTTR and expansion with no scheduled downtime • Compact footprint with 10-inch touchscreen display • Modular design with 50 kW power module enables N+1 redundancy to increase availability • Parallel 4+0, increasing power capacity to 1 MW • Up to 250 kW N+1 in a black one-rack design to conserve valuable real estate • Scalable design: optimize capex, pay as you grow • Unity power factor @40°C • EcoStruxure connected for peace of mind anytime, anywhere • Neutral Lithium-ion Function • Start-up service included Options • Bottom Entry Cabinet • Depth Adapter • Neutral Disconnection Kit for 250 KW • Battery Temperature Sensor • Parallel Communications Kit • Lithium-ion battery option • 600mm wide Seismic Kit for 250 kW • Backfeed Kit 250 kW • Network Management Card • Redundant Intelligence Module 17 Overview Galaxy PX 100-250 kW (400V) UPS delivers robust power protection and availability in a capital-expenditure- friendly package. It is simple to select, quote, install, and maintain, with modular, redundant, scalable options, and Live Swap modules in a compact footprint. SE.com • Small & medium data centers • Telecommunication • Transportation • Healthcare • Process Automation• Commercial buildings • Retail Symmetra PX 400V: 16-500 kW with Symmetra PX 48 All-in-One, 96/160, & 250/500 208V: 10-100 kW with Symmetra PX 20, 40, & 100 480V: 100-500 kW with Symmetra PX 100 & 250/500 Sold: Worldwide 250/500 20 40 48 AIO 96/160 100 250/500 18 SE.com Features Applications & Segments • Data closet • Small, medium, and large data centers • Line up and match NetShelter form factor • Configurable for N+1 internal redundancy • Redundant intelligent modules • Scalable power capacity • Modular power, battery, bypass, and intelligent control modules • Parallel up to 4 UPSs (Symmetra PX 250/500 only) • Dual mains input, top or bottom feed • Embedded power distribution (PX20, 48) • EcoStruxure connected • Network Management Card with Secure NMC Subscription Licenses • Start-up service included Options • Secondary network management card (HTTP/Telnet/SNMP) • Seismic kits (OSHPD) • Battery breaker enclosure Overview Symmetra PX is a high performance, right-sized, modular, scalable, 3-phase UPS that offers power protection with high availability and efficiency for small, medium, and large data centers and mission-critical environments. Made up of dedicated and redundant modules, this architecture can scale power and runtime as demand grows or as higher levels of availability are required. • Extended runtime battery frames • Classic battery cabinets: PX100, 96/160, 250/500 • Lithium-ion battery option for Symmetra PX 250/500 • High-density zones of large data centers • Mission-critical environments • Maintenance bypass cabinets with distribution: PX40, 100, 96/160, 250/500 • Configurable power distribution: PX20, 40, 100 • Modular power distribution: PX48, 96/160, 100 Public 19 Galaxy PW 2nd Gen Features Applications & Segments • Petroleum Petrochemical Gas • Metallurgy • Power Plant • Medical • Semiconductor • Transportation • Food & Beverage • Mining • Manufacturing • Supports dual input • Overload capacity: 125% 10 min; 150% 1 min •

Parallel up to 3+1 (4+0) • ISTA 2B • Robust design for harsh environments • Phase rotation check • Standard protection class: IP31 • Operating temperature: 0-40°C • Supports DC cold start • Designed for easy service • Start-up service included Options • AP9547 Network Management Card with Secure NMC Subscription License • Replaceable dust filters • Parallel Communications Kit • Backfeed Kits 19 10-200 kVA (400V) transformer-based UPS Sold: Europe, Middle East & Africa, Pacific, and Greater China Overview Galaxy PW 2nd Gen is a 10-200 kVA (400V) transformer-based UPS for industrial applications. The DC busbar voltage covers 220VDC and 384VDC, and uses a reliable 6-pulse or 12-pulse SCR rectifier. SE.com • Cable Adapter Kits for Galaxy Pwi • IP42 Kit (ETO) Products 3-phase UPSs Products 3-phase Lithium-ion Battery Cabinets 20 Public 21 Galaxy Lithium-ion Battery Cabinets Features Applications & Segments • Data centers, colocation, computer rooms • Edge computing, Internet DC, cloud computing • Computer rooms • Light industrial and commercial buildings • Infrastructure and transportation • Telecommunications and networking • Critical power infrastructures • Emergency lighting • UP9540A fire tested compliance • 67Ah LMO/NCM battery system • Double your battery life vs. VRLA solutions • Up to 70% more compact footprint frees up floor space for revenue-generating equipment • Boost availability with 2-3x faster recharge rates than VRLA solutions • Built-in 3-level battery management system (BMS) • Green Premium solution • Aesthetic match with Galaxy V Series UPSs • Self feeding SMPS simplifies installation • Fast, simple installation — cabinet ships pre- assembled, except battery modules, and rolls quickly into place • Enhance employee protection with modular touch- safe design, breaker covers, and built-in fuse protection at the battery cell and cabinet level • Seismic kit • EcoStruxure connected • Start-up service options available 21 For Galaxy VS, VM, VL, VX, VXL; Symmetra PX 250/500; Symmetra MW; Easy UPS 3M; Easy UPS 3L/Galaxy 3L; Easy UPS 3-Phase Modular; and Galaxy PX Sold: Worldwide Overview A Galaxy Lithium-ion Battery Cabinet are compact, lightweight, long-lasting, and sophisticated energy storage solution for Galaxy V series and Easy 3-phase UPSs in data centers, industrial processes, and critical infrastructures. This UL9540A-compliant battery solution reduces battery footprint and weight by up to 70%, allowing more effective use of space. Lithium-ion batteries reduce total cost of ownership, both by doubling battery life and by operating at higher temperatures, reducing cooling requirements. SE.com 22 Products 3-phase IT Power Distribution Public 23 Power Distribution Units (PDUs) Features Applications • Small, medium, and large data centers • Colocation facilities • Compartmental design simplifies asset access allocation • Meets the demanding scalability needs of any data center of any size • Factory installed and tested Square D breaker panel configured to meet the unique needs of your site • Easy to install and service with top and bottom cable entry • Low total cost of ownership • Seismic cabinet (OSHPD) • 7-inch display interface • EcoStruxure connected 23 Overview Power Distribution Units are reliable, scalable, and intelligent high-density power distribution solutions ideal for installation in the electrical rooms of data centers. SE.com 400 & 500 kVA (480V) Sold: US, Central America Options • Copper or aluminum transformers • Main input switch or breaker • Main output breaker • Advanced metering • Wide range of 250 Amp, 400 Amp, and 600 Amp branch breaker options from Schneider Electric's PowerPact J- and L-frame breaker series • EPO • Cloud service providers • Industrial applications 400 & 500 kVA (Aluminum) and 400 kVA (Copper) 500 kVA (Copper) Public 24 Galaxy RPP Features Applications • Data centers • Colocation facilities • Cloud service providers • Compact footprint and easy front-access design • Supports installation against walls, back-to-back, or in your EcoStruxure Pod Data Center • Flexible configuration, with factory installed and tested Square D breaker panels configured to your site requirements • Meets the demanding scalability needs of any large data center • PowerLogic Branch Circuit Power Meter monitors single or dual feed installations • Compartmental design simplifies asset access allocation • Top and bottom cable entry • Compatible with all Schneider Electric Power Distribution Units • 7-inch touchscreen display • EcoStruxure connected 24 Overview Galaxy RPP (Remote Power Panels) 250 and 400 Amp (120V/208V) offers highly configurable, highly modular, high-density row-level power distribution for data centers and colocation facilities. SE.com 250 & 400 Amp (120V/208V) Sold: US, Canada, Central America Options • L-frame or J-frame main input breakers • NP, NQ, or IP2X panelboard • QO, QOB, or EDB distribution breakers • Surge protection devices • Start-up service options available Configurable and Modular Power Distribution Units • Top or bottom cable entry (60/150 kW PDU) • Flexible configure-to-order options • Factory assembled and tested • Scalable • Modbus supported • Integrated monitoring • Network enabled • No side access required • Preconfigured cord sets • Compatible with StruxureWare Data Center Expert • Branch circuit monitoring • Power distribution modules with locking connectors (Modular) 25 Features Applications • Small, medium, or large data centers Overview Modular Power Distribution Units (PDUs) mitigate the need to predict the future requirements and configurations of your data center. Configurable Power Distribution Units bring agility, availability, and speed of deployment to your data center. Our factory-tested power distribution units are built to your exact specifications, support overhead or underfloor distribution, and feature a convenient, portable rack form factor. Options 120/208/230/400/480/600V: 72-277 kW (Modular) 208V/480V/600V: 40-150 kW (Configurable) Sold: Worldwide; product availability varies by region Modular Configurable • Shielding troughs Startup service SE.com: Configurable and Modular Upsilon Static Transfer Switches 30-630A standard; 800-1250A on request Sold: All IEC regions worldwide • Industrial applications • Data centers • Telecommunication centers • Infrastructure • Simplifies installation and maintenance while minimizing space requirements • Independent control boards, dual cooling systems, and power supplies ensure high reliability performance • Small footprint reduces required floor space • Text and mimic diagrams display modes of operation, system parameters, and alarms • Allows isolation of a source for maintenance without interrupting power to the protected loads Options • Communication: JBus/Modbus card (supplied as standard), status information card (supplied as standard) • Open frame version Overview Upsilon Static Transfer Switches (STS) provides true redundance and exceptional high reliability for automatic power supply transfer to a range of equipment from two independent and redundant power sources. Static Transfer Switches automatically transfer power to a stable alternate source in less than 4ms under normal operating conditions. Even under extreme conditions, such as 180 degrees out of phase, the STS will have detection and automatic transfer times that are up to 10 times faster than many other switches. 26 SE.com • PDU (36 16A circuit breakers incorporated in the H = 1900 cell, up to 100 A) • Connection at the top of the unit Features Applications & Segments 27 Key Applications and Segments by Product 28 IT Small data centers Medium data centers Large data centers Colocation facilities Cloud computing Commercial facilities Industrial facilities Healthcare Transportation Telecommunications Energy & Chemical Metal, Minerals, and Mining Consumer Packaged Goods Semi Conductor Galaxy VS Galaxy VM Galaxy VL Galaxy VX Galaxy VXL Easy UPS 3S Easy UPS 3M Easy UPS 3M Advanced Easy UPS 3L Galaxy 3L Easy UPS 3-Phase Modular Galaxy PX Symmetra PX Galaxy PW 2nd Gen Galaxy Lithium-ion Battery Cabinets Power Distribution Units (PDUs) Galaxy RPP Configurable and Modular PDUs Upsilon Static Transfer Switches ü Key Applications and Segments by Product To learn more about Schneider Electric 3-Phase UPS products and solutions, contact your Schneider Electric representative or visit www.se.com. Schneider Electric 35 rue Joseph Monier 92500 Rueil Malmaison France Product specifications are subject to change without notice and are provided “as is” without warranty of any kind, express or implied. See apc.com for the most up to date product specifications. • 998-19858418_GMA-US 28 General 05/2024 EcoStruxure™ Power for Semiconductor Fabs Utilizing a Digital Twin for Electrical Distribution to Drive Efficient Facilities Reference Guide EcoStruxure™ Power for Semiconductor Fabs General SECTION 3 – Digital Solutions and Services SECTION 1 – Introduction to the Semiconductor Fab Industry SECTION 2 – How EcoStruxure Power Can Support the Semiconductor Fab BIBLIOGRAPHY Purpose of the Document Target Audience This document is intended to address End User Engineering, Operations and Maintenance, Consultants, EPCs (Engineering, Procurement, and Construction) and Service teams and other qualified personnel. Objective To understand the challenges of designing and operating a Semiconductor Fab with an efficient and sustainable electrical distribution strategy. Table of Contents Overview of capabilities Previous Next Reference Guide EcoStruxure™ Power for Semiconductor Fabs General SECTION 3 – Digital Solutions and Services SECTION 1 – Introduction to the Semiconductor Fab Industry SECTION 2 – How EcoStruxure Power Can Support the Semiconductor Fab BIBLIOGRAPHY Table of Contents SECTION 1: Introduction to the Semiconductor Fab Introduces the context and the challenges of a Semiconductor Fab. SECTION 2: How Schneider Electric Can Support the Semiconductor Fab Industry with EcoStruxure Power Describes the solutions that EcoStruxure Power provides for Semiconductor Fabs, with typical electrical and digital architectures. BIBLIOGRAPHY Contains useful documents to find out more about capabilities. Provides details about Green Premium. SECTION 3: Digital Solutions and Services Gives information about EcoStruxure Power capabilities for Semiconductor Fabs, sorted by value proposition: • Transverse Lifecycle Capabilities • Capabilities to Improve Time To Market • Capabilities to Increase Efficiency • Capabilities to Improve Resiliency • Capabilities to Grow Sustainability Reference Guide EcoStruxure™ Power for Semiconductor Fabs General WHY READ THIS SECTION? SECTION 1 SECTION 3 – Digital Solutions and Services SECTION 1 – Introduction to the Semiconductor Fab Industry SECTION 2 – How EcoStruxure

Power Can Support the Semiconductor Fab BIBLIOGRAPHY Semiconductor Fab Industry Semiconductor Fab Industry Challenges The objective of this section is to: • Introduce the growth, trends and challenges of the Semiconductor Fab industry • Present the 4 pillars to meet the Semiconductor Fab challenges. Introduction to the Semiconductor Fab Industry Reference Guide EcoStruxure™ Power for Semiconductor Fabs General SECTION 3 – Digital Solutions and Services SECTION 2 – How EcoStruxure Power Can Support the Semiconductor Fab BIBLIOGRAPHY SECTION 1 – Introduction to the Semiconductor Fab Industry Semiconductor Fab Industry Semiconductor Fab Industry Challenges Semiconductor Fab Market An industry driven by the growth of new technology Sources Chip Shortages Continue 17% Annual growth in chip demand from 2020-2022, while supply grew at only 6% per year. Strong Robust Growth +7% Robust growth till 2030. Hunt for Talent Intensifies +77% Rise in chip-related job vacancies from 2020. Geopolitical Impacts 65% Global share of value chain activities based in Asia, creating high supply chain risk. Focus on Sustainability +36% Semiconductor companies reinforced ESG* practices (2021 reporting). Acceleration of Digital Transformation +52% Increased use of cloud / automation in 2021. * ESG = Environmental, Social, and Governance Reference Guide EcoStruxure™ Power for Semiconductor Fabs General SECTION 3 – Digital Solutions and Services SECTION 2 – How EcoStruxure Power Can Support the Semiconductor Fab BIBLIOGRAPHY SECTION 1 – Introduction to the Semiconductor Fab Industry Semiconductor Fab Industry Semiconductor Fab Industry Challenges Strong Robust Growth: https://www.mckinsey.com/industries/semiconductors/our-insights/the-semiconductor-decade-a-trillion-dollar-industry Hunt for Talent Intensifies: https://asia.nikkei.com/Business/Business-Spotlight/Chip-talent-war-Taiwan-faces-critical-staffing-shortage Focus on Sustainability: https://arstechnica.com/science/2022/04/can-semiconductor-makers-meet-surging-demands-sustainably/ Geopolitical Impacts: https://www.voanews.com/a/race-for-semiconductors-influences-taiwan-conflict-/6696432.html Acceleration of Digital Transformation: https://quixy.com/blog/top-digital-transformation-statistics-trends- forecasts/
#:~:text=According%20to%20Markets%20and%20Markets,by%205.1%25%20according%20to%20Gartner. Chip Shortages Continue: https://www.mynewsdesk.com/rolandberger/pressreleases/global-semiconductor-shortage-to-persist-for-several-years-beyond- 2022-3151267 Sources Reference Guide EcoStruxure™ Power for Semiconductor Fabs General SECTION 3 – Digital Solutions and Services SECTION 2 – How EcoStruxure Power Can Support the Semiconductor Fab BIBLIOGRAPHY SECTION 1 – Introduction to the Semiconductor Fab Industry Semiconductor Fab Industry Semiconductor Fab Industry Challenges Semiconductor Fab Market The market trends: a changing landscape Significant investment for expansions and modernization A growing focus on efficiency and sustainability High demand for power and water to meet semiconductor production capacity Cybersecurity Reference Guide EcoStruxure™ Power for Semiconductor Fabs General SECTION 3 – Digital Solutions and Services SECTION 2 – How EcoStruxure Power Can Support the Semiconductor Fab BIBLIOGRAPHY Semiconductor Fab Industry Semiconductor Fab Industry Challenges SECTION 1 – Introduction to the Semiconductor Fab Industry How can we reduce our operational costs? How can we improve power quality and minimize downtime? How can we reduce our carbon footprint and integrate more renewable, sustainable energy sources? How can we accelerate the design & build of new semiconductor fabs? Semiconductor Fab Industry Challenges Four pillars to drive efficiency, resiliency and sustainability KPIs The strong growth of the semiconductor industry leads to an increase in fabrication capacity. Creating or expanding this capacity is not without its challenges. Four pillars must be addressed: Grow Sustainability Improve Resiliency Increase Efficiency Improve Time to Market Reference Guide EcoStruxure™ Power for Semiconductor Fabs General WHY READ THIS SECTION? SECTION 2 SECTION 3 – Digital Solutions and Services SECTION 1 – Introduction to the Semiconductor Fab Industry SECTION 2 – How EcoStruxure Power Can Support the Semiconductor Fab BIBLIOGRAPHY Solutions to Address the Four Pillars EcoStruxure Power Value Proposition Example of Electrical & Digital Architectures The objective of this section is to: • Present the solutions to address the four pillars to meet the Semiconductor Fab industry challenges • Explain how Schneider Electric EcoStruxure Power can support this industry • Give an example of electrical and digital architectures. How EcoStruxure Power Can Support the Semiconductor Fab Industry Reference Guide EcoStruxure™ Power for Semiconductor Fabs General EcoStruxure Power Value Proposition Example of Electrical & Digital Architectures Solutions to Address the Four Pillars SECTION 3 – Digital Solutions and Services SECTION 1 – Introduction to the Semiconductor Fab Industry SECTION 2 – How EcoStruxure Power Can Support the Semiconductor Fab BIBLIOGRAPHY Grow Sustainability Improve Resiliency Increase Efficiency Improve Time to Market Solutions to Address the Four Pillars of Semiconductor Fabs The four pillars can be addressed by the following solutions: Improve Facility Performance Minimize Downtime Meet Sustainability KPIs Use Standardized Architectures Use standardized electrical distribution and digital tools to speed up the design,

build and commissioning of new fabs. Turn data into business intelligence and leverage a digital twin to provide actionable insights to drive efficiency. Help assure optimum power quality and reliability while improving safety for your staff and guarding against cyber attacks Engage consultancy services to strategize, digitize and decarbonize. This guide describes the solutions developed by EcoStruxure Power to address these four pillars. Reference Guide EcoStruxure™ Power for Semiconductor Fabs General SECTION 1 – Introduction to the Semiconductor Fab Industry SECTION 2 – How EcoStruxure Power Can Support the Semiconductor Fab Example of Electrical & Digital Architectures Solutions to Address the Four Pillars EcoStruxure Power Value Proposition SECTION 3 – Digital Solutions and Services BIBLIOGRAPHY EcoStruxure Power Value Proposition EcoStruxure Power for Semiconductor Fabs We are your end-to-end digital partner to design, build, operate and maintain semiconductor fabs with the utmost efficiency and resiliency towards a sustainable future. From electrical design to operations and maintenance Our collaborative environments, enhanced by the Electrical Distribution Digital Twin of your fab, enable high productivity operations. Reference Guide EcoStruxure™ Power for Semiconductor Fabs General SECTION 1 – Introduction to the Semiconductor Fab Industry SECTION 2 – How EcoStruxure Power Can Support the Semiconductor Fab Solutions to Address the Four Pillars EcoStruxure Power Value Proposition Example of Electrical & Digital Architectures SECTION 3 – Digital Solutions and Services BIBLIOGRAPHY Example of Electrical and Digital Architectures Typical front-end Semiconductor Fab Energy is key, whether for processes or for utilities: specific attention must be given to the design of the electrical architecture and associated digital architecture which will enable digital solutions and services. Front-end Semiconductor Fab PROCESS 50 % UTILITIES 50 % Ultrapure Water (UPW) Diffusion Photolithography Etching Ion Implantation 1 2 1 2 Subfab Cleanroom Others Clean Dry Air (CDA) and N2 Exhaust System Cooling Water System Physical Vapor Deposition (PVD) / Chemical Vapor Deposition (CVD) Chemical Mechanical Planarization (CMP) Reference Guide EcoStruxure™ Power for Semiconductor Fabs General SECTION 1 – Introduction to the Semiconductor Fab Industry SECTION 2 – How EcoStruxure Power Can Support the Semiconductor Fab Solutions to Address the Four Pillars EcoStruxure Power Value Proposition Example of Electrical & Digital Architectures SECTION 3 – Digital Solutions and Services BIBLIOGRAPHY Example of Electrical Architecture Example of Electrical and Digital Architectures Typical electrical architecture for a Semiconductor Fab General Example of Electrical Architecture UTILITY 50 % Cooling Water System • Chilled Water (MV Chillers, Cooling Towers) • Process Cooling Water (PCW) • AHU, FCU, FFU, Dry Coil Exhaust System Clean Dry Ari (CDA) and N2 Ultrapure Water (UPW) Others • Lighting • Wastewater • Air Recirculation • Make-Up Air Unit • Bulk Gases • Automated Materials Handling System (AMHS) • Abatement PROCESS 50 % Critical Process = Power Availability High Energy demand = Efficient Energy Management Diffusion Photolithography Etching Ion Implantation Chemical Mechanical Planarization (CMP) Physical Vapor Deposition (PVD)/ Chemical Vapor Deposition (CVD) Reference Guide EcoStruxure™ Power for Semiconductor Fabs General SECTION 1 – Introduction to the Semiconductor Fab Industry SECTION 2 – How EcoStruxure Power Can Support the Semiconductor Fab Solutions to Address the Four Pillars EcoStruxure Power Value Proposition Example of Electrical & Digital Architectures SECTION 3 – Digital Solutions and Services BIBLIOGRAPHY Example of Electrical and Digital Architectures Suggested digital architecture (high-level view) for a Semiconductor Fab Example of Digital Architecture (High-Level View) General Example of Digital Architecture (High-Level View) Reference Guide EcoStruxure™ Power for Semiconductor Fabs General SECTION 1 – Introduction to the Semiconductor Fab Industry SECTION 2 – How EcoStruxure Power Can Support the Semiconductor Fab Solutions to Address the Four Pillars EcoStruxure Power Value Proposition Example of Electrical & Digital Architectures SECTION 3 – Digital Solutions and Services BIBLIOGRAPHY Example of Electrical and Digital Architectures Corresponding detailed digital architecture for a Semiconductor Fab Example of Digital Architecture (Detailed View) General Example of Digital Architecture (Detailed View) Reference Guide EcoStruxure™ Power for Semiconductor Fabs General WHY READ THIS SECTION? SECTION 3 SECTION 3 – Digital Solutions and Services Introduction Overview of Digital Solutions and Services Transverse Lifecycle Capabilities Capabilities to Improve Time to Market Capabilities to Improve Your Process Capabilities to Improve Resiliency Capabilities to Grow Sustainability SECTION 1 – Introduction to the Semiconductor Fab Industry SECTION 2 – How EcoStruxure Power Can Support the Semiconductor Fab BIBLIOGRAPHY This section gives information about EcoStruxure Power capabilities for Semiconductor Fabs aligned to the industry challenges. Digital Solutions & Services Reference Guide EcoStruxure™ Power for Semiconductor Fabs General SECTION 3 – Digital Solutions and Services Introduction SECTION 1 – Introduction to the Semiconductor Fab Industry SECTION 2 – How EcoStruxure Power Can Support the Semiconductor Fab BIBLIOGRAPHY Overview of Digital Solutions and Services

Transverse Lifecycle Capabilities Capabilities to Improve Time to Market Capabilities to Increase Efficiency Capabilities to Improve Resiliency Capabilities to Grow Sustainability Grow Sustainability Improve Resiliency Increase Efficiency Improve Time to Market Introduction EcoStruxure Power provides capabilities to support the challenges of Semiconductor Fabs throughout their lifecycle These capabilities provide standardized designs and digital architectures, and enable easy simulation, to reduce cost of design and ownership. These capabilities use digitization to provide intelligent information to the workforce, allowing them to make smart decisions that reduce operating costs and increase efficiency. These capabilities use digitization to reduce unplanned downtime, increase reliability, and thus reduce production waste. These capabilities help track energy consumption and carbon emissions to meet sustainability requirements. Design, Build, Commission (Consultants & EPC) Operate & Maintain (Operators, maintenance team, service teams) Transverse Lifecycle Capabilities Digital Solutions that support your project from the Design, Build, Commission to Operate & Maintain phases. Reference Guide EcoStruxure™ Power for Semiconductor Fabs General SECTION 3 – Digital Solutions and Services Overview of Digital Solutions and Services SECTION 1 – Introduction to the Semiconductor Fab Industry SECTION 2 – How EcoStruxure Power Can Support the Semiconductor Fab BIBLIOGRAPHY Introduction Transverse Lifecycle Capabilities Capabilities to Improve Time to Market Capabilities to Increase Efficiency Capabilities to Improve Resiliency Capabilities to Grow Sustainability Overview of Digital Solutions and Services Electrical Digital Twin Green Premium Operator training simulation Energy monitoring and usage analysis Energy performance, modeling and verification Capacity management + + + + Cybersecurity Carbon neutrality consulting services Energy efficiency compliance Greenhouse gas reporting + + + Grow Sustainability Improve Resiliency Increase Efficiency Improve Time to Market Design, Build, Commission (Consultants & EPC) Operate & Maintain (Operators, maintenance team, service teams) Transverse Lifecycle Capabilities Asset performance Power quality monitoring and compliance Thermal and partial discharge monitoring Electrical distribution monitoring and alarming Power event analysis Predictive simulation Power quality and power factor correction + + + + + + + Arc flash protection+ Simulate before Operate+ AC&DC electrical network bus design and simulation Electrical network short circuit simulation Network load flow and voltage drop simulation Device coordination and selectivity Arc fault protection and coordination Power quality simulation and modeling Renewable & microgrid energy storage sizing simulation + + + + + + + Power system study+ Reference Guide EcoStruxure™ Power for Semiconductor Fabs General SECTION 3 – Digital Solutions and Services Transverse Lifecycle Capabilities SECTION 2 – How EcoStruxure Power Can Support the Semiconductor Fab BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Capabilities to Improve Time to Market Capabilities to Increase Efficiency Capabilities to Improve Resiliency Capabilities to Grow Sustainability SECTION 1 – Introduction to the Semiconductor Fab Industry Transverse Lifecycle Capabilities Electrical Digital Twin Green Premium Operator training simulation Energy monitoring and usage analysis Energy performance, modeling and verification Capacity management + + + + Cybersecurity Carbon neutrality consulting services Energy efficiency compliance Greenhouse gas reporting + + + Transverse Lifecycle Capabilities Asset performance Power quality monitoring and compliance Thermal and partial discharge monitoring Electrical distribution monitoring and alarming Power event analysis Predictive simulation Power quality and power factor correction + + + + + + + Arc flash protection+ Simulate before Operate+ AC&DC electrical network bus design and simulation Electrical network short circuit simulation Network load flow and voltage drop simulation Device coordination and selectivity Arc fault protection and coordination Power quality simulation and modeling Renewable & microgrid energy storage sizing simulation + + + + + + + Power system study Grow Sustainability Improve Resiliency Increase Efficiency Improve Time to Market Design, Build, Commission (Consultants & EPC) Operate & Maintain (Operators, maintenance team, service teams) Reference Guide EcoStruxure™ Power for Semiconductor Fabs General SECTION 3 – Digital Solutions and Services Transverse Lifecycle Capabilities SECTION 2 – How EcoStruxure Power Can Support the Semiconductor Fab BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Capabilities to Improve Time to Market Capabilities to Increase Efficiency Capabilities to Improve Resiliency Capabilities to Grow Sustainability SECTION 1 – Introduction to the Semiconductor Fab Industry Electrical Digital Twin Benefits • Intelligent user-interface for all levels of AC and DC networks • Enables users, from the design to operate phases, to model, simulate, analyze and validate electrical power systems to predict their electrical network behavior • Takes the day-to-day system modeling and design tasks to a new level of speed, accuracy and ease Maintain a Digital Twin of your electrical distribution Transverse Lifecycle Capabilities Electrical Digital Twin Reference Guide EcoStruxure™ Power for Semiconductor Fabs General SECTION 3 – Digital Solutions and Services Transverse Lifecycle Capabilities SECTION 2 – How EcoStruxure Power Can Support the Semiconductor

Fab BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Capabilities to Improve Time to Market Capabilities to Increase Efficiency Capabilities to Improve Resiliency Capabilities to Grow Sustainability SECTION 1 – Introduction to the Semiconductor Fab Industry Green Premium Benefits • Green Premium* products provide detailed information on their regulatory compliance, material content, environmental impact, and circularity attributes. Manage sustainability from design to end of life Transverse Lifecycle Capabilities Compliance and transparency (compliance certificates, circularity profiles, environmental footprint, etc.)1 Circular performance Durability, upgradeability, re-manufacture, recycled content, recyclability Well-being performance E.g. free of PVC, mercury, silicone, SVHC, lead, toxic heavy metal and compliant with California Prop 65 4 Resource performance Optimized energy performance Lower carbon emissions 2 3 * The Green Premium label was created to provide Schneider Electric's customers with more sustainable products and to be transparent with environmental information. Supporting your efforts for a LEED certified building Helping you achieve Living Building Challenge certification Green Premium Value Proposition Learn more about: • Green Premium Reference Guide EcoStruxure™ Power for Semiconductor Fabs General SECTION 3 – Digital Solutions and Services Transverse Lifecycle Capabilities SECTION 2 – How EcoStruxure Power Can Support the Semiconductor Fab BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Capabilities to Improve Time to Market Capabilities to Increase Efficiency Capabilities to Improve Resiliency Capabilities to Grow Sustainability SECTION 1 – Introduction to the Semiconductor Fab Industry Cybersecurity Benefits • Provides a selection of cybersecurity certified products • Provides certified system architectures and solutions • Delivers lifecycle services Help secure the digital power distribution system Transverse Lifecycle Capabilities Learn more about: • Cybersecurity Certified products developed according to IEC 62443 functional requirements with Secure Development Lifecycle processes. Consulting services from design, implementation, operations and maintenance to tailor your security solutions to your strategy and budget. Lifecycle services Certified secure system architecture according to IEC 62443-3-3 with documented processes and solutions for a secure system. Cybersecurity system configuration software for consistent security policy deployment. Certified products Certified systems & solutions Reference Guide EcoStruxure™ Power for Semiconductor Fabs General SECTION 3 – Digital Solutions and Services Capabilities to Improve Time to Market SECTION 1 – Introduction to the Semiconductor Fab Industry SECTION 2 – How EcoStruxure Power Can Support the Semiconductor Fab BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Transverse Lifecycle Capabilities Capabilities to Increase Efficiency Capabilities to Improve Resiliency Capabilities to Grow Sustainability Capabilities to Improve Time to Market Electrical Digital Twin Green Premium Operator training simulation Energy monitoring and usage analysis Energy performance, modeling and verification Capacity management + + + + Cybersecurity Carbon neutrality consulting services Energy efficiency compliance Greenhouse gas reporting + + + Transverse Lifecycle Capabilities Asset performance Power quality monitoring and compliance Thermal and partial discharge monitoring Electrical distribution monitoring and alarming Power event analysis Predictive simulation Power quality and power factor correction Simulate before Operate Arc flash protection + + + + + + + + + AC&DC electrical network bus design and simulation Electrical network short circuit simulation Network load flow and voltage drop simulation Device coordination and selectivity Arc fault protection and coordination Power quality simulation and modeling Renewable & Microgrid energy storage sizing simulation + + + + + + + + Power system study+ Grow Sustainability Improve Resiliency Increase Efficiency Improve Time to Market Design, Build, Commission (Consultants & EPC) Operate & Maintain (Operators, maintenance team, service teams) Reference Guide EcoStruxure™ Power for Semiconductor Fabs General SECTION 3 – Digital Solutions and Services Capabilities to Improve Time to Market SECTION 1 – Introduction to the Semiconductor Fab Industry SECTION 2 – How EcoStruxure Power Can Support the Semiconductor Fab BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Transverse Lifecycle Capabilities Capabilities to Increase Efficiency Capabilities to Improve Resiliency Capabilities to Grow Sustainability AC and DC Electrical Network Bus Design and Simulation Primary Department • Design • Construction Benefits • Single solution/environment - Unified AC & DC solution from HV to LV - One unique platform and one database • Efficient profile management - User-defined loading and generation profiles - External data profile based on field measurements • Scalability - Load growth study for future planning • Event simulations within the calculation period Optimize bus design allocation and simulation ETAP Electrical Network Model Capabilities to Improve Time to Market Reference Guide EcoStruxure™ Power for Semiconductor Fabs General SECTION 3 – Digital Solutions and Services Capabilities to Improve Time to Market SECTION 1 – Introduction to the Semiconductor Fab Industry SECTION 2 – How EcoStruxure Power Can Support the Semiconductor Fab BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Transverse

Lifecycle Capabilities Capabilities to Increase Efficiency Capabilities to Improve Resiliency Capabilities to Grow Sustainability Electrical Network Short Circuit Simulation Primary Department • Design • Construction Benefits • Expedite design studies with a wide range of calculation scenarios, including advanced fault analysis - IEC & ANSI duty calculation for balanced and unbalanced faults - Simultaneous fault at selected nodes - Inclusive 3-Phase and 1-Phase fault analysis - Pre-Fault system loading consideration Design and simulate unbalanced short circuits Electrical Network Short Circuit Simulation in ETAP Capabilities to Improve Time to Market Reference Guide EcoStruxure™ Power for Semiconductor Fabs General SECTION 3 – Digital Solutions and Services Capabilities to Improve Time to Market SECTION 1 – Introduction to the Semiconductor Fab Industry SECTION 2 – How EcoStruxure Power Can Support the Semiconductor Fab BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Transverse Lifecycle Capabilities Capabilities to Increase Efficiency Capabilities to Improve Resiliency Capabilities to Grow Sustainability Network Load Flow and Voltage Drop Simulation Primary Department • Design • Construction Benefits • Simulation of bus voltages, branch power factors, currents, system losses, power generation versus loading • Use of ETAP Electrical Digital Twin model with powerful calculation engines and user-friendly interface • Simulation using multiple loading and generation conditions Perform power flow analysis and voltage drop calculations Network Load Flow and Voltage Drop Simulation in ETAP Capabilities to Improve Time to Market Reference Guide EcoStruxure™ Power for Semiconductor Fabs General SECTION 3 – Digital Solutions and Services Capabilities to Improve Time to Market SECTION 1 – Introduction to the Semiconductor Fab Industry SECTION 2 – How EcoStruxure Power Can Support the Semiconductor Fab BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Transverse Lifecycle Capabilities Capabilities to Increase Efficiency Capabilities to Improve Resiliency Capabilities to Grow Sustainability Device Coordination and Selectivity Primary Department • Design • Construction Benefits • Verified and validated libraries • Graphically adjustable device settings • Detailed device settings reporting • Continuous synchronization with one-line and integrated equipment database Automatically detect and evaluate the system protection and coordination/selectivity Device Coordination and Selectivity in ETAP Capabilities to Improve Time to Market Reference Guide EcoStruxure™ Power for Semiconductor Fabs General SECTION 3 – Digital Solutions and Services Capabilities to Improve Time to Market SECTION 1 – Introduction to the Semiconductor Fab Industry SECTION 2 – How EcoStruxure Power Can Support the Semiconductor Fab BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Transverse Lifecycle Capabilities Capabilities to Increase Efficiency Capabilities to Improve Resiliency Capabilities to Grow Sustainability Arc Fault Protection and Coordination Primary Department • Design • Construction Benefits • Evaluate, verify, and confirm the operation and selectivity of the protective devices for various types of faults for any location directly from the single-line diagram • Animation displayed on the single-line diagram • 3-phase / 1-phase sequence of operation Perform sequence of operation for arc fault and bolted fault Arc Fault Protection and Coordination in ETAP Capabilities to Improve Time to Market Reference Guide EcoStruxure™ Power for Semiconductor Fabs General SECTION 3 – Digital Solutions and Services Capabilities to Improve Time to Market SECTION 1 – Introduction to the Semiconductor Fab Industry SECTION 2 – How EcoStruxure Power Can Support the Semiconductor Fab BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Transverse Lifecycle Capabilities Capabilities to Increase Efficiency Capabilities to Improve Resiliency Capabilities to Grow Sustainability Power Quality Simulation and Modeling Primary Department • Design • Construction Benefits • Simulate harmonic current and voltage sources: - To identify potential harmonic problems (report of harmonic voltage and current distortion limit violations) - To identify the need for a harmonics filter • Simulate and analyze the size of the harmonics filter your system will need to optimize performance and reduce nuisance trips Evaluate and validate distortion due to harmonics Power Quality Simulation and Modeling in ETAP Capabilities to Improve Time to Market Reference Guide EcoStruxure™ Power for Semiconductor Fabs General SECTION 3 – Digital Solutions and Services Capabilities to Improve Time to Market SECTION 1 – Introduction to the Semiconductor Fab Industry SECTION 2 – How EcoStruxure Power Can Support the Semiconductor Fab BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Transverse Lifecycle Capabilities Capabilities to Increase Efficiency Capabilities to Improve Resiliency Capabilities to Grow Sustainability Renewable and Microgrid Energy Storage Sizing Simulation Primary Department • Design • Construction Benefits • Build renewable energy models combined with full spectrum power system analysis calculations for: - Accurate simulation - Predictive analysis - Equipment sizing - Field verification of wind, solar farms and other DERs • Enable designers and engineers to conceptualize the collector systems, determine wind penetration and perform grid interconnection studies Design and optimize the microgrid system Microgrid Energy Storage Sizing Simulation in ETAP Capabilities to Improve Time to Market Reference Guide EcoStruxure™ Power for

Semiconductor Fabs General SECTION 3 – Digital Solutions and Services Capabilities to Improve Time to Market SECTION 1 – Introduction to the Semiconductor Fab Industry SECTION 2 – How EcoStruxure Power Can Support the Semiconductor Fab BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Transverse Lifecycle Capabilities Capabilities to Increase Efficiency Capabilities to Improve Resiliency Capabilities to Grow Sustainability Power System Study Primary Department • Design • Construction • Facilities Electrical Department Benefits • Partner with a global team of experts, engaged with industry standards committees, to develop common safety standards and practices. • Create a standardized approach to Power System Studies to support multisite deployments with consistent results Work with engineering experts to provide Power System Studies Study (Analyze) Assess Design Capabilities to Improve Time to Market Reference Guide EcoStruxure™ Power for Semiconductor Fabs General SECTION 3 – Digital Solutions and Services Capabilities to Increase Efficiency SECTION 1 – Introduction to the Semiconductor Fab Industry SECTION 2 – How EcoStruxure Power Can Support the Semiconductor Fab BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Transverse Lifecycle Capabilities Capabilities to Improve Time to Market Capabilities to Improve Resiliency Capabilities to Grow Sustainability Capabilities to Increase Efficiency Electrical Digital Twin Green Premium Operator training simulation Energy monitoring and usage analysis Energy performance, modeling and verification Capacity management + + + + Cybersecurity Carbon neutrality consulting services Energy efficiency compliance Greenhouse gas reporting + + + Transverse Lifecycle Capabilities Asset performance Power quality monitoring and compliance Thermal and partial discharge monitoring Electrical distribution monitoring and alarming Power event analysis Predictive simulation Power quality and power factor correction Arc flash protection Simulate before Operate + + + + + + + + + AC&DC electrical network bus design and simulation Electrical network short circuit simulation Network load flow and voltage drop simulation Device coordination and selectivity Arc fault protection and coordination Power quality simulation and modeling Renewable & microgrid energy storage sizing simulation + + + + + + + Power system study Grow Sustainability Improve Resiliency Increase Efficiency Improve Time to Market Design, Build, Commission (Consultants & EPC) Operate & Maintain (Operators, maintenance team, service teams) Reference Guide EcoStruxure™ Power for Semiconductor Fabs General SECTION 3 – Digital Solutions and Services Capabilities to Increase Efficiency SECTION 1 – Introduction to the Semiconductor Fab Industry SECTION 2 – How EcoStruxure Power Can Support the Semiconductor Fab BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Transverse Lifecycle Capabilities Capabilities to Improve Time to Market Capabilities to Improve Resiliency Capabilities to Grow Sustainability Operator Training Simulation Primary Department • Facility Operations & Maintenance Benefits • Practice operation within a simulated but highly realistic environment to enhance safety and operational efficiency • Track and review trainee actions to analyze and challenge them Train new employees and build confidence on new systems + Capabilities to Increase Efficiency Principle of Operator Training Simulation Application Learn more about: • Operator Training Simulation (IEC / NEMA) Operator Training Simulation Reference Architecture General Operator Training Simulation Reference Architecture Reference Guide EcoStruxure™ Power for Semiconductor Fabs General SECTION 3 – Digital Solutions and Services Capabilities to Increase Efficiency SECTION 1 – Introduction to the Semiconductor Fab Industry SECTION 2 – How EcoStruxure Power Can Support the Semiconductor Fab BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Transverse Lifecycle Capabilities Capabilities to Improve Time to Market Capabilities to Improve Resiliency Capabilities to Grow Sustainability Energy Monitoring and Usage Analysis Primary Department • Facility Operations & Maintenance Benefits • Bring awareness to utility consumption - Turn data into easy-to-interpret graphical dashboards and reports to raise awareness amongst key stakeholders • Identify “quick-win” opportunities for energy savings - By comparing and visualizing energy usage and cost for different utilities over different time periods - By identifying and prioritizing which areas lend themselves to a high energy-saving return on investment Determine where to focus energy conservation initiatives Capabilities to Increase Efficiency Energy Usage Analysis Dashboards in EcoStruxure Power Operation Learn more about: • Energy Monitoring (IEC / NEMA) Energy Monitoring and Usage Analysis Reference Architecture General Energy Monitoring and Usage Analysis Reference Architecture Reference Guide EcoStruxure™ Power for Semiconductor Fabs General SECTION 3 – Digital Solutions and Services Capabilities to Increase Efficiency SECTION 1 – Introduction to the Semiconductor Fab Industry SECTION 2 – How EcoStruxure Power Can Support the Semiconductor Fab BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Transverse Lifecycle Capabilities Capabilities to Improve Time to Market Capabilities to Improve Resiliency Capabilities to Grow Sustainability Energy Performance, Modeling and Verification Primary Department • Facility Operations & Maintenance Benefits •

Provide energy usage information based on equipment and processes • Compare model versus actual consumption • Compare pre-retrofit versus post-retrofit energy consumption to track improved performance and savings as a result of energy conservation initiatives Analyze the energy performance of a plant against a model baseline Capabilities to Increase Efficiency Energy Performance, Modeling and Verification Output in EcoStruxure Power Operation Energy Performance, Modeling and Verification Reference Architecture Learn more about: • Energy Performance (IEC / NEMA) • Energy Modeling and verification (IEC / NEMA) General Energy Performance Modeling and Verification Reference Architecture Reference Guide EcoStruxure™ Power for Semiconductor Fabs General SECTION 3 – Digital Solutions and Services Capabilities to Increase Efficiency SECTION 1 – Introduction to the Semiconductor Fab Industry SECTION 2 – How EcoStruxure Power Can Support the Semiconductor Fab BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Transverse Lifecycle Capabilities Capabilities to Improve Time to Market Capabilities to Improve Resiliency Capabilities to Grow Sustainability Capacity Management Primary Department • Facility Operations & Maintenance Benefits • Monitor electrical network capacity • Track and review capacity efficiency • Minimize downtime by tracking the capacity of transformers, circuit breakers, UPSs, generators, etc. Monitor the capacity of electrical distribution Capabilities to Increase Efficiency Breaker Capacity Single-line Diagram in EcoStruxure Power Operation Capacity Management Reference Architecture Learn more about: • Capacity Management (IEC / NEMA) General Capacity Management Reference Architecture Reference Guide EcoStruxure™ Power for Semiconductor Fabs General SECTION 3 – Digital Solutions and Services Capabilities to Improve Resiliency SECTION 1 – Introduction to the Semiconductor Fab Industry SECTION 2 – How EcoStruxure Power Can Support the Semiconductor Fab BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Transverse Lifecycle Capabilities Capabilities to Improve Time to Market Capabilities to Increase Efficiency Capabilities to Grow Sustainability Capabilities to Improve Resiliency Electrical Digital Twin Green Premium Operator training simulation Energy monitoring and usage analysis Energy performance, modeling and verification Capacity management + + + + Cybersecurity Carbon neutrality consulting services Energy efficiency compliance Greenhouse gas reporting + + + Transverse Lifecycle Capabilities Asset performance Power quality monitoring and compliance Thermal and partial discharge monitoring Electrical distribution monitoring and alarming Power event analysis Predictive simulation Power quality and power factor correction + + + + + + + Arc flash protection+ Simulate before Operate+ AC&DC electrical network bus design and simulation Electrical network short circuit simulation Network load flow and voltage drop simulation Device coordination and selectivity Arc fault protection and coordination Power quality simulation and modeling Renewable & microgrid energy storage sizing simulation + + + + + + + Power system study Grow Sustainability Improve Resiliency Increase Efficiency Improve Time to Market Design, Build, Commission (Consultants & EPC) Operate & Maintain (Operators, maintenance team, service teams) Reference Guide EcoStruxure™ Power for Semiconductor Fabs General SECTION 3 – Digital Solutions and Services Capabilities to Improve Resiliency SECTION 1 – Introduction to the Semiconductor Fab Industry SECTION 2 – How EcoStruxure Power Can Support the Semiconductor Fab BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Transverse Lifecycle Capabilities Capabilities to Improve Time to Market Capabilities to Increase Efficiency Capabilities to Grow Sustainability Predictive Simulation Help employees make better decisions Primary Department • Facility Engineering • Design Engineering Benefits • Reduce safety risks by practicing emergencies and high-risk situations • Enhance operational efficiency by running "what-if" scenarios • Provide faster analysis response to incidents Capabilities to Improve Resiliency + Predictive Simulation Reference Architecture Principle of Predictive Simulation Application General Predictive Simulation Reference Architecture Reference Guide EcoStruxure™ Power for Semiconductor Fabs General SECTION 3 – Digital Solutions and Services Capabilities to Improve Resiliency SECTION 1 – Introduction to the Semiconductor Fab Industry SECTION 2 – How EcoStruxure Power Can Support the Semiconductor Fab BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Transverse Lifecycle Capabilities Capabilities to Improve Time to Market Capabilities to Increase Efficiency Capabilities to Grow Sustainability Simulate Before Operate Empower operators with predictive outcomes Primary Department • Facility Operations & Maintenance Benefits • Provide operators with a list of potential side effects, prior to executing a command • Empower employees to feel more confident when operating their facilities by providing real time guidance • Reduce human error that could lead to outages or safety concerns Capabilities to Improve Resiliency + Simulate Before Operate Reference Architecture Principle of Simulate before Operate Application Learn more about: • Simulate Before Operate (IEC / NEMA) General Simulate Before Operate Reference Architecture Reference Guide EcoStruxure™ Power for Semiconductor Fabs General SECTION 3 – Digital Solutions and Services Capabilities to Improve Resiliency SECTION 1 –

Introduction to the Semiconductor Fab Industry SECTION 2 – How EcoStruxure Power Can Support the Semiconductor Fab BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Transverse Lifecycle Capabilities Capabilities to Improve Time to Market Capabilities to Increase Efficiency Capabilities to Grow Sustainability Electrical Distribution Monitoring and Alarming Monitor and control electrical network Primary Department • Facility Operations & Maintenance Benefits • Show real-time status of the power distribution • Customized single-line diagram • 24/7 power monitoring and alarm notification Capabilities to Improve Resiliency Electrical Distribution Monitoring and Alarming Single-line Diagram in EcoStruxure Power Operation Electrical Distribution Monitoring and Alarming Reference Architecture Learn more about: • Electrical distribution monitoring and alarming (IEC / NEMA) • Power Source and Load Control (IEC / NEMA) General Electrical Distribution Monitoring and Alarming Reference Architecture Reference Guide EcoStruxure™ Power for Semiconductor Fabs General SECTION 3 – Digital Solutions and Services Capabilities to Improve Resiliency SECTION 1 – Introduction to the Semiconductor Fab Industry SECTION 2 – How EcoStruxure Power Can Support the Semiconductor Fab BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Transverse Lifecycle Capabilities Capabilities to Improve Time to Market Capabilities to Increase Efficiency Capabilities to Grow Sustainability Power Events Analysis Analyze the root causes of electrical events Primary Department • Facility Operations & Maintenance Benefits • Automatically classifies and describes any electrical events • Uses system intelligence to determine root cause and location of events • Shows context and sequence of events using the timeline analysis interface Capabilities to Improve Resiliency Event and Alarm Status view in EcoStruxure Power Operation Event and Alarm Status Timeline in EcoStruxure Power Operation Power Event Analysis Reference Architecture Learn more about: • Power Event Analysis (IEC / NEMA) General Power Events Analysis Reference Architecture Reference Guide EcoStruxure™ Power for Semiconductor Fabs General SECTION 3 – Digital Solutions and Services Capabilities to Improve Resiliency SECTION 1 – Introduction to the Semiconductor Fab Industry SECTION 2 – How EcoStruxure Power Can Support the Semiconductor Fab BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Transverse Lifecycle Capabilities Capabilities to Improve Time to Market Capabilities to Increase Efficiency Capabilities to Grow Sustainability Asset Performance Benefit from a strategic maintenance approach Primary Department • Facility Operations & Maintenance Benefits • Move from reactive or preventive to condition-based (predictive) maintenance strategies for critical assets like circuit breakers, gensets, transformers, etc. • Provide event details and notification to the operator if a protection setting has been changed • Receive notifications and diagnostics reports from expert service engineers with recommendations to optimize maintenance by asset or site Capabilities to Improve Resiliency Asset Performance Reference Architecture Aging Diagram for Circuit Breakers in EcoStruxure Power Operation Gigafactory Learn more about: • Asset Performance (IEC / NEMA) General Asset Performance Reference Architecture Reference Guide EcoStruxure™ Power for Semiconductor Fabs General SECTION 3 – Digital Solutions and Services Capabilities to Improve Resiliency SECTION 1 – Introduction to the Semiconductor Fab Industry SECTION 2 – How EcoStruxure Power Can Support the Semiconductor Fab BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Transverse Lifecycle Capabilities Capabilities to Improve Time to Market Capabilities to Increase Efficiency Capabilities to Grow Sustainability Power Quality Monitoring and Compliance Gain insights to improve power quality and comply with standards Primary Department • Facility Operations & Maintenance Benefits • Bring awareness of power quality • Enhance operational efficiency by making sure clean power is fed to sensitive process equipment • Help protect sensitive equipment by tracking power quality problems before they arise Capabilities to Improve Resiliency Power Quality and Compliance Dashboards in EcoStruxure Power Operation Power Quality and Compliance Report in EcoStruxure Power Operation Power Quality Monitoring and Compliance Reference Architecture Learn more about: • Power Quality Monitoring and Compliance (IEC / NEMA) General Power Quality Monitoring and Compliance Reference Architecture Reference Guide EcoStruxure™ Power for Semiconductor Fabs General SECTION 3 – Digital Solutions and Services Capabilities to Improve Resiliency SECTION 1 – Introduction to the Semiconductor Fab Industry SECTION 2 – How EcoStruxure Power Can Support the Semiconductor Fab BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Transverse Lifecycle Capabilities Capabilities to Improve Time to Market Capabilities to Increase Efficiency Capabilities to Grow Sustainability Power Quality and Power Factor Correction Help protect sensitive equipment from power quality issues Primary Department • Facility Operations & Maintenance Benefits • Monitor sensitive process lines and busbars • Provide clean power to sensitive process equipment • Track Power Quality problems to help avoid downtime • Reduce financial impact of power factor on energy bill Capabilities to Improve Resiliency Galaxy VM Power Quality Information in EcoStruxure Power Operation Before and After Power Quality and Power

Factor Correction Implementation Power Quality and Power Factor Correction Reference Architecture Learn more about: • Power Quality Correction (IEC / NEMA) • Power Factor Correction (IEC / NEMA) General Power Quality and Power Factor Correction Reference Architecture Reference Guide EcoStruxure™ Power for Semiconductor Fabs General SECTION 3 – Digital Solutions and Services Capabilities to Improve Resiliency SECTION 1 – Introduction to the Semiconductor Fab Industry SECTION 2 – How EcoStruxure Power Can Support the Semiconductor Fab BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Transverse Lifecycle Capabilities Capabilities to Improve Time to Market Capabilities to Increase Efficiency Capabilities to Grow Sustainability Continuous Thermal Monitoring & Partial Discharge Monitoring Help prevent electrical fires and help protect employees and equipment Primary Department • Facility Operations & Maintenance Benefits • Provide early detection of internal arcing or temperature abnormalities in equipment that can cause damage - To help reduce the risk of equipment and electrical room damage - To improve service continuity • Enable optimized maintenance schedules by providing continuous monitoring vs calendar-based service Capabilities to Improve Resiliency Continuous Thermal Monitoring & Partial Discharge Monitoring Reference Architecture Learn more about: • Continuous Thermal monitoring (IEC / NEMA) Continuous Thermal Monitoring in the Single-line Diagram of EcoStruxure Power Operation General Continuous Thermal Monitoring and Partial Discharge Monitoring Reference Architecture Reference Guide EcoStruxure™ Power for Semiconductor Fabs General SECTION 3 – Digital Solutions and Services Capabilities to Improve Resiliency SECTION 1 – Introduction to the Semiconductor Fab Industry SECTION 2 – How EcoStruxure Power Can Support the Semiconductor Fab BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Transverse Lifecycle Capabilities Capabilities to Improve Time to Market Capabilities to Increase Efficiency Capabilities to Grow Sustainability Arc Flash Protection Help protect employees and equipment Primary Department • Facility Operations & Maintenance Benefits • Help prevent loss of life and reduce the risk of equipment and electrical room damage • Improve maintenance team awareness to help troubleshoot and identify the root cause of arc flash events Arc Flash in a Switchboard Arc Flash Alert and Location in EcoStruxure Power Operation Capabilities to Improve Resiliency Arc Flash Protection Reference Architecture Learn more about: • Arc Flash Protection (IEC / NEMA) General Arc Flash Protection Reference Architecture Reference Guide EcoStruxure™ Power for Semiconductor Fabs General SECTION 3 – Digital Solutions and Services Capabilities to Grow Sustainability SECTION 1 – Introduction to the Semiconductor Fab Industry SECTION 2 – How EcoStruxure Power Can Support the Semiconductor Fab BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Transverse Lifecycle Capabilities Capabilities to Improve Time to Market Capabilities to Increase Efficiency Capabilities to Improve Resiliency Capabilities to Grow Sustainability Electrical Digital Twin Green Premium Operator training simulation Energy monitoring and usage analysis Energy performance, modeling and verification Capacity management + + + + Cybersecurity Carbon neutrality consulting services Energy efficiency compliance Greenhouse gas reporting + + + Transverse Lifecycle Capabilities Asset performance Power quality monitoring and compliance Thermal and partial discharge monitoring Electrical distribution monitoring and alarming Power event analysis Predictive simulation Power quality and power factor correction + + + + + + + Arc flash protection+ Simulate before Operate+ AC&DC electrical network bus design and simulation Electrical network short circuit simulation Network load flow and voltage drop simulation Device coordination and selectivity Arc fault protection and coordination Power quality simulation and modeling Renewable & microgrid energy storage sizing simulation + + + + + + + Power system study Grow Sustainability Improve Resiliency Increase Efficiency Improve Time to Market Design, Build, Commission (Consultants & EPC) Operate & Maintain (Operators, maintenance team, service teams) Reference Guide EcoStruxure™ Power for Semiconductor Fabs General SECTION 3 – Digital Solutions and Services Capabilities to Grow Sustainability SECTION 1 – Introduction to the Semiconductor Fab Industry SECTION 2 – How EcoStruxure Power Can Support the Semiconductor Fab BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Transverse Lifecycle Capabilities Capabilities to Improve Time to Market Capabilities to Increase Efficiency Capabilities to Improve Resiliency Carbon Neutrality Consulting Services Track and reduce carbon emissions to demonstrate the carbon neutrality of the company Primary Department • Facility Operations & Maintenance • Sustainability Office Benefits • Get support from our consulting services to define your strategy for achieving carbon neutrality Capabilities to Grow Sustainability + Services Carbon neutrality Reduce Carbon Emissions Produce Renewable Energy Purchase Renewables/Offsets Energy Efficiency • Sustainable building design & operations – HVAC Efficiency – Lighting Efficiency – Operational Efficiency Behind-the-Meter Renewables • Solar Panels / Heating • Wind • Geothermal Purchase Renewables • Renewable Power Purchasing Agreements (PPA) • Renewable Energy Certificates (REC) • Biofuels Supporting

Technologies • Microgrid with Smart Management • Battery Storage • Fuel Cells Purchase Offsets • Carbon Credits – Carbon Capture – Tree Planting 1 2 3 Reference Guide EcoStruxure™ Power for Semiconductor Fabs General SECTION 3 – Digital Solutions and Services Capabilities to Grow Sustainability SECTION 1 – Introduction to the Semiconductor Fab Industry SECTION 2 – How EcoStruxure Power Can Support the Semiconductor Fab BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Transverse Lifecycle Capabilities Capabilities to Improve Time to Market Capabilities to Increase Efficiency Capabilities to Improve Resiliency Energy Efficiency Compliance Comply with standards related to energy management systems Primary Department • Facility Operations & Maintenance • Sustainability Office Benefits • Report and show facility compliance to local sustainability requirements - To benefit from tax credits - To gain credibility to participate in new projects Capabilities to Improve Sustainability EcoStruxure Power Operation Energy Star Compliance Dashboard EcoStruxure Resource Advisor Dashboard in EcoStruxure Power Operation Sustainable Organizations and Standards Energy Efficiency Compliance Reference Architecture Learn more about: • Energy Efficiency Compliance (IEC / NEMA) General Energy Efficiency Compliance Reference Architecture Reference Guide EcoStruxure™ Power for Semiconductor Fabs General SECTION 3 – Digital Solutions and Services Capabilities to Grow Sustainability SECTION 1 – Introduction to the Semiconductor Fab Industry SECTION 2 – How EcoStruxure Power Can Support the Semiconductor Fab BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Transverse Lifecycle Capabilities Capabilities to Improve Time to Market Capabilities to Increase Efficiency Capabilities to Improve Resiliency Greenhouse Gas Reporting Track and report carbon emissions Primary Department • Facility Operations & Maintenance • Sustainability Office Benefits • Track and report carbon emissions and waste (e.g., water) in one single place • Provide period-over-period usage comparison to detect a drift Capabilities to Improve Sustainability Greenhouse Gas Reporting Reference Architecture Learn more about: • Greenhouse Gas Reporting (IEC / NEMA) Greenhouse Gas Reporting and Dashboard Examples in EcoStruxure Power Operation General Greenhouse Gas Reporting Reference Architecture Reference Guide EcoStruxure™ Power for Semiconductor Fabs General Legal Information SECTION 3 – Digital Solutions and Services SECTION 1 – Introduction to the Semiconductor Fab Industry SECTION 2 – How EcoStruxure Power Can Support the Semiconductor Fab BIBLIOGRAPHY Reference Documents BIBLIOGRAPHY Reference Guide EcoStruxure™ Power for Semiconductor Fabs General Legal Information BIBLIOGRAPHY Reference Documents SECTION 3 – Digital Solutions and Services SECTION 1 – Introduction to the Semiconductor Fab Industry SECTION 2 – How EcoStruxure Power Can Support the Semiconductor Fab Reference Documents Design Guide IEC EcoStruxure Power Design Guide Ref: ESXP2G001EN 02/2024 Digital Applications for Large Buildings and Critical Facilities The Digital Applications Design Guide provides comprehensive details on the building blocks of EcoStruxure Power: the IoT applications are driven by a software layer to control the traditional electrical distribution infrastructure. Developed to help engineering consultants and designers, this guide is an invaluable resource for specifying, designing and prescribing EcoStruxure Power architectures capable of performing one or more of the business-driven applications described within. NEMA EcoStruxure Power Design Guide Ref: 0100DB1802 01/2024 https://www.se.com/ ww/en/downl oad/document/ESXP2G001EN/ https://www.se.com/us/en/download/ document/0100DB1802/ Web version PDF version Web version https://go.schneider- electric.com/WW_202004_Digital-Applications-for-Large-Buildings-and- Critical-Facilities_EA-LP.html PDF version https://go.schneider-electric.com/WW_202004_Digital- Applications-Design-Guide_EA-LP.html Landing page: https:// www.se.com/ww/en/work/campaign/innovation/power-digital-applications-design-guide.jsp Reference Guide EcoStruxure™ Power for Semiconductor Fabs General Legal Information SECTION 3 – Digital Solutions and Services SECTION 1 – Introduction to the Semiconductor Fab Industry SECTION 2 – How EcoStruxure Power Can Support the Semiconductor Fab BIBLIOGRAPHY Reference Documents Legal Information The information provided in this document contains general descriptions, technical characteristics and/or recommendations related to products/solutions. 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All other brands are trademarks of their respective owners 2024/05/28 ESXP2RG002EN PEP method for assessing 3-Phase UPS sustainability se.com Table of contents Life is On | Schneider Electric Introduction 1 Conclusion 5 Environmental declarations 2 UPS carbon footprint comparisons 3 UPS carbon calculation tool 4 • Common errors to avoid when comparing UPSs • Steps for accurate UPS comparisons • What is a PEP and how to read it • Product specific rules (PSR) for 3-phase UPS • Carbon profile of a typical 3-phase UPS Life is On | Schneider Electric Introduction Life is On | Schneider Electric Introduction As discussed in White Paper 64, Why Data Centers Must Prioritize Environmental Sustainability: Four Key Drivers, companies are seeking ways of decreasing their data center's environmental footprint and of their company in general. These needs apply to all data center sizes, from the largest multi-megawatt purpose-built data center to a single-rack micro data center in a branch office. Most vendors recognize these needs and therefore promote their product's sustainability as a means to help their customers attain their sustainability goals. As one of the leading companies in demonstrating sustainability1 , Schneider Electric believes that customers care about three key topics when it comes to sustainable products: 1 Schneider Electric recognized in Corporate Knights' Global 100 for the 12th year in a row 2 Sustainability data that is free and available to all customers and validates product claims, including documentation like environmental product disclosures and product end-of-life treatments. 3 Performance characteristics that improve a product's sustainability, including lower impact materials, energy efficiency, durability, repairability, and take-back. 1 Compliance with applicable regulations, particularly those related to hazardous substances. Includes mandatory compliance to hazardous substance regulations such as the European directive for Restriction of Hazardous Substances (RoHS); European Regulation for Registration, Evaluation (REACh); European directive for Waste from Electrical and Electronic Equipment (WEEE); China RoHS; and California Proposition 65. Life is On | Schneider Electric Environmental declarations An environmental product declaration (EPD) summarizes the environmental life cycle data of a product or service and is normally valid for five years. These documents help specifiers make Uninterruptible Power Supply (UPS) decisions based on environmental impacts like carbon footprint and water use, making it easier to compare UPSs of the same category. The International Organization for Standardization (ISO) publishes the standards that underly EPDs, in particular ISO 14025. EPDs must be based on life cycle assessment (LCA) data or life cycle inventory analysis (LCI) data, which are governed by the ISO 14040 standard. For more information on ISO standards, see Schneider Electric White Paper 70. Note that ISO 14040 is generic and applies to all types of products and services. The following sections explain how to read an EPD, explain three key concepts of a 3-phase UPS PSR, and describe the typical carbon profile of a 3-phase UPS. Life is On | Schneider Electric Environmental declarations Program operators like the P.E.P. Association administer programs in compliance with ISO 14025 so that EPDs report the same type of information. They develop, approve, and publish product category rules (PCR) and product-specific rules (PSR) for Type III environmental declarations. All EPDs must be independently verified by internal2 or external experts and provide information need to track Scope 1, 2, and 3 3 emissions. For this e-guide, the PCR related to a UPS covers electrical, electronic, and HVAC-R products and defines how vendors should perform the LCA. When the PCR isn't detailed enough to develop EPDs for specific products, program operators develop PSRs. P.E.P. Association 11/17, rue de l'Amiral Hamelin - 75016 Paris Non-profit association (Law of 1901) – SIRET No.: 789 180 320 00010 PEP ecopassport® PROGRAM PCR Product Category Rules for Electrical, Electronic and HVAC-R Products PCR-ed4-EN-2021 09 06 © 2021 P.E.P. Association Copyright of PCR Product Category Rules are © PEP

Ecopassport® Program property, if nothing else has been specified (e.g. the cross-publication of PCR from other programs). The use of the PCR for any other purpose than to develop PSRs and register PEPs in the International PEP Ecopassport® Program are subject to approval by the General Secretariat, which may be contacted at: contact@pep-ecopassport.org Reporting environmental data for a UPS 2 This applies to business-to-business products only. 3 See Appendix of White Paper 67, Guide to Environmental Sustainability Metrics for Data Centers, for information on Scope 1, 2, and 3. Life is On | Schneider Electric What is a PEP and how to read it PEP stands for Product Environmental Profile. The PEP Ecopassport association defines which mandatory information a PEP must provide. While the templates change from vendor to vendor, the key information needed for a UPS comparison is usually presented in the following order: 6 Verification information 5 Environmental impacts 4 Additional environmental information 3 Constituent materials 2 The "function" or "functional unit" 1 The "reference product" or "representative product" All values in the PEP are expressed in scientific notation using a decimal value with an exponential (E) of 10. In this example: 1.97E06 = 1.97 x 10E6 = 1.97 x 1,000,000 = 1,970,000 PEP contains the CO_2 emissions data of the product PEP Extract of a 3-phase UPS: Galaxy VX The 'Contribution to climate change' contains the CO_2 Emissions of the product expressed in kg CO_2 equivalent. Description of the different Life Stages of the product Life is On | Schneider Electric The PSRs define rules for specific products within the larger product category. Due to their unique function, such as multiple operating modes, UPSs are one of those products that require their own product specific rules. There are 3 key concepts in the UPS PSR that play a significant role in determining the life cycle carbon footprint of a UPS. 1. Reference Service Life (RSL) The RSL is the length of time the UPS is expected to remain in service. According to section 3.5.5.1 of the PSR, a 3-phase UPS over 10 kW has a service life of 15 years. This means that the life cycle assessment accounts for 15 years of UPS emissions. For example, if the electricity use emissions for the UPS is 100,000 kg CO_2 e per year, its lifetime electricity emissions would be 100,000 kg CO_2 e x 15 years or 1,500,000 kg CO_2 e. 2. Typical load profile A load profile is meant to ensure that all manufacturers use the same assumptions to calculate electricity use. A load profile includes % load, length of time a UPS operates during its lifetime, and UPS operating mode. For 3-phase UPSs greater than 10 kW, the electricity use is based on operating at: • 25% load for 25% of the UPS life (3.75 years) • 50% load for 50% of the UPS life (7.5 years) • 75% load for 25% of the UPS life (3.75 years) • 100% load at 0% of the UPS life (0 years) Product specific rules (PSR) for 3-phase UPS Reference Service Life (RSL) of a UPS Typical load profile of a UPS Life is On | Schneider Electric 3. Energy efficiency calculation The percent load and operating mode are important because they determine the UPS's efficiency at a specific load percentage. If a UPS has two operating modes, it will have two different efficiency values that characterize each mode. However, according to UPS PSR section 3.5.5.3, the electricity use calculation must be based on the UPS's operating mode with the worst case weighted efficiency; which in most cases is double conversion. The weighted efficiency for a 3-phase UPS (>10 kW) is calculated according to the formula: Weighted efficiency = 25% x Eff25% + 50% x Eff50% + 25% x Eff75% + 0% x Eff100% Product specific rules (PSR) for 3-phase UPS (continued) Efficiency figures at different load percentages for two operating modes (example: Galaxy VX 1250 kW) Weighted efficiency in double conversion = 25% x 95.6% + 50% X 96% + 25% x 95.7% + 0% x 95.2% = 95.8% Weighted efficiency in eConversion = 25% x 97.9% + 50% X 98.8% + 25% x 98.9% + 0% x 99% = 98.6% Life is On | Schneider Electric Because a UPS operates continuously over its lifetime, the largest contribution to its carbon emissions comes from the "use" stage. While there are significant differences among UPS models in terms of efficiency and the associated electrical losses, electricity consumption is by far the largest contributor of CO_2 e life cycle emissions. Here is an example of how each stage of the lifecycle contributes to the CO_2 e emissions of a 3-phase UPS taken from the Galaxy VX PEP. The use stage emissions represent about 93% of the UPS's carbon footprint. Carbon profile of a typical 3-phase UPS Manufacturing 6.2% Distribution 0.1% Installation 0.0% Use 93.3% End of life 0.4% Galaxy VX UPS 1250 - CO_2e emissions per life stage Manufacturing Distribution Installation Use End of life Use 93.3% Breakdown of total carbon footprint for a 3-phase UPS (example: Galaxy VX). Life is On | Schneider Electric UPS carbon footprint comparisons Life is On | Schneider Electric • A sustainability comparison makes sense only after developing a list of UPS models that meet your functional requirements. • In the case of a UPS, requirements may include kW capacity, physical footprint, efficiency, modularity, etc. Once you have a list of UPSs, then you can quantitatively compare their environmental characteristics. • The most effective way to do this is to compare their PEPs. • A comprehensive UPS carbon footprint comparison should consider all five of its life cycle stages. This section first explains common errors to avoid when comparing UPSs and then provides step by step guidance on comparing each of the five life cycle stages. • We use two UPSs to demonstrate the comparison. A key theme in this section is the concept of comparing “apples to apples.” UPS carbon footprint comparisons Common errors to avoid when comparing products While the ISO standards provide the basis for LCAs and PEPs, they don’t eliminate vendor mistakes or ensure valid comparisons. Therefore, end users must be vigilant when comparing PEPs for two or more UPSs, especially if they’re from different vendors. This section covers the major errors people make when comparing the carbon footprint of two or more UPS. Life is On | Schneider Electric An emission factor is the ratio of greenhouse gas emitted for every kWh of electricity a utility generates. The emission factor is multiplied by the energy (kWh) the UPS uses in its lifetime to arrive at the use stage emissions from electrical losses. Because a UPS operates continuously over its lifetime, the largest contribution to its carbon emissions comes from the use stage. Even a small difference in emission factors has a major impact on a comparison. This is why you can’t compare UPSs with different grid emission factors. An example of this frequent error is illustrated here. As shown in the table below, it’s quite possible for a PEP of an inefficient UPS (e.g., UPS X at 94%) to show lower total emissions than a more efficient UPS (e.g., Galaxy VX at 95.8%) with an (erroneously calculated) 980,000 kg CO2 e vs. 2,000,000 kg CO2 e. In reality, only the second and the third line can be used for an apples-to-apples comparison, which shows that UPS X emissions are much higher than Galaxy VX. How different grid emission factors impact CO2 e emissions declaration. Example: 1250kW UPS Efficiency % Grid Emissions Factor (kgCO2/kWH) Grid geography CO2 emissions declared in PeP (Use phase) in kgCO2 UPS X 94% 0,2 FR 980 000 94% 0,41 EU-27 2 000 000 Galaxy VX 95,8% 0,41 EU-27 1 400 000 2 22kW UPS Comparing “use stage” carbon emissions based on different utility grid emission factorsError #1 When the emission factors are set equal (0.41 kg CO2 e/kWh), the total CO2 e footprint for the low-efficiency UPS is 1.4 times higher than the high-efficiency UPS. This example was calculated assuming an overall emission factor for the 27 European countries (0.41 kg CO2 e/kWh) compared to that of France (0.2 kg CO2 e/kWh) 6 . 6 This is an older (and higher) value than today’s EU-27 and France values. The program operator, P.E.P. Association, tries to keep this value consistent over the years to avoid publishing PEP documents based on different emission factors. Life is On | Schneider Electric Example of CO2 footprint comparison between UPS with different emission factors. Because PEPs use codes that can be difficult to understand, an easier way to assess the use stage emissions between two or more UPSs is to compare their efficiencies with the same grid emission factor. The 3-phase UPS Efficiency Comparison Calculator simplifies this task. 0 500,000 1,000,000 1,500,000 2,000,000 2,500,000 Manufacturing Distribution Installation Use End of life UPS CO2e footprint UPS X - 94% eff using French EF (0.2 kg CO2e/kWh UPS X - 94% eff using European EF (0.4 kg CO2e/kWh GVX - 96% eff using European EF (0.4 kg CO2e/kWh Incorrect comparison Correct comparison since both UPS use the same emission factor (EF) 2 2 2 Common errors to avoid when comparing products Life is On | Schneider Electric If a UPS has two operating modes, it will have two efficiency curves characterizing each mode. An example of this is illustrated using the Three Phase UPS Efficiency Comparison Calculator. Example of UPS efficiency curves for two different operating modes. • UPS with two operating modes will have two efficiency curves • Generally cannot compare values from different operating modes • If operator uses high-efficiency for one UPS but double conversion with another, values cannot be compared Comparing “use stage” carbon emissions with different operating modesError #2 Life is On | Schneider Electric Common errors to avoid when comparing products Declaring a winning attribute that is within the margin of errorError #7 Granting recycling credit without evidence of recycling programError #6 Assuming a PEP includes expected componentsError #5 Comparing UPS PEPs with different PSR and PCR versionsError #4 Comparing UPSs with different capacitiesError #3 Life is On | Schneider Electric Calculate the weighted UPS efficiency for the operating mode that will actually be used (e.g., double conversion or high-efficiency mode). The typical operating mode is double conversion. Do this for each UPS you’re comparing using the formula provided below: This step requires: • The total energy consumption (kWh) – sum of all reference test loads from Step 2 • The grid emission factor (kg CO2 e/kWh) – Ideally, the emission factor is the same as that of the electric grid supplying the UPS. This final step sums the emissions from all five life cycle stages (i.e., manufacturing, distribution, installation, use, and end of life) using the UPS PEP document. If the UPSs have different rated capacities, then you should compare the total carbon footprint using the ‘K- factor’ described above, or use the data from the nearest UPS rating provided in the PEP. This will allow you to see which UPS has the lowest total carbon footprint. This step requires the following for each UPS you’re comparing: • The efficiencies from Step 1 • The grid emission factor (kg CO2 e/kWh) – Ideally, the emission factor is the same as that of the electric grid supplying the UPS. • The rated capacity of the UPS (kW) • The UPS reference service life (RSL) (15 years) Step 1: Calculate the weighted efficiency. Step 3: Calculate UPS electricity CO2 emissions. Step 4: Add CO2 emissions from the other life stages. Step 2: Calculate

UPS electricity consumption. Four steps for accurate UPS comparisons This section describes the steps required to accurately compare two or more UPSs. UPS life cycle electricity emissions (kg CO2 e) Weighted efficiency Total energy consumption kWh Emission factor (kg CO2 e/kWh) = = x 25% x Eff25% + 50% x Eff50% + 25% x Eff75% + 0% x Eff100% Life is On | Schneider Electric UPS carbon calculation tool This section describes the excel worksheet that facilitates UPS carbon footprint comparisons using the four steps described in the previous section. We describe each input that the worksheet uses to calculate the total life cycle carbon footprint for the UPS models you're comparing. All input cells are highlighted in yellow. Main input cells: UPS carbon footprint comparison tool In Step 1, the set of inputs describe the efficiency of the UPSs you're comparing. The UPS model and operating mode inputs are used only to label the efficiency data. The efficiency data should have at least one decimal of precision. Note, you must choose the operating mode that will actually be used at the site (typically double conversion). With the data provided by the Three Phase UPS Efficiency Comparison Calculator, you can enter the efficiencies in the yellow cells for most Schneider Electric UPSs. Table used to calculate weighted UPS efficiency: In Step 2 & 3, with the data entered thus far, the tool calculates the electricity consumption (kWh) and electricity-based emissions (kg CO2 e) in the green rows. Table used to calculate the electricity consumption (kWh) and electricity- based emissions (kg CO2 e): Per Step 4, the last part of the worksheet sums the emissions from the remaining life cycle stages (i.e., manufacturing, distribution, installation, and end of life) using the values in the UPS PEP document. The worksheet also calculates the emissions per unit kW of rated UPS capacity in case the UPSs have different rated capacities. Table used to calculate the total UPS life cycle carbon emissions (kg CO2 e): Life is On | Schneider Electric Conclusion Life is On | Schneider Electric As more companies and consumers seek to reduce their environmental footprint, vendors are responding with claims of environmentally sustainable UPSs. Assessing the environmental sustainability of a UPS is complex and claims are difficult to ascertain without knowing the underlying assumptions and standards upon which they are made. By understanding the calculations behind the sustainability claims of the UPS you are considering, you can confidently choose a UPS that is better for your operations and the planet. This e-guide defined and covered five life cycle stages that encompass a UPS's environmental sustainability performance. We provided explanations for how to calculate the electricity-based UPS emissions. Finally, we offered guidance for how to accurately assess the sustainability of similar UPSs and a tool to help with UPS comparisons. Conclusion 998-23218491_GMA To learn more about addressing your UPS's environmental sustainability, visit: se.com Schneider Electric 35 rue Joseph Monier 92500 Rueil-Malmaison, France Tel : +33 (0)1 41 29 70 00 General 05/2024 EcoStruxure™ Power for EV Battery Manufacturing Plants Utilizing a Digital Twin for Electrical Distribution to Drive Efficient Facilities Reference Guide EcoStruxure™ Power for EV Battery Manufacturing Plants General SECTION 3 – Digital Solutions and Services SECTION 1 – Introduction to the EV Battery Manufacturing Industry SECTION 2 – How SE Can Support EV Battery Manufacturing Plants BIBLIOGRAPHY Purpose of the Document Target Audience This document is intended to address End User Engineering, Operations and Maintenance, Consultants, EPCs (Engineering, Procurement, and Construction) and Service teams and other qualified personnel. Objective To understand the challenges of designing and operating an EV battery manufacturing plant with an efficient and sustainable electrical distribution strategy. Table of Contents Overview of capabilities Previous Next Reference Guide EcoStruxure™ Power for EV Battery Manufacturing Plants General SECTION 3 – Digital Solutions and Services SECTION 1 – Introduction to the EV Battery Manufacturing Industry SECTION 2 – How SE Can Support EV Battery Manufacturing Plants BIBLIOGRAPHY Table of Contents SECTION 1: Introduction to the Electrical Vehicle Battery Manufacturing Plants Introduces the context and the challenges of EV battery manufacturing plants. SECTION 2: How Schneider Electric Can Support Electrical Vehicle Battery Manufacturing Plants Describes the solutions that Schneider Electric and, more specifically EcoStruxure Power provides for EV battery manufacturing plants, with typical electrical and digital architecture. BIBLIOGRAPHY Contains useful documents to find out more about capabilities. Provides details about Green Premium. SECTION 3: Digital Solutions and Services Gives information about EcoStruxure Power capabilities for EV battery Manufacturing plants, sorted by value proposition: • Transverse Lifecycle Capabilities • Capabilities to Improve Time To Market • Capabilities to Improve Your Process • Capabilities to Improve Quality • Capabilities to Grow Sustainability Reference Guide EcoStruxure™ Power for EV Battery Manufacturing Plants General WHY READ THIS SECTION? SECTION 1 SECTION 3 – Digital Solutions and Services SECTION 1 – Introduction to the EV Battery Manufacturing Industry SECTION 2 –

How SE Can Support EV Battery Manufacturing Plants BIBLIOGRAPHY EV Battery Market EV Battery Manufacturing Plant Challenges The objective of this section is to: • Introduce the growth, trends and challenges of the EV battery market • Present the 4 pillars to meet the EV battery manufacturing plant challenges. Introduction to the Electrical Vehicle Battery Manufacturing Industry Reference Guide EcoStruxure™ Power for EV Battery Manufacturing Plants General SECTION 3 – Digital Solutions and Services SECTION 2 – How SE Can Support EV Battery Manufacturing Plants BIBLIOGRAPHY SECTION 1 – Introduction to the EV Battery Manufacturing Industry EV Battery Market EV Battery Manufacturing Plant Challenges EV Battery Market An industry driven by the electrical vehicle market 8 EV models Launched by Nissan by the end of 2023. Goal is to be on pace to sell 1M hybrid or electric vehicles per year globally. 15-25% sales of hybrid & EV For BMW by 2025. 20 EV models Launched by Audi by the end of 2025. 27 B$ investment By General Motors in EV infrastructure through 2025 with the aim of releasing 30 EV vehicles onto the market within the same timeframe 1 M hybrid & electrical vehicles On the road pledged by Volvo by end of 2025. Expectation of 50% of global sales from EVs. 10 EV models Introduced by Mercedes by the end of 2023. Ban of diesel- and gas-powered cars In the UK expected to go into effect by 2030. Sources https://www.caranddriver.com/news/g35562831/ev-plans-automakers-timeline/ Reference Guide EcoStruxure™ Power for EV Battery Manufacturing Plants General SECTION 3 – Digital Solutions and Services SECTION 2 – How SE Can Support EV Battery Manufacturing Plants BIBLIOGRAPHY SECTION 1 – Introduction to the EV Battery Manufacturing Industry EV Battery Market EV Battery Manufacturing Plant Challenges EV Battery Market The market trends: a changing landscape Significant investment in Greenfield and expansions A growing focus on efficiency and sustainability High demand for energy and power to meet battery production capacity Cybersecurity Reference Guide EcoStruxure™ Power for EV Battery Manufacturing Plants General SECTION 3 – Digital Solutions and Services SECTION 2 – How SE Can Support EV Battery Manufacturing Plants BIBLIOGRAPHY SECTION 1 – Introduction to the EV Battery Manufacturing Industry EV Battery Market EV Battery Manufacturing Plant Challenges How can we minimize downtime to increase yield rates and improve production quality? How can we be best-in-class for CO2 emissions per kWh? How to improve the overall energy efficiency of the plant and process? How can we accelerate the design & build of new EV battery plants? EV Battery Manufacturing Plant Challenges Four pillars to drive efficiency, reliability and sustainability KPIs The strong growth of the EV market leads to an increasing need for battery manufacturing plants. Creating or expanding EV battery manufacturing plants is not without its challenges. Four pillars must be addressed: Grow Sustainability Improve Quality Improve Your Process Improve Time to Market How can we reduce the cost of finished battery cells? Reference Guide EcoStruxure™ Power for EV Battery Manufacturing Plants General WHY READ THIS SECTION? SECTION 2 SECTION 3 – Digital Solutions and Services SECTION 1 – Introduction to the EV Battery Manufacturing Industry SECTION 2 – How SE Can Support EV Battery Manufacturing Plants BIBLIOGRAPHY Solutions to Address the Four Pillars Schneider Electric Value Propositions Example of Electrical and Digital Architecture The objective of this section is to: • Present the solutions to address the four pillars to meet the EV battery manufacturing plant challenges • Explain how Schneider Electric EcoStruxure™ Power can support this industry • Give an example of electrical and digital architectures. How Schneider Electric Can Support Electrical Vehicle Battery Manufacturing Plants Reference Guide EcoStruxure™ Power for EV Battery Manufacturing Plants General Schneider Electric Value Propositions Example of Electrical and Digital Architecture Solutions to Address the Four Pillars SECTION 3 – Digital Solutions and Services SECTION 1 – Introduction to the EV Battery Manufacturing Industry SECTION 2 – How SE Can Support EV Battery Manufacturing Plants BIBLIOGRAPHY Grow Sustainability Improve Quality Improve Your Process Improve Time to Market Solutions to Address the Four Pillars of EV Battery Manufacturing Plants The four pillars can be addressed by the following solutions: Increase Production Efficiency Reduce Production Hazards Track Sustainability KPIs Use Standardized Architectures Use standardized electrical distribution and IT infrastructures in order to speed up the “design, build and commission” phase of new plants. Digitize and modernize your operations and turn data into useful business intelligence to empower your workforce, understand the profitability of your production assets and make smart business decisions for your entire ecosystem. Reduce downtimes and manage end-to-end quality to reduce production scrap. Utilize control tower and IoT platforms to collect analytics on processes, settings and maintenance. Monitor sustainability criteria to accelerate environmental transition and be compliant with sustainability standards and customer expectations. Reference Guide EcoStruxure™ Power for EV Battery Manufacturing Plants General SECTION 2 – How SE Can Support EV Battery Manufacturing Plants Example of Electrical and Digital Architecture Solutions to Address the Four Pillars Schneider Electric Value Propositions SECTION 3 – Digital Solutions and Services SECTION 1 –

Introduction to the EV Battery Manufacturing Industry BIBLIOGRAPHY Schneider Electric Value Propositions At company level Through its entire organization, Schneider Electric has developed value propositions to address the four pillars for the different parts of EV battery manufacturing plants: Infrastructure / Facility Manufacturing Process Manufacturing Machine Design and Modeling Digital Automation & IOT Framework EcoStruxure Machine Architecture Energy Efficiency Process Efficiency Machine Performance & Flexibility Power Availability Predictive Quality Machine Tracking & Monitoring Green House Gas and Energy Compliance Energy Optimization Sustainable Sourcing Grow Sustainability Improve Quality Improve Your Process Improve Time to Market Transverse Lifecycle Capabilities (Cybersecurity, Green Premium, Digital Twin) Reference Guide EcoStruxure™ Power for EV Battery Manufacturing Plants General SECTION 2 – How SE Can Support EV Battery Manufacturing Plants Example of Electrical and Digital Architecture Solutions to Address the Four Pillars Schneider Electric Value Propositions SECTION 3 – Digital Solutions and Services SECTION 1 – Introduction to the EV Battery Manufacturing Industry BIBLIOGRAPHY Schneider Electric Value Propositions At EcoStruxure Power level This guide focuses more specifically on value propositions provided by EcoStruxure Power: Manufacturing Process Manufacturing Machine Digital Automation & IOT Framework EcoStruxure Machine Architecture Process Efficiency Machine Performance & Flexibility Predictive Quality Machine Tracking & Monitoring Energy Optimization Sustainable Sourcing Grow Sustainability Improve Quality Improve Your Process Improve Time to Market Transverse Lifecycle Capabilities (Cybersecurity, Green Premium, Electrical Digital Twin) Infrastructure / Facility Design and Modeling Energy Efficiency Power Availability Green House Gas and Energy Compliance Reference Guide EcoStruxure™ Power for EV Battery Manufacturing Plants General SECTION 2 – How SE Can Support EV Battery Manufacturing Plants Example of Electrical and Digital Architecture Solutions to Address the Four Pillars Schneider Electric Value Propositions SECTION 3 – Digital Solutions and Services SECTION 1 – Introduction to the EV Battery Manufacturing Industry BIBLIOGRAPHY Schneider Electric Value Propositions At EcoStruxure Power level EcoStruxure Power helps deliver an end-to-end digital solution for efficient, reliable and sustainable EV Battery Plants. From electrode production to cell finishing, From electrical design to operations and maintenance, Our collaborative environments, enhanced by the Electrical Distribution Digital Twin of your Plant, enable high productivity operations. Reference Guide EcoStruxure™ Power for EV Battery Manufacturing Plants General SECTION 2 – How SE Can Support EV Battery Manufacturing Plants Solutions to Address the Four Pillars Schneider Electric Value Propositions Example of Electrical and Digital Architecture SECTION 3 – Digital Solutions and Services SECTION 1 – Introduction to the EV Battery Manufacturing Industry BIBLIOGRAPHY Example of Electrical and Digital Architecture Typical EV battery manufacturing plant Energy is key, whether for processes or for utilities: specific attention must be given to the design of the electrical architecture and associated digital architecture which will enable digital solutions and services. EV battery manufacturing plant PROCESS Energy consumption 60 % UTILITY Energy consumption 40 % Cell assembly Utilities – Clean and dry room Ageing/Formation Utilities Infrastructure 3%Mixing Coating and drying Vacuum drying Calendering Slitting 23 % 2% 2% 2% 2% 26 % 37 % 3% Reference Guide EcoStruxure™ Power for EV Battery Manufacturing Plants General SECTION 2 – How SE Can Support EV Battery Manufacturing Plants Solutions to Address the Four Pillars Schneider Electric Value Propositions Example of Electrical and Digital Architecture SECTION 3 – Digital Solutions and Services SECTION 1 – Introduction to the EV Battery Manufacturing Industry BIBLIOGRAPHY Example of Electrical and Digital Architecture Typical electrical architecture for an EV battery manufacturing plant Example of Electrical Architecture General Example of Electrical Architecture Expensive Process = Power Availability High Energy demand = Efficient Energy Management ELECTRODE PRODUCTION • Mixing • Coating & Drying • Calendering • Slitting • Vacuum Drying CELL ASSEMBLY • Electrode shaping • Stacking • Electric contacting • Case insertion • Case closure CELL FINISHING • Electrolyte filling Pre-charging • Filling hole closure • Ageing & formation INFRASTRUCTURE • Emergency Loads • IT and Control Room • Lightings and other UTILITIES • Dry Room MV Chillers and Dryers • Clean Room MV Chillers • Cooling Water • Waste Treatment • Inert gas (N2) PROCESS UTILITY 60 % 40 % Reference Guide EcoStruxure™ Power for EV Battery Manufacturing Plants General SECTION 2 – How SE Can Support EV Battery Manufacturing Plants Solutions to Address the Four Pillars Schneider Electric Value Propositions Example of Electrical and Digital Architecture SECTION 3 – Digital Solutions and Services SECTION 1 – Introduction to the EV Battery Manufacturing Industry BIBLIOGRAPHY Example of Electrical and Digital Architectures Suggested digital architecture (high-level view) for an EV battery manufacturing plant Example of Digital Architecture (High-Level View) General Example of Digital Architecture (High-Level View) Reference Guide EcoStruxure™ Power for EV Battery Manufacturing Plants General SECTION 2 – How SE Can Support EV

Battery Manufacturing Plants Solutions to Address the Four Pillars Schneider Electric Value Propositions Example of Electrical and Digital Architecture SECTION 3 – Digital Solutions and Services SECTION 1 – Introduction to the EV Battery Manufacturing Industry BIBLIOGRAPHY Example of Electrical and Digital Architectures Corresponding detailed digital architecture for an EV battery manufacturing plant Example of Digital Architecture (Detailed View) General Example Digital Architecture (Detailed View) Reference Guide EcoStruxure™ Power for EV Battery Manufacturing Plants General WHY READ THIS SECTION? SECTION 3 SECTION 3 – Digital Solutions and Services Introduction Overview of Digital Solutions and Services Transverse Lifecycle Capabilities Capabilities to Improve Time to Market Capabilities to Improve Your Process Capabilities to Improve Quality Capabilities to Grow Sustainability SECTION 1 – Introduction to the EV Battery Manufacturing Industry SECTION 2 – How SE Can Support EV Battery Manufacturing Plants BIBLIOGRAPHY This section gives information about EcoStruxure Power capabilities for EV battery manufacturing plants aligned to the industry challenges. Digital Solutions & Services Reference Guide EcoStruxure™ Power for EV Battery Manufacturing Plants General SECTION 3 – Digital Solutions and Services Introduction SECTION 1 – Introduction to the EV Battery Manufacturing Industry SECTION 2 – How SE Can Support EV Battery Manufacturing Plants BIBLIOGRAPHY Overview of Digital Solutions and Services Transverse Lifecycle Capabilities Capabilities to Improve Time to Market Capabilities to Improve Your Process Capabilities to Improve Quality Capabilities to Grow Sustainability Grow Sustainability Improve Quality Improve Your Process Improve Time to Market Introduction EcoStruxure Power provides capabilities to support the challenges of EV battery manufacturing plant throughout the plant lifecycle: These capabilities provide standardized designs and digital architectures, and enable easy simulation, to reduce cost of design and ownership. These capabilities use digitization to provide intelligent information to the workforce, allowing them to make smart decisions that reduce operating costs and increase efficiency. These capabilities use digitization to reduce unplanned downtime, increase reliability, and thus reduce production waste. These capabilities help track energy consumption and carbon emissions to meet sustainability requirements. Design, Build, Commission (Consultants & EPC) Operate & Maintain (Operators, maintenance team, service teams) Transverse Lifecycle Capabilities Digital Solutions that support your project from the Design, Build, Commission to Operate & Maintain phases. Reference Guide EcoStruxure™ Power for EV Battery Manufacturing Plants General SECTION 3 – Digital Solutions and Services Overview of Digital Solutions and Services SECTION 1 – Introduction to the EV Battery Manufacturing Industry SECTION 2 – How SE Can Support EV Battery Manufacturing Plants BIBLIOGRAPHY Introduction Transverse Lifecycle Capabilities Capabilities to Improve Time to Market Capabilities to Improve Your Process Capabilities to Improve Quality Capabilities to Grow Sustainability Overview of Digital Solutions and Services Electrical Digital Twin Green Premium Operator training simulation Energy monitoring and usage analysis Energy performance, modeling and verification Capacity management + + + + Cybersecurity Carbon neutrality consulting services Energy efficiency compliance Greenhouse gas reporting + + + Grow Sustainability Improve Quality Improve Your Process Improve Time to Market Design, Build, Commission (Consultants & EPC) Operate & Maintain (Operators, maintenance team, service teams) Transverse Lifecycle Capabilities AC&DC electrical network bus design and simulation Electrical network short circuit simulation Network load flow and voltage drop simulation Device coordination and selectivity Arc fault protection and coordination Power quality simulation and modeling Renewable & microgrid energy storage sizing simulation + + + + + + + Asset performance Power quality monitoring and compliance Continuous thermal monitoring Electrical distribution monitoring and alarming Power event analysis Predictive simulation Power quality and power factor correction + + + + + + + Arc flash protection+ Simulate before Operate+ Reference Guide EcoStruxure™ Power for EV Battery Manufacturing Plants General SECTION 3 – Digital Solutions and Services Transverse Lifecycle Capabilities SECTION 2 – How SE Can Support EV Battery Manufacturing Plants BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Capabilities to Improve Time to Market Capabilities to Improve Your Process Capabilities to Improve Quality SECTION 1 – Introduction to the EV Battery Manufacturing Industry Capabilities to Grow Sustainability Overview of Digital Solutions and Services Electrical Digital Twin Green Premium Operator training simulation Energy monitoring and usage analysis Energy performance, modeling and verification Capacity management + + + + Cybersecurity Carbon neutrality consulting services Energy efficiency compliance Greenhouse gas reporting + + + Grow Sustainability Improve Quality Improve Your Process Improve Time to Market Design, Build, Commission (Consultants & EPC) Operate & Maintain (Operators, maintenance team, service teams) Transverse Lifecycle Capabilities AC&DC electrical network bus design and simulation Electrical network short circuit simulation Network load flow and voltage drop simulation Device coordination and selectivity Arc fault protection and coordination Power quality simulation and modeling Renewable & microgrid energy storage sizing simulation + + + + + + + Asset performance Power quality monitoring and compliance Continuous thermal monitoring Electrical distribution monitoring and alarming Power event analysis Predictive simulation Power quality and power factor correction + + + + + + + Arc flash protection+ Simulate before Operate+ Reference Guide EcoStruxure™ Power for EV Battery Manufacturing Plants General SECTION 3 – Digital Solutions and Services Transverse Lifecycle Capabilities SECTION 2 – How SE Can Support EV Battery Manufacturing Plants BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Capabilities to Improve Time to Market Capabilities to Improve Your Process Capabilities to Improve Quality SECTION 1 – Introduction to the EV Battery Manufacturing Industry Capabilities to Grow Sustainability Electrical Digital Twin Maintain a Digital Twin of your electrical distribution Benefits • Intelligent user-interface for all levels of AC and DC networks • Enables users, from the design to operate phases, to model, simulate, analyze and validate electrical power systems to predict their electrical network behavior • Takes the day-to-day system modeling and design tasks to a new level of speed, accuracy and ease Electrical Digital Twin Transverse Lifecycle Capabilities Reference Guide EcoStruxure™ Power for EV Battery Manufacturing Plants General SECTION 3 – Digital Solutions and Services Transverse Lifecycle Capabilities SECTION 2 – How SE Can Support EV Battery Manufacturing Plants BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Capabilities to Improve Time to Market Capabilities to Improve Your Process Capabilities to Improve Quality SECTION 1 – Introduction to the EV Battery Manufacturing Industry Capabilities to Grow Sustainability Green Premium Manage sustainability from design to end of life Benefits • Green Premium* products provide detailed information on their regulatory compliance, material content, environmental impact, and circularity attributes. Transverse Lifecycle Capabilities Compliance and transparency (compliance certificates, circularity profiles, environmental footprint, etc.)1 Circular performance Durability, upgradeability, re-manufacture, recycled content, recyclability Well-being performance E.g. free of PVC, mercury, silicone, SVHC, lead, toxic heavy metal and compliant with California Prop 65 4 Resource performance Optimized energy performance Lower carbon emissions 2 3 * The Green Premium label was created to provide Schneider Electric's customers with more sustainable products and to be transparent with environmental information. Supporting your efforts for a LEED certified building Helping you achieve Living Building Challenge certification Green Premium Value Proposition Learn more about: • Green Premium Reference Guide EcoStruxure™ Power for EV Battery Manufacturing Plants General SECTION 3 – Digital Solutions and Services Transverse Lifecycle Capabilities SECTION 2 – How SE Can Support EV Battery Manufacturing Plants BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Capabilities to Improve Time to Market Capabilities to Improve Your Process Capabilities to Improve Quality SECTION 1 – Introduction to the EV Battery Manufacturing Industry Capabilities to Grow Sustainability Cybersecurity Help secure the digital power distribution system Benefits • Provides a selection of cybersecurity certified products • Provides certified system architectures and solutions • Delivers lifecycle services Transverse Lifecycle Capabilities Learn more about: • Cybersecurity Certified products developed according to IEC 62443 functional requirements with Secure Development Lifecycle processes. Consulting services from design, implementation, operations and maintenance to tailor your security solutions to your strategy and budget. Lifecycle services Certified secure system architecture according to IEC 62443-3-3 with documented processes and solutions for a secure system. Cybersecurity system configuration software for consistent security policy deployment. Certified products Certified systems & solutions Reference Guide EcoStruxure™ Power for EV Battery Manufacturing Plants General SECTION 3 – Digital Solutions and Services Capabilities to Improve Time to Market SECTION 1 – Introduction to the EV Battery Manufacturing Industry SECTION 2 – How SE Can Support EV Battery Manufacturing Plants BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Transverse Lifecycle Capabilities Capabilities to Improve Your Process Capabilities to Improve Quality Capabilities to Grow Sustainability Overview of Digital Solutions and Services Electrical Digital Twin Green Premium Operator training simulation Energy monitoring and usage analysis Energy performance, modeling and verification Capacity management + + + + Cybersecurity Carbon neutrality consulting services Energy efficiency compliance Greenhouse gas reporting + + + Grow Sustainability Improve Quality Improve Your Process Improve Time to Market Design, Build, Commission (Consultants & EPC) Operate & Maintain (Operators, maintenance team, service teams) Transverse Lifecycle Capabilities AC&DC electrical network bus design and simulation Electrical network short circuit simulation Network load flow and voltage drop simulation Device coordination and selectivity Arc fault protection and coordination Power quality simulation and modeling Renewable & microgrid energy storage sizing simulation + + + + + + + Asset performance Power quality monitoring and compliance Continuous thermal monitoring Electrical distribution monitoring and alarming Power event analysis Predictive simulation Power quality and power factor correction Simulate before Operate Arc flash protection + + + + + + + + + Reference Guide EcoStruxure™ Power for EV Battery Manufacturing Plants General SECTION 3 – Digital Solutions and Services Capabilities to Improve Time to Market SECTION 1 – Introduction to the EV Battery Manufacturing Industry SECTION 2 – How SE Can Support EV Battery Manufacturing Plants BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Transverse Lifecycle Capabilities Capabilities to Improve Your Process Capabilities to Improve Quality Capabilities to Grow Sustainability AC and DC Electrical Network Bus Design and Simulation Optimize bus design allocation and simulation Primary Department • Design • Construction Benefits • Single solution/environment - Unified AC & DC solution from HV to LV - One unique platform and one database • Efficient profile management - User-defined loading and generation profiles - External data profile based on field measurements • Scalability - Load growth study for future planning • Event simulations within the calculation period Capabilities to Improve Time to Market ETAP Electrical Network Model Reference Guide EcoStruxure™ Power for EV Battery Manufacturing Plants General SECTION 3 – Digital Solutions and Services Capabilities to Improve Time to Market SECTION 1 – Introduction to the EV Battery Manufacturing Industry SECTION 2 – How SE Can Support EV Battery Manufacturing Plants BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Transverse Lifecycle Capabilities Capabilities to Improve Your Process Capabilities to Improve Quality Capabilities to Grow Sustainability Electrical Network Short Circuit Simulation Design and simulate unbalanced short circuits Primary Department • Design • Construction Benefits • Expedite design studies with a wide range of calculation scenarios, including advanced fault analysis - IEC & ANSI duty calculation for balanced and unbalanced faults - Simultaneous fault at selected nodes - Inclusive 3-Phase and 1-Phase fault analysis - Pre-Fault system loading consideration Electrical Network Short Circuit Simulation in ETAP Capabilities to Improve Time to Market Reference Guide EcoStruxure™ Power for EV Battery Manufacturing Plants General SECTION 3 – Digital Solutions and Services Capabilities to Improve Time to Market SECTION 1 – Introduction to the EV Battery Manufacturing Industry SECTION 2 – How SE Can Support EV Battery Manufacturing Plants BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Transverse Lifecycle Capabilities Capabilities to Improve Your Process Capabilities to Improve Quality Capabilities to Grow Sustainability Network Load Flow and Voltage Drop Simulation Perform power flow analysis and voltage drop calculations Primary Department • Design • Construction Benefits • Simulation of bus voltages, branch power factors, currents, system losses, power generation versus loading • Use of ETAP Electrical Digital Twin model with powerful calculation engines and user-friendly interface • Simulation using multiple loading and generation conditions Network Load Flow and Voltage Drop Simulation in ETAP Capabilities to Improve Time to Market Reference Guide EcoStruxure™ Power for EV Battery Manufacturing Plants General SECTION 3 – Digital Solutions and Services Capabilities to Improve Time to Market SECTION 1 – Introduction to the EV Battery Manufacturing Industry SECTION 2 – How SE Can Support EV Battery Manufacturing Plants BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Transverse Lifecycle Capabilities Capabilities to Improve Your Process Capabilities to Improve Quality Capabilities to Grow Sustainability Device Coordination and Selectivity Automatically detect and evaluate the system protection and coordination/selectivity Primary Department • Design • Construction Benefits • Verified and validated libraries • Graphically adjustable device settings • Detailed device settings reporting • Continuous synchronization with one-line and integrated equipment database Device Coordination and Selectivity in ETAP Capabilities to Improve Time to Market Reference Guide EcoStruxure™ Power for EV Battery Manufacturing Plants General SECTION 3 – Digital Solutions and Services Capabilities to Improve Time to Market SECTION 1 – Introduction to the EV Battery Manufacturing Industry SECTION 2 – How SE Can Support EV Battery Manufacturing Plants BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Transverse Lifecycle Capabilities Capabilities to Improve Your Process Capabilities to Improve Quality Capabilities to Grow Sustainability Arc Fault Protection and Coordination Perform sequence of operation for arc fault and bolted fault Primary Department • Design • Construction Benefits • Evaluate, verify, and confirm the operation and selectivity of the protective devices for various types of faults for any location directly from the single-line diagram • Animation displayed on the single-line diagram • 3-phase / 1-phase sequence of operation Arc Fault Protection and Coordination in ETAP Capabilities to Improve Time to Market Reference Guide EcoStruxure™ Power for EV Battery Manufacturing Plants General SECTION 3 – Digital Solutions and Services Capabilities to Improve Time to Market SECTION 1 – Introduction to the EV Battery Manufacturing Industry SECTION 2 – How SE Can Support EV Battery Manufacturing Plants BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Transverse Lifecycle Capabilities Capabilities to Improve Your Process Capabilities to Improve Quality Capabilities to Grow Sustainability

Power Quality Simulation and Modeling Evaluate and validate distortion due to harmonics Primary Department • Design • Construction Benefits • Simulate harmonic current and voltage sources: - To identify potential harmonic problems (report of harmonic voltage and current distortion limit violations) - To identify the need for a harmonics filter • Simulate and analyze the size of the harmonics filter your system will need to optimize performance and reduce nuisance trips Capabilities to Improve Time to Market Power Quality Simulation and Modeling in ETAP Reference Guide EcoStruxure™ Power for EV Battery Manufacturing Plants General SECTION 3 – Digital Solutions and Services Capabilities to Improve Time to Market SECTION 1 – Introduction to the EV Battery Manufacturing Industry SECTION 2 – How SE Can Support EV Battery Manufacturing Plants BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Transverse Lifecycle Capabilities Capabilities to Improve Your Process Capabilities to Improve Quality Capabilities to Grow Sustainability Renewable and Microgrid Energy Storage Sizing Simulation Design and optimize the microgrid system Primary Department • Design • Construction Benefits • Build renewable energy models combined with full spectrum power system analysis calculations for: - Accurate simulation - Predictive analysis - Equipment sizing - Field verification of wind, solar farms and other DERs • Enable designers and engineers to conceptualize the collector systems, determine wind penetration and perform grid interconnection studies Microgrid Energy Storage Sizing Simulation in ETAP Capabilities to Improve Time to Market Reference Guide EcoStruxure™ Power for EV Battery Manufacturing Plants General SECTION 3 – Digital Solutions and Services Capabilities to Improve Your Process SECTION 1 – Introduction to the EV Battery Manufacturing Industry SECTION 2 – How SE Can Support EV Battery Manufacturing Plants BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Transverse Lifecycle Capabilities Capabilities to Improve Time to Market Capabilities to Improve Quality Capabilities to Grow Sustainability Overview of Digital Solutions and Services Electrical Digital Twin Green Premium Operator training simulation Energy monitoring and usage analysis Energy performance, modeling and verification Capacity management + + + + Cybersecurity Carbon neutrality consulting services Energy efficiency compliance Greenhouse gas reporting + + + Grow Sustainability Improve Quality Improve Your Process Improve Time to Market Design, Build, Commission (Consultants & EPC) Operate & Maintain (Operators, maintenance team, service teams) Transverse Lifecycle Capabilities AC&DC electrical network bus design and simulation Electrical network short circuit simulation Network load flow and voltage drop simulation Device coordination and selectivity Arc fault protection and coordination Power quality simulation and modeling Renewable & microgrid energy storage sizing simulation + + + + + + + Asset performance Power quality monitoring and compliance Continuous thermal monitoring Electrical distribution monitoring and alarming Power event analysis Predictive simulation Power quality and power factor correction Arc flash protection Simulate before Operate + + + + + + + + + Reference Guide EcoStruxure™ Power for EV Battery Manufacturing Plants General SECTION 3 – Digital Solutions and Services Capabilities to Improve Your Process SECTION 1 – Introduction to the EV Battery Manufacturing Industry SECTION 2 – How SE Can Support EV Battery Manufacturing Plants BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Transverse Lifecycle Capabilities Capabilities to Improve Time to Market Capabilities to Improve Quality Capabilities to Grow Sustainability Operator Training Simulation Train new employees and build confidence on new systems Primary Department • Facility Operations & Maintenance Benefits • Practice operation within a simulated but highly realistic environment to enhance safety and operational efficiency • Track and review trainee actions to analyze and challenge them + Capabilities to Improve Your Process Learn more about: • Operator Training Simulation (IEC / NEMA) Principle of Operator Training Simulation Application Operator Training Simulation Reference Architecture General Operator Training Simulation Reference Architecture Reference Guide EcoStruxure™ Power for EV Battery Manufacturing Plants General SECTION 3 – Digital Solutions and Services Capabilities to Improve Your Process SECTION 1 – Introduction to the EV Battery Manufacturing Industry SECTION 2 – How SE Can Support EV Battery Manufacturing Plants BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Transverse Lifecycle Capabilities Capabilities to Improve Time to Market Capabilities to Improve Quality Capabilities to Grow Sustainability Energy Monitoring and Usage Analysis Determine where to focus energy conservation initiatives Primary Department • Facility Operations & Maintenance Benefits • Bring awareness to utility consumption - Turn data into easy-to-interpret graphical dashboards and reports to raise awareness amongst key stakeholders • Identify “quick-win” opportunities for energy savings - By comparing and visualizing energy usage and cost for different utilities over different time periods - By identifying and prioritizing which areas lend themselves to a high energy-saving return on investment Capabilities to Improve Your Process Energy Usage Analysis Dashboards in EcoStruxure Power Operation Learn more about: • Energy Monitoring (IEC / NEMA) Energy Monitoring and Usage Analysis Reference Architecture

General Energy Monitoring and Usage Analysis Reference Architecture Reference Guide EcoStruxure™ Power for EV Battery Manufacturing Plants General SECTION 3 – Digital Solutions and Services Capabilities to Improve Your Process SECTION 1 – Introduction to the EV Battery Manufacturing Industry SECTION 2 – How SE Can Support EV Battery Manufacturing Plants BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Transverse Lifecycle Capabilities Capabilities to Improve Time to Market Capabilities to Improve Quality Capabilities to Grow Sustainability Energy Performance, Modeling and Verification Analyze the energy performance of a plant against a model baseline Primary Department • Facility Operations & Maintenance Benefits • Provide energy usage information based on equipment and processes • Compare model versus actual consumption • Compare pre-retrofit versus post-retrofit energy consumption to track improved performance and savings as a result of energy conservation initiatives Capabilities to Improve Your Process Energy Performance, Modeling and Verification Output in EcoStruxure Power Operation Learn more about: • Energy Performance (IEC / NEMA) • Energy Modeling and verification (IEC / NEMA) Energy Performance, Modeling and Verification Reference Architecture General Energy Performance Modeling and Verification Reference Architecture Reference Guide EcoStruxure™ Power for EV Battery Manufacturing Plants General SECTION 3 – Digital Solutions and Services Capabilities to Improve Your Process SECTION 1 – Introduction to the EV Battery Manufacturing Industry SECTION 2 – How SE Can Support EV Battery Manufacturing Plants BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Transverse Lifecycle Capabilities Capabilities to Improve Time to Market Capabilities to Improve Quality Capabilities to Grow Sustainability Capacity Management Monitor the capacity of electrical distribution Primary Department • Facility Operations & Maintenance Benefits • Monitor electrical network capacity • Track and review capacity efficiency • Minimize downtime by tracking the capacity of transformers, circuit breakers, UPSs, generators, etc. Capabilities to Improve Your Process Breaker Capacity Single-line Diagram in EcoStruxure Power Operation Learn more about: • Capacity Management (IEC / NEMA) Capacity Management Reference Architecture General Capacity Management Reference Architecture Reference Guide EcoStruxure™ Power for EV Battery Manufacturing Plants General SECTION 3 – Digital Solutions and Services Capabilities to Improve Quality SECTION 1 – Introduction to the EV Battery Manufacturing Industry SECTION 2 – How SE Can Support EV Battery Manufacturing Plants BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Transverse Lifecycle Capabilities Capabilities to Improve Time to Market Capabilities to Improve Your Process Capabilities to Grow Sustainability AC&DC electrical network bus design and simulation Electrical network short circuit simulation Network load flow and voltage drop simulation Device coordination and selectivity Arc fault protection and coordination Power quality simulation and modeling Renewable & microgrid energy storage sizing simulation + + + + + + + Overview of Digital Solutions and Services Electrical Digital Twin Green Premium Operator training simulation Energy monitoring and usage analysis Energy performance, modeling and verification Capacity management + + + + Cybersecurity Carbon neutrality consulting services Energy efficiency compliance Greenhouse gas reporting + + + Grow Sustainability Improve Quality Improve Your Process Improve Time to Market Design, Build, Commission (Consultants & EPC) Operate & Maintain (Operators, maintenance team, service teams) Transverse Lifecycle Capabilities Asset performance Power quality monitoring and compliance Continuous thermal monitoring Electrical distribution monitoring and alarming Power event analysis Predictive simulation Power quality and power factor correction + + + + + + + Arc flash protection+ Simulate before Operate+ Reference Guide EcoStruxure™ Power for EV Battery Manufacturing Plants General SECTION 3 – Digital Solutions and Services Capabilities to Improve Quality SECTION 1 – Introduction to the EV Battery Manufacturing Industry SECTION 2 – How SE Can Support EV Battery Manufacturing Plants BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Transverse Lifecycle Capabilities Capabilities to Improve Time to Market Capabilities to Improve Your Process Capabilities to Grow Sustainability Predictive Simulation Help employees make better decisions Primary Department • Facility Engineering • Design Engineering Benefits • Reduce safety risks by practicing emergencies and high-risk situations • Enhance operational efficiency by running “what-if” scenarios • Provide faster analysis response to incidents Capabilities to Improve Quality + Principle of Predictive Simulation Application Predictive Simulation Reference Architecture General Predictive Simulation Application Digital Architecture Reference Guide EcoStruxure™ Power for EV Battery Manufacturing Plants General SECTION 3 – Digital Solutions and Services Capabilities to Improve Quality SECTION 1 – Introduction to the EV Battery Manufacturing Industry SECTION 2 – How SE Can Support EV Battery Manufacturing Plants BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Transverse Lifecycle Capabilities Capabilities to Improve Time to Market Capabilities to Improve Your Process Capabilities to Grow Sustainability Simulate Before Operate Empower operators with predictive outcomes Primary Department • Facility Operations & Maintenance Benefits • Provide operators with a list of potential side effects, prior to executing a command • Empower employees to feel more confident when operating their facilities by providing real time guidance • Reduce human error that could lead to outages or safety concerns Capabilities to Improve Quality Learn more about: • Simulate Before Operate (IEC / NEMA) Principle of Simulate before Operate Application Simulate Before Operate Reference Architecture General Simulate Before Operate Application Digital Architecture Reference Guide EcoStruxure™ Power for EV Battery Manufacturing Plants General SECTION 3 – Digital Solutions and Services Capabilities to Improve Quality SECTION 1 – Introduction to the EV Battery Manufacturing Industry SECTION 2 – How SE Can Support EV Battery Manufacturing Plants BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Transverse Lifecycle Capabilities Capabilities to Improve Time to Market Capabilities to Improve Your Process Capabilities to Grow Sustainability Electrical Distribution Monitoring and Alarming Monitor and control electrical network Primary Department • Facility Operations & Maintenance Benefits • Show real-time status of the power distribution • Customized single-line diagram • 24/7 power monitoring and alarm notification Capabilities to Improve Quality Electrical Distribution Monitoring and Alarming Single-line Diagram in EcoStruxure Power Operation Learn more about: • Electrical distribution monitoring and alarming (IEC / NEMA) • Power Source and Load Control (IEC / NEMA) Electrical Distribution Monitoring and Alarming Reference Architecture General Electrical Distribution Monitoring and Alarming Reference Architecture Reference Guide EcoStruxure™ Power for EV Battery Manufacturing Plants General SECTION 3 – Digital Solutions and Services Capabilities to Improve Quality SECTION 1 – Introduction to the EV Battery Manufacturing Industry SECTION 2 – How SE Can Support EV Battery Manufacturing Plants BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Transverse Lifecycle Capabilities Capabilities to Improve Time to Market Capabilities to Improve Your Process Capabilities to Grow Sustainability Power Event Analysis Analyze the root causes of electrical events Primary Department • Facility Operations & Maintenance Benefits • Automatically classifies and describes any electrical events • Uses system intelligence to determine root cause and location of events • Shows context and sequence of events using the timeline analysis interface Event and Alarm Status view in EcoStruxure Power Operation Event and Alarm Status Timeline in EcoStruxure Power Operation Capabilities to Improve Quality Learn more about: • Power Event Analysis (IEC / NEMA) Power Event Analysis Reference Architecture General Power Event Analysis Reference Architecture Reference Guide EcoStruxure™ Power for EV Battery Manufacturing Plants General SECTION 3 – Digital Solutions and Services Capabilities to Improve Quality SECTION 1 – Introduction to the EV Battery Manufacturing Industry SECTION 2 – How SE Can Support EV Battery Manufacturing Plants BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Transverse Lifecycle Capabilities Capabilities to Improve Time to Market Capabilities to Improve Your Process Capabilities to Grow Sustainability Asset Performance Benefit from a strategic maintenance approach Primary Department • Facility Operations & Maintenance Benefits • Move from reactive or preventive to condition-based (predictive) maintenance strategies for critical assets like circuit breakers, gensets, transformers, etc. • Provide event details and notification to the operator if a protection setting has been changed • Receive notifications and diagnostics reports from expert service engineers with recommendations to optimize maintenance by asset or site Capabilities to Improve Quality Aging Diagram for Circuit Breakers in EcoStruxure Power Operation Gigafactory Learn more about: • Asset Performance (IEC / NEMA) Asset Performance Reference Architecture General Asset Performance Reference Architecture Reference Guide EcoStruxure™ Power for EV Battery Manufacturing Plants General SECTION 3 – Digital Solutions and Services Capabilities to Improve Quality SECTION 1 – Introduction to the EV Battery Manufacturing Industry SECTION 2 – How SE Can Support EV Battery Manufacturing Plants BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Transverse Lifecycle Capabilities Capabilities to Improve Time to Market Capabilities to Improve Your Process Capabilities to Grow Sustainability Power Quality Monitoring and Compliance Gain insights to improve power quality and comply with standards Primary Department • Facility Operations & Maintenance Benefits • Bring awareness of power quality • Enhance operational efficiency by making sure clean power is fed to sensitive process equipment • Help protect sensitive equipment by tracking power quality problems before they arise Capabilities to Improve Quality Power Quality and Compliance Dashboards in EcoStruxure Power Operation Power Quality and Compliance Report in EcoStruxure Power Operation Learn more about: • Power Quality Monitoring and Compliance (IEC / NEMA) Power Quality Monitoring and Compliance Reference Architecture General Power Quality Monitoring and Compliance Reference Architecture Reference Guide EcoStruxure™ Power for EV Battery Manufacturing Plants General SECTION 3 – Digital Solutions and Services Capabilities to Improve Quality SECTION 1 – Introduction to the EV Battery

Manufacturing Industry SECTION 2 – How SE Can Support EV Battery Manufacturing Plants BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Transverse Lifecycle Capabilities Capabilities to Improve Time to Market Capabilities to Improve Your Process Capabilities to Grow Sustainability Power Quality and Power Factor Correction Help protect sensitive equipment from power quality issues Primary Department • Facility Operations & Maintenance Benefits • Monitor sensitive process lines and busbars • Provide clean power to sensitive process equipment • Track Power Quality problems to help avoid downtime • Reduce financial impact of power factor on energy bill Capabilities to Improve Quality Galaxy VM Power Quality Information in EcoStruxure Power Operation Before and After Power Quality and Power Factor Correction ImplementationLearn more about: • Power Quality Correction (IEC / NEMA) • Power Factor Correction (IEC / NEMA) Power Quality and Power Factor Correction Reference Architecture General Power Quality and Power Factor Correction Reference Architecture Reference Guide EcoStruxure™ Power for EV Battery Manufacturing Plants General SECTION 3 – Digital Solutions and Services Capabilities to Improve Quality SECTION 1 – Introduction to the EV Battery Manufacturing Industry SECTION 2 – How SE Can Support EV Battery Manufacturing Plants BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Transverse Lifecycle Capabilities Capabilities to Improve Time to Market Capabilities to Improve Your Process Capabilities to Grow Sustainability Continuous Thermal Monitoring Help prevent electrical fires and help protect equipment Primary Department • Facility Operations & Maintenance Benefits • Bring early detection of temperature abnormalities • Help reduce the risk of equipment and electrical room damage and improve service continuity • Enable cost effective maintenance Continuous Thermal Monitoring in the Single-line Diagram of EcoStruxure Power Operation Continuous Thermal Monitoring Reference Architecture Capabilities to Improve Quality Learn more about: • Continuous Thermal monitoring (IEC / NEMA) General Continuous Thermal Monitoring Reference Architecture Reference Guide EcoStruxure™ Power for EV Battery Manufacturing Plants General SECTION 3 – Digital Solutions and Services Capabilities to Improve Quality SECTION 1 – Introduction to the EV Battery Manufacturing Industry SECTION 2 – How SE Can Support EV Battery Manufacturing Plants BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Transverse Lifecycle Capabilities Capabilities to Improve Time to Market Capabilities to Improve Your Process Capabilities to Grow Sustainability Arc Flash Protection Help protect employees and equipment Primary Department • Facility Operations & Maintenance Benefits • Help prevent loss of life and reduce the risk of equipment and electrical room damage • Improve maintenance team awareness to help troubleshoot and identify the root cause of arc flash events Capabilities to Improve Quality Learn more about: • Arc Flash Protection (IEC / NEMA) Arc Flash in a Switchboard Arc Flash Alert and Location in EcoStruxure Power Operation Arc Flash Protection Reference Architecture General Arc Flash Protection Reference Architecture Reference Guide EcoStruxure™ Power for EV Battery Manufacturing Plants General SECTION 3 – Digital Solutions and Services Capabilities to Grow Sustainability SECTION 1 – Introduction to the EV Battery Manufacturing Industry SECTION 2 – How SE Can Support EV Battery Manufacturing Plants BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Transverse Lifecycle Capabilities Capabilities to Improve Time to Market Capabilities to Improve Your Process Capabilities to Improve Quality Overview of Digital Solutions and Services Electrical Digital Twin Green Premium Operator training simulation Energy monitoring and usage analysis Energy performance, modeling and verification Capacity management + + + + Cybersecurity Carbon neutrality consulting services Energy efficiency compliance Greenhouse gas reporting + + + Grow Sustainability Improve Quality Improve Your Process Improve Time to Market Design, Build, Commission (Consultants & EPC) Operate & Maintain (Operators, maintenance team, service teams) Transverse Lifecycle Capabilities AC&DC electrical network bus design and simulation Electrical network short circuit simulation Network load flow and voltage drop simulation Device coordination and selectivity Arc fault protection and coordination Power quality simulation and modeling Renewable & microgrid energy storage sizing simulation + + + + + + + Asset performance Power quality monitoring and compliance Continuous thermal monitoring Electrical distribution monitoring and alarming Power event analysis Predictive simulation Power quality and power factor correction + + + + + + + Arc flash protection+ Simulate before Operate+ Reference Guide EcoStruxure™ Power for EV Battery Manufacturing Plants General SECTION 3 – Digital Solutions and Services Capabilities to Grow Sustainability SECTION 1 – Introduction to the EV Battery Manufacturing Industry SECTION 2 – How SE Can Support EV Battery Manufacturing Plants BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Transverse Lifecycle Capabilities Capabilities to Improve Time to Market Capabilities to Improve Your Process Capabilities to Improve Quality Carbon Neutrality Consulting Services Primary Department • Facility Operations & Maintenance • Sustainability Office Benefits • Get support from our consulting services to define your strategy for achieving carbon neutrality Track and reduce carbon emissions to demonstrate the carbon neutrality of the company Capabilities to Grow Sustainability + Services Carbon neutrality Reduce Carbon Emissions Produce Renewable Energy Purchase Renewables/Offsets Energy Efficiency • Sustainable building design & operations – HVAC Efficiency – Lighting Efficiency – Operational Efficiency Behind-the-Meter Renewables • Solar Panels / Heating • Wind • Geothermal Purchase Renewables • Renewable Power Purchasing Agreements (PPA) • Renewable Energy Certificates (REC) • Biofuels Supporting Technologies • Microgrid with Smart Management • Battery Storage • Fuel Cells Purchase Offsets • Carbon Credits – Carbon Capture – Tree Planting 1 2 3 Reference Guide EcoStruxure™ Power for EV Battery Manufacturing Plants General SECTION 3 – Digital Solutions and Services Capabilities to Grow Sustainability SECTION 1 – Introduction to the EV Battery Manufacturing Industry SECTION 2 – How SE Can Support EV Battery Manufacturing Plants BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Transverse Lifecycle Capabilities Capabilities to Improve Time to Market Capabilities to Improve Your Process Capabilities to Improve Quality Energy Efficiency Compliance Primary Department • Facility Operations & Maintenance • Sustainability Office Benefits • Report and show facility compliance to local sustainability requirements - To benefit from tax credits - To gain credibility to participate in new projects Comply with standards related to energy management systems Capabilities to Grow Sustainability EcoStruxure Power Operation Energy Star Compliance Dashboard EcoStruxure Resource Advisor Dashboard in EcoStruxure Power Operation Sustainable Organizations and Standards Learn more about: • Energy Efficiency Compliance (IEC / NEMA) Energy Efficiency Compliance Reference Architecture General Energy Efficiency Compliance Reference Architecture Reference Guide EcoStruxure™ Power for EV Battery Manufacturing Plants General SECTION 3 – Digital Solutions and Services Capabilities to Grow Sustainability SECTION 1 – Introduction to the EV Battery Manufacturing Industry SECTION 2 – How SE Can Support EV Battery Manufacturing Plants BIBLIOGRAPHY Introduction Overview of Digital Solutions and Services Transverse Lifecycle Capabilities Capabilities to Improve Time to Market Capabilities to Improve Your Process Capabilities to Improve Quality Greenhouse Gas Reporting Primary Department • Facility Operations & Maintenance • Sustainability Office Benefits • Track and report carbon emissions and waste (e.g., water) in one single place • Provide period-over-period usage comparison to detect a drift Track and report carbon emissions Greenhouse Gas Reporting and Dashboard Examples in EcoStruxure Power Operation Capabilities to Grow Sustainability Greenhouse Gas Reporting Reference Architecture Learn more about: • Greenhouse Gas Reporting (IEC / NEMA) General Greenhouse Gas Reporting Reference Architecture Reference Guide EcoStruxure™ Power for EV Battery Manufacturing Plants General SECTION 3 – Digital Solutions and Services SECTION 1 – Introduction to the EV Battery Manufacturing Industry SECTION 2 – How SE Can Support EV Battery Manufacturing Plants BIBLIOGRAPHY Reference Documents Legal Information BIBLIOGRAPHY Reference Guide EcoStruxure™ Power for EV Battery Manufacturing Plants General BIBLIOGRAPHY Reference Documents SECTION 3 – Digital Solutions and Services SECTION 1 – Introduction to the EV Battery Manufacturing Industry SECTION 2 – How SE Can Support EV Battery Manufacturing Plants Legal Information Reference Documents Design Guide IEC EcoStruxure Power Design Guide Ref: ESXP2G001EN 02/2024 Digital Applications for Large Buildings and Critical Facilities The Digital Applications Design Guide provides comprehensive details on the building blocks of EcoStruxure Power: the IoT applications are driven by a software layer to control the traditional electrical distribution infrastructure. Developed to help engineering consultants and designers, this guide is an invaluable resource for specifying, designing and prescribing EcoStruxure Power architectures capable of performing one or more of the business-driven applications described within. 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All other brands are trademarks of their respective owners Modicon Standard Register Number Absolute Starting Register Address, (Hexa-decimal) Absolute Starting Register Address, (Decimal) Bit Data Point Length # register s Data Type Multiply Reading By: Divide Reading By: Valid Response Status Data 40002 0x0001 1 UPS Status 1 0 UPS operation mode - Battery BOOLEAN 1=UPS operation mode - Battery 1 Battery is below minimum acceptable runtime BOOLEAN 1=Battery is below minimum acceptable runtime 2 Bypass BOOLEAN 1=UPS is in Bypass 3 UPS operation mode - Battery Test BOOLEAN 1=UPS operation mode - Battery Test 4 Reserved BOOLEAN 5 High Efficiency Mode disable by system BOOLEAN 1=High Efficiency Mode (ECO, ECOnversion) disable by system 6 Reserved BOOLEAN 7 Reserved BOOLEAN 8 Reserved BOOLEAN 9 Battery fault BOOLEAN 1=Battery fault 10 Reserved BOOLEAN 11 Reserved BOOLEAN 12 Reserved BOOLEAN 13 Informational alarm present BOOLEAN 1=Informational alarm present 14 Warning alarm present BOOLEAN 1=Warning alarm present 15 Critical alarm present BOOLEAN 1=Critical alarm present 40003 0x0002 2 Alarm Register 1 0 Lost local network management interface - to - UPS communication BOOLEAN 1=Lost local network management interface - to - UPS communication 1 Display communication is lost BOOLEAN 1=Main Controller is unable to communicate with the display 2 Parallel communication incorrect on PBUS cable 1 BOOLEAN 1=Parallel communication incorrect on PBUS cable 1 3 Parallel communication incorrect on PBUS cable 2 BOOLEAN 1=Parallel communication incorrect on PBUS cable 2 4 MegaTie activation alarm BOOLEAN 1=MegaTie activation is present 5 Reserved BOOLEAN 6 Reserved BOOLEAN 7 Reserved BOOLEAN 8 Reserved BOOLEAN 9 Reserved BOOLEAN 10 Reserved BOOLEAN 11 Reserved BOOLEAN 12 Communication cable termination fault BOOLEAN 1=Communication cable termination fault 13 General parallel system incorrect BOOLEAN 1=General parallel system incorrect 14 Lost parallel redundancy BOOLEAN 1=Lost parallel redundancy 15 Reserved BOOLEAN 40004 0x0003 3 Alarm Register 0 Reserved BOOLEAN 1 UPS operation mode - Requested Static Bypass BOOLEAN 1=UPS operation mode - Requested Static Bypass 2 UPS operation mode - Forced Static Bypass BOOLEAN 1=UPS operation mode - Forced Static Bypass Modbus Register Map:Galaxy VX (3:3 250kW-1500kW) Scale Notes: 1. 16-bit registers are transmitted MSB first (i.e. big-endian). 2. INT32 and UINT32 are most-significant word in n+0, least significant word in n+1 (i.e. big-endian). 3. Function codes 3 and 4 are supported 4. Modbus serial RTU and Modbus over TCP is supported. 5. Signed numbers are twos-compliment 6. Status bits are atomic within a single Modbus register. User should not look for consistency across multiple registers, only within a single register. 7. For ASCII strings less than the maximum length, the unused characters are filled with nulls. 8. Single-register reads of reserved or undefined registers will return an error. Block reads which begin with a valid register will not return an error but will return zeros for undefined registers. 9. Strings are two characters per register, first character in high-order byte, second character in low-order byte. Printable ASCII only. 10. Bit #0 is least significant bit. 11. Data Type column: "INT16"=signed 16-bit integer, "UINT16" = unsigned 16-bit integer, "INT32" = signed 32-

bit integer, "UINT32" = unsigned 32-bit integer, "ENUM" is a UINT16 value which maps to a defined list of states, "ASCII" = the printable ASCII subset from 0x20 - 0x7E. BOOLEAN= a single bit, 0 or 1. 12. "Absolute Starting Register Address" = 0 (the column heading used in this table) is equivalent to "Register 40001" in Modicon terminology, which is address zero when transmitted over the wire. For detailed modbus configuration settings, please refer to the Display or AP9635 User's Guide. 990-5915E May/ 2024 Modicon Standard Register Number Absolute Starting Register Address, (Hexa-decimal) Absolute Starting Register Address, (Decimal) Bit Data Point Length # register s Data Type Multiply Reading By: Divide Reading By: Valid Response Scale 3 UPS operation mode - Maintenance Bypass BOOLEAN 1=UPS operation mode - Maintenance Bypass 4 Reserved BOOLEAN 5 UPS operation mode - Off BOOLEAN 1=UPS operation mode - Off 6 UPS operation mode - Initialize BOOLEAN 1=UPS operation mode - Initialize 7 Reserved BOOLEAN 8 Reserved BOOLEAN 9 Reserved BOOLEAN 10 Reserved BOOLEAN 11 Input phase sequence incorrect BOOLEAN 1=Input phase sequence incorrect 12 Input frequency out of range BOOLEAN 1=Input frequency out of range 13 Input voltage out of range BOOLEAN 1=Input voltage is out of range 14 Selftest - Failed BOOLEAN 1=Self test has failed 15 Power cabinet mixed operation mode (Battery and Normal) BOOLEAN 1=Power Cabinet in mixed operation mode (Battery and Normal) 40005 0x0004 4 Alarm Register 1 0 Reserved BOOLEAN 1 Reserved BOOLEAN 2 Reserved BOOLEAN 3 Bypass frequency out of range BOOLEAN 1=Bypass frequency out of range 4 Bypass phase sequence incorrect BOOLEAN 1=Bypass phase sequence incorrect 5 Reserved BOOLEAN 6 Reserved BOOLEAN 7 Reserved BOOLEAN 8 Overload on UPS BOOLEAN 1=Overload on UPS 9 Overload on Static bypass switch BOOLEAN 1=Overload on Static bypass switch 10 Ambient temperature out of range BOOLEAN 1=Ambient temperature out of range 11 EPO Switch Activated BOOLEAN 1=EPO Switch activated 12 Ground fault detected BOOLEAN 1=Ground fault detected 13 Reserved BOOLEAN 14 Bypass voltage out of range BOOLEAN 1=Bypass voltage is out of range 15 High Efficiency mode is disable due to bypass UTHD BOOLEAN 1=Bypass UTHD is out of range for High Efficiency Mode 40006 0x0005 5 Alarm Register 1 0 System locked in bypass operation BOOLEAN 1=System locked in bypass operation 1 Batteries are discharging BOOLEAN 1=Batteries are discharging 2 Reserved BOOLEAN 3 Reserved BOOLEAN 4 Continuous Overload on UPS BOOLEAN 1=Overload on UPS present. Load below Continuous Overload Threshold. 5 Charge power is reduced BOOLEAN 1=Charge power is reduced 6 Reserved BOOLEAN 7 Reserved BOOLEAN 8 Reserved BOOLEAN 9 Distributed Energy Reserved Mode activated BOOLEAN 1= Distributed Energy Reserved mode activated 10 Reserved BOOLEAN 11 Reserved BOOLEAN 12 Battery condition is weak BOOLEAN 1=Battery condition is weak 13 Battery condition is poor BOOLEAN 1=Battery condition is poor 14 Reserved BOOLEAN 15 Battery capacity is below minimum acceptable level BOOLEAN 1=Battery capacity is below minimum acceptable level 40007 0x0006 6 Alarm Register 1 0 Reserved BOOLEAN 1 Reserved BOOLEAN 2 Reserved BOOLEAN 3 Reserved BOOLEAN 4 Reserved BOOLEAN 5 Reserved BOOLEAN 6 Reserved BOOLEAN 7 Reserved BOOLEAN 8 Reserved BOOLEAN 9 Reserved BOOLEAN 10 Reserved BOOLEAN 11 Reserved BOOLEAN 12 Reserved BOOLEAN 13 Reserved BOOLEAN 14 Reserved BOOLEAN 15 Power cabinet redundancy lost BOOLEAN 1=Power cabinet redundancy lost 40008 0x0007 7 Alarm Register 1 0 Reserved BOOLEAN 1 Bypass transfert inhibited by relay input activated BOOLEAN 1= transfert to bypass is inhibited by input relay activated 2 DC ground fault BOOLEAN 1= DC ground fault is present Modicon Standard Register Number Absolute Starting Register Address, (Hexa-decimal) Absolute Starting Register Address, (Decimal) Bit Data Point Length # register s Data Type Multiply Reading By: Divide Reading By: Valid Response Scale 3 Ambient temperature high BOOLEAN 1 = Ambient temperature is high 4 Overload on UPS due to high ambient temperature BOOLEAN 1 = Overload on UPS due to high ambient temperature 5 Output frequency out of range BOOLEAN 1=Output frequency out of range 6 Output voltage out of range BOOLEAN 1=Output voltage is out of range 7 Reserved BOOLEAN 8 Reserved BOOLEAN 9 Reserved BOOLEAN 10 Reserved BOOLEAN 11 Reserved BOOLEAN 12 Overload on installation BOOLEAN 1=Overload on installation 13 Reserved BOOLEAN 14 Reserved BOOLEAN 15 Reserved BOOLEAN 40009 0x0008 8 Alarm Register 1 0 Reserved BOOLEAN 1 Reserved BOOLEAN 2 Reserved BOOLEAN 3 Reserved BOOLEAN 4 Reserved BOOLEAN 5 Reserved BOOLEAN 6 Reserved BOOLEAN 7 Reserved BOOLEAN 8 Reserved BOOLEAN 9 Reserved BOOLEAN 10 Reserved BOOLEAN 11 Reserved BOOLEAN 12 UOB Auxiliary wiring not correct BOOLEAN 1= UOB Aux wiring is not correct 13 Reserved BOOLEAN 14 Reserved BOOLEAN 15 Reserved BOOLEAN 40010 0x0009 9 Alarm Register 1 0 Reserved BOOLEAN 1 Reserved BOOLEAN 2 Reserved BOOLEAN 3 Reserved BOOLEAN 4 Load bank breaker closed, parallel test mode enabled BOOLEAN 1=Load bank breaker closed, parallel test mode enabled 5 Reserved BOOLEAN 6 Reserved BOOLEAN 7 Reserved BOOLEAN 8 Reserved BOOLEAN 9 Unit Unit Breaker (UIB) open BOOLEAN 1=Unit Unit

Breaker (UIB) open 10 Unit Ouput Breaker (UOB) open BOOLEAN 1=Unit Ouput Breaker (UOB) open 11 Maintenance Bypass Breaker (MBB) closed BOOLEAN 1=Maintenance Bypass Breaker (MBB) closed 12 System Isolation Breaker (SIB) open BOOLEAN 1=System Isolation Breaker (SIB) open 13 Static Switch Input Breaker (SSIB) open BOOLEAN 1=Static Switch Input Breaker (SSIB) open 14 Reserved BOOLEAN 15 Reserved BOOLEAN 40011 0x000A 10 Alarm Register 1 0 Reserved BOOLEAN 1 Reserved BOOLEAN 2 Reserved BOOLEAN 3 Reserved BOOLEAN 4 Reserved BOOLEAN 5 Reserved BOOLEAN 6 Reserved BOOLEAN 7 Reserved BOOLEAN 8 Static bypass switch inoperable BOOLEAN 1=Static bypass switch has a critical alarm that prevents it from operating 9 Static bypass switch warning BOOLEAN 1=Static bypass switch has an alarm with severity level warning 10 Reserved BOOLEAN 11 Reserved BOOLEAN 12 Reserved BOOLEAN 13 Reserved BOOLEAN 14 Reserved BOOLEAN 15 Reserved BOOLEAN 40012 0x000B 11 RESERVED 2 40014 0x000D 13 Alarm Register 1 0 Reserved BOOLEAN 1 Reserved BOOLEAN 2 Reserved BOOLEAN Modicon Standard Register Number Absolute Starting Register Address, (Hexa-decimal) Absolute Starting Register Address, (Decimal) Bit Data Point Length # register s Data Type Multiply Reading By: Divide Reading By: Valid Response Scale 3 Reserved BOOLEAN 4 Battery room ventilation inoperable BOOLEAN 1=Battery room ventilation inoperable 5 Reserved BOOLEAN 6 Reserved BOOLEAN 7 Reserved BOOLEAN 8 Reserved BOOLEAN 9 Reserved BOOLEAN 10 External battery monitoring alarm BOOLEAN 1=External battery monitoring alarm 11 Reserved BOOLEAN 12 Reserved BOOLEAN 13 Reserved BOOLEAN 14 Reserved BOOLEAN 15 Reserved BOOLEAN 40015 0x000E 14 Alarm Register 1 BOOLEAN 0 Reserved BOOLEAN 1 Reserved BOOLEAN 2 Reserved BOOLEAN 3 High Battery Temperature Level BOOLEAN 1=Battery temperature above alarm setting 4 Low Battery Temperature Level BOOLEAN 1=Battery temperature below alarm setting 5 Reserved BOOLEAN 6 Reserved BOOLEAN 7 Reserved BOOLEAN 8 Reserved BOOLEAN 9 Reserved BOOLEAN 10 Reserved BOOLEAN 11 Battery breaker BB1 open BOOLEAN 1=Battery breaker BB1 open 12 Battery breaker BB2 open BOOLEAN 1=Battery breaker BB2 open 13 Battery breaker BB3 open BOOLEAN 1=Battery breaker BB3 open 14 Battery breaker BB4 open BOOLEAN 1=Battery breaker BB4 open 15 Delayed transfer from Battery to Normal Operation BOOLEAN 1=The delayed transfer from Battery to Normal Operation is active. 40016 0x000F 15 Alarm Register 1 0 Reserved BOOLEAN 1 Reserved BOOLEAN 2 Reserved BOOLEAN 3 Reserved BOOLEAN 4 Reserved BOOLEAN 5 Reserved BOOLEAN 6 Reserved BOOLEAN 7 Reserved BOOLEAN 8 Reserved BOOLEAN 9 Breaker BF2 open BOOLEAN 1= breaker BF2 open 10 Reserved BOOLEAN 11 Reserved BOOLEAN 12 Reserved BOOLEAN 13 Reserved BOOLEAN 14 Li-Ion AC Supply Breaker BMS:B1/BMS:B2 open BOOLEAN 1=Li-Ion AC Supply Breaker BMS:B1/BMS:B2 open 15 Reserved BOOLEAN 40017 0x0010 16 Alarm Register 1 0 UPS operation mode - Static bypass standby BOOLEAN 1=UPS operation mode - Static bypass standby 1 UPS operation mode - Inverter standby BOOLEAN 1=UPS operation mode - Inverter standby 2 Reserved BOOLEAN 3 Reserved BOOLEAN 4 General UPS settings incorrect BOOLEAN 1=General UPS settings incorrect 5 UPS configuration incorrect BOOLEAN 1=UPS general configuration is incorrect 6 Synchronization unavailable BOOLEAN 1=Synchronization unavaliable - system is free running 7 Fan inoperable BOOLEAN 1=UPS has one or more inoperable fans. Fan redundancy is lost. 8 Inverter is Off due to a request by the user BOOLEAN 1= Inverter is Off due to a request by the user 9 Restricted air flow BOOLEAN 1=Restricted air flow 10 Surveillance detected a fault BOOLEAN 1=Surveillance detected a fault 11 Charger status BOOLEAN 1=Inoperable 12 Inverter status BOOLEAN 1=Inoperable 13 PFC status BOOLEAN 1=Inoperable 14 Battery status BOOLEAN 1=Inoperable 15 Reserved BOOLEAN 40018 0x0011 17 Alarm Register 1 0 Technical check recommended BOOLEAN 1=Technical check recommended 1 Start-up recommended BOOLEAN 1= Secure start-up recommended 2 Warranty expiring soon BOOLEAN 1=Warranty expiring soon 3 Reserved BOOLEAN Modicon Standard Register Number Absolute Starting Register Address, (Hexa-decimal) Absolute Starting Register Address, (Decimal) Bit Data Point Length # register s Data Type Multiply Reading By: Divide Reading By: Valid Response Scale 4 Air filter check recommened BOOLEAN 1=Air filter check recommened 5 Reserved BOOLEAN 6 Reserved BOOLEAN 7 Reserved BOOLEAN 8 Reserved BOOLEAN 9 Reserved BOOLEAN 10 Reserved BOOLEAN 11 Reserved BOOLEAN 12 Reserved BOOLEAN 13 Reserved BOOLEAN 14 Reserved BOOLEAN 15 Reserved BOOLEAN 40019 0x0012 18 RESERVED 1 40020 0x0013 19 Alarm Register 1 0 Reserved BOOLEAN 1 Reserved BOOLEAN 2 Reserved BOOLEAN 3 Reserved BOOLEAN 4 Reserved BOOLEAN 5 Not enough UPSs ready to turn on inverter BOOLEAN 1=Not enough UPSs ready to turn on inverter 6 Parallel UPS 1 not present BOOLEAN 1=Parallel UPS 1 not present 7 Parallel UPS 2 not present BOOLEAN 1=Parallel UPS 2 not present 8 Parallel UPS 3 not present BOOLEAN 1=Parallel UPS 3 not present 9 Parallel UPS 4 not present BOOLEAN 1=Parallel UPS 4 not present 10 Parallel UPS 5 not present BOOLEAN 1=Parallel UPS

5 not present 11 Parallel mixed operation mode BOOLEAN 1=Parallel mixed operation mode 12 Firmware versions in parallel UPS units are not identical BOOLEAN 1=Firmware versions in parallel UPS units are not identical 13 Reserved BOOLEAN 14 Reserved BOOLEAN 15 Reserved BOOLEAN 40021 0x0014 20 RESERVED 1 40022 0x0015 21 Alarm Register 1 0 System operation mode - Off BOOLEAN 1 = System operation mode - Off 1 System operation mode - Forced static bypass BOOLEAN 1 = System operation mode - Forced static bypass 2 System operation mode - Requested static bypass BOOLEAN 1 = System operation mode - Requested static bypass 3 System operation mode - Maintenance bypass BOOLEAN 1 = System operation mode - Maintenance bypass 4 System operation mode - Static Bypass Standby BOOLEAN 1 = System operation mode - Static Bypass Standby 5 Reserved BOOLEAN 6 Reserved BOOLEAN 7 Reserved BOOLEAN 8 Reserved BOOLEAN 9 Reserved BOOLEAN 10 Reserved BOOLEAN 11 Reserved BOOLEAN 12 Reserved BOOLEAN 13 Reserved BOOLEAN 14 Reserved BOOLEAN 15 Reserved BOOLEAN 40023 0x0016 22 Alarm Register 1 0 Input missing phase BOOLEAN 1=Input is missing a phase 1 Bypass missing phase BOOLEAN 1=Bypass input is missing a phase 2 External sync voltage out of range BOOLEAN 1=External sync voltage is out of range 3 External sync phase sequence incorrect BOOLEAN 1=The phase rotation on external sync is wrong 4 External sync frequency out of range BOOLEAN 1=External sync frequency is out of range 5 External sync missing phase BOOLEAN 1=External sync is missing a phase 6 External sync temporarily disabled BOOLEAN 1=External sync temporarily disabled 7 Flywheel inoperable BOOLEAN 1=Flywheel inoperable 8 Display firmware incompatibility detected BOOLEAN 1=Display firmware incompatibility detected 9 NMC 1 firmware incompatibility detected BOOLEAN 1=NMC 1 firmware incompatibility detected 10 NMC 2 firmware incompatibility detected BOOLEAN 1=NMC 2 firmware incompatibility detected 11 10-Inch display incompatibility detected BOOLEAN 1=10 inch Display firmware incompatibility detected 12 Inverter output is not in phase with bypass input BOOLEAN 1=Inverter output is not in phase with bypass input 13 Engineering Firmware Version detected BOOLEAN 1=Alarm Engineering Firmware Version detected 14 Reserved BOOLEAN 15 Reserved BOOLEAN 40024 0x0017 23 Alarm Register 1 0 Reserved BOOLEAN 1 Reserved BOOLEAN Modicon Standard Register Number Absolute Starting Register Address, (Hexa-decimal) Absolute Starting Register Address, (Decimal) Bit Data Point Length # register s Data Type Multiply Reading By: Divide Reading By: Valid Response Scale 2 Reserved BOOLEAN 3 Reserved BOOLEAN 4 Reserved BOOLEAN 5 Reserved BOOLEAN 6 Reserved BOOLEAN 7 Reserved BOOLEAN 8 Reserved BOOLEAN 9 Reserved BOOLEAN 10 Reserved BOOLEAN 11 Reserved BOOLEAN 12 Reserved BOOLEAN 13 Reserved BOOLEAN 14 Reserved BOOLEAN 15 Reserved BOOLEAN 40025 0x0018 24 Alarm Register 1 0 Reserved BOOLEAN 1 Reserved BOOLEAN 2 Reserved BOOLEAN 3 Reserved BOOLEAN 4 Reserved BOOLEAN 5 Reserved BOOLEAN 6 Reserved BOOLEAN 7 Reserved BOOLEAN 8 Reserved BOOLEAN 9 Reserved BOOLEAN 10 Reserved BOOLEAN 11 Reserved BOOLEAN 12 Reserved BOOLEAN 13 Reserved BOOLEAN 14 Reserved BOOLEAN 15 Reserved BOOLEAN 40026 0x0019 25 Alarm Register 1 0 Sensor AP9810 - Input contact A in sensor 1 BOOLEAN 1 = Alarm from sensor 1 / contact A 1 Sensor AP9810 - Input contact B in sensor 1 BOOLEAN 1 = Alarm from sensor 1 / contact B 2 Sensor AP9810 - Input contact A in sensor 2 BOOLEAN 1 = Alarm from sensor 2 / contact A 3 Sensor AP9810 - Input contact B in sensor 2 BOOLEAN 1 = Alarm from sensor 2 / contact B 4 Sensor AP9335T or AP9335TH - temperature alarm in sensor 1 BOOLEAN 1 = temperature alarm in sensor 1 5 Sensor AP9335T or AP9335TH - temperature alarm in sensor 2 BOOLEAN 1 = temperature alarm in sensor 2 6 Sensor AP9335TH - humidity alarm in sensor 1 BOOLEAN 1 = humidity alarm in sensor 1 7 Sensor AP9335TH - humidity alarm in sensor 2 BOOLEAN 1 = humidity alarm in sensor 2 8 Sensor Communication Lost with sensor 1 BOOLEAN 1 = communication lost with sensor 1 9 Sensor Communication Lost with sensor 2 BOOLEAN 1= communication lost with sensor 2 10 Reserved BOOLEAN 11 Reserved BOOLEAN 12 Reserved BOOLEAN 13 Reserved BOOLEAN 14 Reserved BOOLEAN 15 Reserved BOOLEAN 40027 0x0020 26 Alarm Register 1 0 Power Cabinet 1 surveillance detected a fault BOOLEAN 1 = Power Cabinet 1 surveillance detected a fault 1 Power Cabinet 2 surveillance detected a fault BOOLEAN 1 = Power Cabinet 2 surveillance detected a fault 2 Power Cabinet 3 surveillance detected a fault BOOLEAN 1 = Power Cabinet 3 surveillance detected a fault 3 Power Cabinet 4 surveillance detected a fault BOOLEAN 1 = Power Cabinet 4 surveillance detected a fault 4 Power Cabinet 5 surveillance detected a fault BOOLEAN 1 = Power Cabinet 5 surveillance detected a fault 5 Power Cabinet 6 surveillance detected a fault BOOLEAN 1 = Power Cabinet 6 surveillance detected a fault 6 Power Cabinet 7 surveillance detected a fault BOOLEAN 1 = Power Cabinet 7 surveillance detected a fault 7 Reserved BOOLEAN 8 Power Cabinet 1 inoperable BOOLEAN 1 = Power cabinet inoperable 9 Power Cabinet 2 inoperable BOOLEAN 1 = Power cabinet inoperable 10 Power Cabinet 3 inoperable BOOLEAN 1 = Power cabinet inoperable 11 Power

Cabinet 4 inoperable BOOLEAN 1 = Power cabinet inoperable 12 Power Cabinet 5 inoperable BOOLEAN 1 = Power cabinet inoperable 13 Power Cabinet 6 inoperable BOOLEAN 1 = Power cabinet inoperable 14 Power Cabinet 7 inoperable BOOLEAN 1 = Power cabinet inoperable 15 Reserved BOOLEAN 40028 0x0021 27 Alarm Register 1 0 Input dry contact: Genset supplying UPS BOOLEAN 1= a Genset supply the UPS 1 Input dry contact: Battery room ventilation inoperable BOOLEAN 1= Battery room ventilation inoperable 2 Input dry contact: External battery monitoring inoperable BOOLEAN 1= External battery monitoring inoperable Modicon Standard Register Number Absolute Starting Register Address, (Hexa-decimal) Absolute Starting Register Address, (Decimal) Bit Data Point Length # register s Data Type Multiply Reading By: Divide Reading By: Valid Response Scale 3 Input dry contact: Ground fault detected BOOLEAN 1= Ground fault detected 4 Input dry contact: UPS locked in static bypass mode is actived BOOLEAN 1= UPS locked in static bypass mode is actived 5 Input dry contact: User-defined input dry contacts 1 BOOLEAN 1= User-defined input dry contacts 1, in alarm position 6 Input dry contact: User-defined input dry contacts 2 BOOLEAN 1= User-defined input dry contacts 2, in alarm position 7 Input dry contact: Flywheel inoperable BOOLEAN 1= Flywheel inoperable 8 Input dry contact: External energy storage monitoring major alarm BOOLEAN 1= External energy storage monitoring major alarm 9 Input dry contact: External energy storage monitoring minor alarm BOOLEAN 1= External energy storage monitoring minor alarm 10 Input dry contact: Force Charger Off BOOLEAN 1= Force Charger Off 11 Input dry contact: Disable High Efficiency Mode BOOLEAN 1= Disable High Efficiency Mode 12 Input dry contact: Transfer from Battery to Normal Operation delay BOOLEAN 1=Transfer from Battery to Normal Operation delay 13 Input dry contact: Force Battery Operation BOOLEAN 1=Force Battery Operation 14 Input dry contact: Request Bypass operation BOOLEAN 1=Requested Bypass command from input relay activated 15 Reserved BOOLEAN 40029 0x0022 28 Alarm Register 1 0 Power Cabinet 1 surveillance fault BOOLEAN 1 = Temporized Power Cabinet surveillance fault 1 Power Cabinet 1 inoperable BOOLEAN 1 = Temporized Power Cabinet inoperable 2 Power Cabinet 1 - Power Bloc L1A - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault 3 Power Cabinet 1 - Power Bloc L2A - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault 4 Power Cabinet 1 - Power Bloc L3A - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault 5 Power Cabinet 1 - Power Bloc L1B - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault 6 Power Cabinet 1 - Power Bloc L2B - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault 7 Power Cabinet 1 - Power Bloc L3B - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault 8 Power Cabinet 2 surveillance fault BOOLEAN 1 = Temporized Power Cabinet surveillance fault 9 Power Cabinet 2 inoperable BOOLEAN 1 = Temporized Power Cabinet inoperable 10 Power Cabinet 2 - Power Bloc L1A - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault 11 Power Cabinet 2 - Power Bloc L2A - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault 12 Power Cabinet 2 - Power Bloc L3A - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault 13 Power Cabinet 2 - Power Bloc L1B - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault 14 Power Cabinet 2 - Power Bloc L2B - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault 15 Power Cabinet 2 - Power Bloc L3B - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault 40030 0x0023 29 Alarm Register 1 0 Power Cabinet 3 surveillance fault BOOLEAN 1 = Temporized Power Cabinet surveillance fault 1 Power Cabinet 3 inoperable BOOLEAN 1 = Temporized Power Cabinet inoperable 2 Power Cabinet 3 - Power Bloc L1A - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault 3 Power Cabinet 3 - Power Bloc L2A - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault 4 Power Cabinet 3 - Power Bloc L3A - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault 5 Power Cabinet 3 - Power Bloc L1B - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault 6 Power Cabinet 3 - Power Bloc L2B - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault 7 Power Cabinet 3 - Power Bloc L3B - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault 8 Power Cabinet 4 surveillance fault BOOLEAN 1 = Temporized Power Cabinet surveillance fault 9 Power Cabinet 4 inoperable BOOLEAN 1 = Temporized Power Cabinet inoperable 10 Power Cabinet 4 - Power Bloc L1A - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault 11 Power Cabinet 4 - Power Bloc L2A - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault 12 Power Cabinet 4 - Power Bloc L3A - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault 13 Power Cabinet 4 - Power Bloc L1B - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault 14 Power Cabinet 4 - Power Bloc L2B - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault 15

Power Cabinet 4 - Power Bloc L3B - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault 40031 0x0024 30 Alarm Register 1 0 Power Cabinet 5 surveillance fault BOOLEAN 1 = Temporized Power Cabinet surveillance fault 1 Power Cabinet 5 inoperable BOOLEAN 1 = Temporized Power Cabinet inoperable 2 Power Cabinet 5 - Power Bloc L1A - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault 3 Power Cabinet 5 - Power Bloc L2A - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault 4 Power Cabinet 5 - Power Bloc L3A - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault 5 Power Cabinet 5 - Power Bloc L1B - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault 6 Power Cabinet 5 - Power Bloc L2B - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault 7 Power Cabinet 5 - Power Bloc L3B - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault 8 Power Cabinet 6 surveillance fault BOOLEAN 1 = Temporized Power Cabinet surveillance fault 9 Power Cabinet 6 inoperable BOOLEAN 1 = Temporized Power Cabinet inoperable 10 Power Cabinet 6 - Power Bloc L1A - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault 11 Power Cabinet 6 - Power Bloc L2A - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault 12 Power Cabinet 6 - Power Bloc L3A - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault 13 Power Cabinet 6 - Power Bloc L1B - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault 14 Power Cabinet 6 - Power Bloc L2B - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault 15 Power Cabinet 6 - Power Bloc L3B - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault 40032 0x0025 31 Alarm Register 1 Modicon Standard Register Number Absolute Starting Register Address, (Hexa-decimal) Absolute Starting Register Address, (Decimal) Bit Data Point Length # register s Data Type Multiply Reading By: Divide Reading By: Valid Response Scale 0 Power Cabinet 7 surveillance fault BOOLEAN 1 = Temporized Power Cabinet surveillance fault 1 Power Cabinet 7 inoperable BOOLEAN 1 = Temporized Power Cabinet inoperable 2 Power Cabinet 7 - Power Bloc L1A - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault 3 Power Cabinet 7 - Power Bloc L2A - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault 4 Power Cabinet 7 - Power Bloc L3A - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault 5 Power Cabinet 7 - Power Bloc L1B - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault 6 Power Cabinet 7 - Power Bloc L2B - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault 7 Power Cabinet 7 - Power Bloc L3B - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault 8 Reserved BOOLEAN 9 Surveillance Limit Detected on Power Cabinet 1 BOOLEAN 1= SurvLimitDetected on Power Cabinet 1 10 Surveillance Limit Detected on Power Cabinet 2 BOOLEAN 1= SurvLimitDetected on Power Cabinet 2 11 Surveillance Limit Detected on Power Cabinet 3 BOOLEAN 1= SurvLimitDetected on Power Cabinet 3 12 Surveillance Limit Detected on Power Cabinet 4 BOOLEAN 1= SurvLimitDetected on Power Cabinet 4 13 Surveillance Limit Detected on Power Cabinet 5 BOOLEAN 1= SurvLimitDetected on Power Cabinet 5 14 Surveillance Limit Detected on Power Cabinet 6 BOOLEAN 1= SurvLimitDetected on Power Cabinet 6 15 Surveillance Limit Detected on Power Cabinet 7 BOOLEAN 1= SurvLimitDetected on Power Cabinet 7 Static Data 44097 0x1000 4096 Display/NMC Model Number 9 ASCII 44106 0x1009 4105 Display/NMC Serial Number 8 ASCII 44114 0x1011 4113 Display/NMC Firmware Revision APP 9 ASCII 44123 0x101A 4122 Display/NMC Hardware Revision 9 ASCII 44132 0x1023 4131 Display/NMC Date of Manufacture 6 ASCII 44138 0x1029 4137 RESERVED 8 44146 0x1031 4145 UPS Serial Number 6 ASCII 44152 0x1037 4151 UPS Firmware Version 12 ASCII 44164 0x1043 4163 Product Name 40 ASCII 44204 0x106B 4203 UPS Serial Number for 14 characters 8 ASCII for new 3-phases UPS, using 14 characters Dynamic Data 44353 0x1100 4352 RESERVED 2 44355 0x1102 4354 Runtime remaining 2 UINT32 1 1 Seconds 44357 0x1104 4356 Estimated charge time 2 UINT32 1 1 Seconds 44359 0x1106 4358 Estimated charge % 1 UINT16 1 1 % 44360 0x1107 4359 RESERVED 8 44368 0x110F 4367 Battery Temperature (for classic battery solution) 1 UINT16 1 1 °C or °F 44369 0x1110 4368 Charger Mode 1 0 Float Charging BOOLEAN 1=Charger mode is float charging 1 Boost Charging BOOLEAN 1=Charger mode is boost charging 2 Reserved BOOLEAN 3 Reserved BOOLEAN 4 Reserved BOOLEAN 5 Equalization Charging BOOLEAN 1=Charger mode is eqalization charging 6 Not Charging BOOLEAN 1=Charger mode is Off 7 Test In Progress BOOLEAN 1=Test is in progress 8 Cyclic Charging BOOLEAN 1=Charge mode is cyclic charging 9 Reserved BOOLEAN 10 Reserved BOOLEAN 11 Reserved BOOLEAN 12 Reserved BOOLEAN 13 Reserved BOOLEAN 14 Reserved BOOLEAN 15 Reserved BOOLEAN 44370 0x1111 4369 Battery Power 1 UNIT16 0.1 10 kW 44371 0x1112 4370 RESERVED 1 44372 0x1113 4371 Battery Voltage 1 UINT16 0.1 10 Vdc 44373 0x1114 4372 Battery Current, for GVX up to 1000kVA 1 UNIT16 0.1 10 Amps - Caution overflow possible. There is a current limitation [– 3276A, 3276A]. That register can be use for GVX up to 1000KVA. When GVX power rating exceed 1000 kVA (1250KVA and 1500kVA) used register 0x111D 44374 0x1115 4373 RESERVED 1 UINT16 1 1 44375 0x1116 4374 RESERVED 1 UINT16 1 1 44376 0x1117 4375 RESERVED 1 UINT16 1 1 44377 0x1118 4376 RESERVED 1 UINT16 1 1 44378 0x1119 4377 RESERVED 1 UINT16 1 1 44379 0x111A 4378 RESERVED 1 UINT16 1 1 44380 0x111B 4379 RESERVED 1 UINT16 1 1 44381 0x111C 4380 RESERVED 1 UINT16 1 1 Modicon Standard Register Number Absolute Starting Register Address, (Hexa-decimal) Absolute Starting Register Address, (Decimal) Bit Data Point Length # register s Data Type Multiply Reading By: Divide Reading By: Valid Response Scale 44382 0x111D 4381 Battery Current, for all GVX power rating (from 250kVA up to 1500kVA) 1 UNT16 1 1 Amps - Recommended register for GVX. To be used when UPS power rating exceed 1000 kVA. This register supports all GVX power rating (from 250KVA up to 1500kVA). 44383 0x111E 4382 Battery Test Process Status ENUM 0= Inactive 1= Battery Calibration is In Progress 2= Battery Calibration is Passed 5= Battery Calibration is Aborted 44384 0x111F 4383 Battery Calibration Process Status ENUM 0= Inactive 1= Battery Calibration is In Progress 2= Battery Calibration is Passed 5= Battery Calibration is Aborted 44385 0x1120 4384 Battery Test Status ENUM 0= Unknown 1= Battery OK 2= Battery CapacityReduced 3= Battery Defect 44609 0x1200 4608 Frequency (input) 1 UINT16 0.1 10 Hz 44610 0x1201 4609 Voltage L1-2 (input) 1 UINT16 1 1 Volts 44611 0x1202 4610 Voltage L2-3 (input) 1 UINT16 1 1 Volts 44612 0x1203 4611 Voltage L3-1 (input) 1 UINT16 1 1 Volts 44613 0x1204 4612 Current L1 (input) 1 UINT16 1 1 amps 44614 0x1205 4613 Current L2 (input) 1 UINT16 1 1 amps 44615 0x1206 4614 Current L3 (input) 1 UINT16 1 1 amps 44616 0x1207 4615 Active power L1 (input) 1 UINT16 1 1 kW 44617 0x1208 4616 Active power L2 (input) 1 UINT16 1 1 kW 44618 0x1209 4617 Active power L3 (input) 1 UINT16 1 1 kW 44619 0x120A 4618 Apparent power L1 (input) 1 UINT16 1 1 kVA 44620 0x120B 4619 Apparent power L2 (input) 1 UINT16 1 1 kVA 44621 0x120C 4620 Apparent power L3 (input) 1 UINT16 1 1 kVA 44622 0x120D 4621 Total active power (input) 1 UINT16 1 1 kW 44623 0x120E 4622 Total apparent power (input) 1 UINT16 1 1 kVA 44624 0x120F 4623 Voltage L1-N (input) 1 UINT16 1 1 Volts 44625 0x1210 4624 Voltage L2-N (input) 1 UINT16 1 1 Volts 44626 0x1211 4625 Voltage L3-N (input) 1 UINT16 1 1 Volts 44627 0x1212 4626 Maximum RMS Current L1 (input) 2 UINT32 1 1 amps 44629 0x1214 4628 Maximum RMS Current L2 (input) 2 UINT32 1 1 amps 44631 0x1216 4630 Maximum RMS Current L3 (input) 2 UINT32 1 1 amps 44633 0x1218 4632 Power factor L1 (input) 1 UINT16 0.01 100 Unitless 44634 0x1219 4633 Power factor L2 (input) 1 UINT16 0.01 100 Unitless 44635 0x121A 4634 Power factor L3 (input) 1 UINT16 0.01 100 Unitless 44865 0x1300 4864 Frequency (bypass) 1 UINT16 0.1 10 Hz 44866 0x1301 4865 Voltage L1-2 (bypass) 1 UINT16 1 1 Volts 44867 0x1302 4866 Voltage L2-3 (bypass) 1 UINT16 1 1 Volts 44868 0x1303 4867 Voltage L3-1 (bypass) 1 UINT16 1 1 Volts 44869 0x1304 4868 Current L1 (bypass) 1 UINT16 1 1 amps 44870 0x1305 4869 Current L2 (bypass) 1 UINT16 1 1 amps 44871 0x1306 4870 Current L3 (bypass) 1 UINT16 1 1 amps 44872 0x1307 4871 Active power L1 (bypass) 1 UINT16 1 1 kW 44873 0x1308 4872 Active power L2 (bypass) 1 UINT16 1 1 kW 44874 0x1309 4873 Active power L3 (bypass) 1 UINT16 1 1 kW 44875 0x130A 4874 Apparent power L1 (bypass) 1 UINT16 1 1 kVA 44876 0x130B 4875 Apparent power L2 (bypass) 1 UINT16 1 1 kVA 44877 0x130C 4876 Apparent power L3 (bypass) 1 UINT16 1 1 kVA 44878 0x130D 4877 Total active power (bypass) 1 UINT16 1 1 kW 44879 0x130E 4878 Total apparent power (bypass) 1 UINT16 1 1 kVA 44880 0x130F 4879 Voltage L1-N (bypass) 1 UINT16 1 1 Volts 44881 0x1310 4880 Voltage L2-N (bypass) 1 UINT16 1 1 Volts 44882 0x1311 4881 Voltage L3-N (bypass) 1 UINT16 1 1 Volts 44883 0x1312 4882 Maximum RMS Current L1 (bypass) 2 UINT32 1 1 amps 44885 0x1314 4884 Maximum RMS Current L2 (bypass) 2 UINT32 1 1 amps 44887 0x1316 4886 Maximum RMS Current L3 (bypass) 2 UINT32 1 1 amps 44889 0x1318 4888 Power factor L1 (bypass) 1 UINT16 0.01 100 Unitless 44890 0x1319 4889 Power factor L2 (bypass) 1 UINT16 0.01 100 Unitless 44891 0x131A 4890 Power factor L3 (bypass) 1 UINT16 0.01 100 Unitless 44892 0x131B 4891 UTHD - Voltage THD L1 (bypass) 1 UINT16 0.1 10 % 44893 0x131C 4892 UTHD - Voltage THD L2 (bypass) 1 UINT16 0.1 10 % 44894 0x131D 4893 UTHD - Voltage THD L3 (bypass) 1 UINT16 0.1 10 % 45121 0x1400 5120 UPS Power Rating 1 UINT16 1 1 kVA 45122 0x1401 5121 Frequency (output) 1 UINT16 0.1 10 Hz 45123 0x1402 5122 Voltage L1-2 (output) 1 UINT16 1 1 Volts Modicon Standard Register Number Absolute Starting Register Address, (Hexa-decimal) Absolute Starting Register Address, (Decimal) Bit Data Point Length # register s Data Type Multiply Reading By: Divide Reading By: Valid Response Scale 45124 0x1403 5123 Voltage L2-3 (output) 1 UINT16 1 1 Volts 45125 0x1404 5124 Voltage L3-1 (output) 1 UINT16 1 1 Volts 45126 0x1405 5125 Current L1 (output) 1 UINT16 1 1 amps 45127 0x1406 5126 Current L2 (output) 1 UINT16 1 1 amps 45128 0x1407 5127 Current L3 (output) 1 UINT16 1 1 amps 45129 0x1408 5128 Maximum RMS current L1 (output) 2 UINT32 1 1 amps 45131 0x140A 5130 Maximum RMS current L2 (output) 2 UINT32 1 1 amps 45133 0x140C 5132 Maximum

RMS current L3 (output) 2 UINT32 1 1 amps 45135 0x140E 5134 Active power L1 (output) 1 UINT16 1 1 kW 45136 0x140F 5135 Active power L2 (output) 1 UINT16 1 1 kW 45137 0x1410 5136 Active power L3 (output) 1 UINT16 1 1 kW 45138 0x1411 5137 Apparent power L1 (output) 1 UINT16 1 1 kVA 45139 0x1412 5138 Apparent power L2 (output) 1 UINT16 1 1 kVA 45140 0x1413 5139 Apparent power L3 (output) 1 UINT16 1 1 kVA 45141 0x1414 5140 Apparent power percent L1 (output) 1 UINT16 0.1 10 % 45142 0x1415 5141 Apparent power percent L2 (output) 1 UINT16 0.1 10 % 45143 0x1416 5142 Apparent power percent L3 (output) 1 UINT16 0.1 10 % 45144 0x1417 5143 Total active power (output) 1 UINT16 1 1 kW 45145 0x1418 5144 Total apparent power (output) 1 UINT16 1 1 kVA 45146 0x1419 5145 Total Output Percent load 1 UINT16 0.1 10 % 45147 0x141A 5146 Power factor L1 (output) 1 UINT16 0.01 100 power factor 45148 0x141B 5147 Power factor L2 (output) 1 UINT16 0.01 100 power factor 45149 0x141C 5148 Power factor L3 (output) 1 UINT16 0.01 100 power factor 45150 0x141D 5149 Current crest factor L1 (output) 1 UINT16 0.1 10 crest factor 45151 0x141E 5150 Current crest factor L2 (output) 1 UINT16 0.1 10 crest factor 45152 0x141F 5151 Current crest factor L3 (output) 1 UINT16 0.1 10 crest factor 45153 0x1420 5152 Voltage L1-N (output) 1 UINT16 1 1 Volts 45154 0x1421 5153 Voltage L2-N (output) 1 UINT16 1 1 Volts 45155 0x1422 5154 Voltage L3-N (output) 1 UINT16 1 1 Volts 45156 0x1423 5155 Neutral current (output) 1 UINT16 1 1 amps 45157 0x1424 5156 Current THD L1 (output) 1 UINT16 0.1 10 % 45158 0x1425 5157 Current THD L2 (output) 1 UINT16 0.1 10 % 45159 0x1426 5158 Current THD L3 (output) 1 UINT16 0.1 10 % 45160 0x1427 5159 IOC Power Rating 1 UINT16 1 1 kVA 45161 0x1428 5160 Available UPS Power Rating 1 UINT16 1 1 kVA 45376 0x14FF 5375 RESERVED 1 UINT16 1 1 45377 0x1500 5376 IOC Ambient temperature 1 UINT16 1 1 °C or °F 45378 0x1501 5377 Switch gear status 1 Bit mask For each bit, 0 = open, 1 =closed 0 Unit Input Breaker (UIB) BOOLEAN 1 Unit Output Breaker (UOB) BOOLEAN 2 Maintenance Bypass Breaker (MBB) BOOLEAN 3 System Isolation Breaker (SIB) BOOLEAN 4 Static Switch Input Breaker (SSIB) BOOLEAN 5 Battery Breaker 1 (for classic battery solution) BOOLEAN 6 Battery Breaker 2 (for classic battery solution) BOOLEAN 7 Battery Breaker 3 (for classic battery solution) BOOLEAN 8 Battery Breaker 4 (for classic battery solution) BOOLEAN 9 BF2 BOOLEAN 10 Reserved BOOLEAN 11 Reserved BOOLEAN 12 Reserved BOOLEAN 13 Reserved BOOLEAN 14 Reserved BOOLEAN 15 Reserved BOOLEAN Modicon Standard Register Number Absolute Starting Register Address, (Hexa-decimal) Absolute Starting Register Address, (Decimal) Bit Data Point Length # register s Data Type Multiply Reading By: Divide Reading By: Valid Response Scale 45379 0x1502 5378 UPS Operation Mode 1 ENUM 1 = Normal operation 2 = Battery Operation 3 = Battery Test 4 = Requested Static Bypass 5 = Forced Static Bypass 6 = Maintenance Bypass 7 = Off 8 = Emergency Static Bypass 9 = Static Bypass Standby 10 = Inverter Standby 11 = Power Saving Mode 12 = Inverter SPoT Mode 13 = ECO Mode 14 = ECOnversion 45380 0x1503 5379 Number of Active Alarms 1 UINT16 1 1 Number of active alarms in the system 45381 0x1504 5380 Highest alarm severity 1 UINT16 1 1 0 = none 1 = informational 2 = warning 3 = critical 45382 0x1505 5381 System Mode 1 ENUM 1 = Inverter 2 = Requested Static Bypass 3 = Forced Static Bypass 4 = Off 5 = Reserved 6 = Maintenance Bypass 7 = ECO Mode 45383 0x1506 5382 RESERVED 3 45385 0x1508 5384 UPS Redundancy Status 1 UINT16 1 1 45386 0x1509 5385 NMC/UPS Time 4 ASCII hh:mm:ss format 45390 0x150D 5389 NMC/UPS Date 5 ASCII mm/dd/yyyy format 45395 0x1512 5394 Input kWh 2 UINT32 1 1 kWh 45397 0x1514 5396 Output kWh 2 UINT32 1 1 kWh 45399 0x1516 5398 IOC Exhaust Air Temperature 1 UINT16 1 1 °C or °F 45400 0x1517 5399 Ambient Temperature from Power Cabinet [1] 1 UINT16 1 1 °C or °F 45401 0x1518 5400 Exhaust Temperature from Power Cabinet [1] 1 UINT16 1 1 °C or °F 45402 0x1519 5401 Ambient Temperature from Power Cabinet [2] 1 UINT16 1 1 °C or °F 45403 0x151A 5402 Exhaust Temperature from Power Cabinet [2] 1 UINT16 1 1 °C or °F 45404 0x151B 5403 Ambient Temperature from Power Cabinet [3] 1 UINT16 1 1 °C or °F 45405 0x151C 5404 Exhaust Temperature from Power Cabinet [3] 1 UINT16 1 1 °C or °F 45406 0x151D 5405 Ambient Temperature from Power Cabinet [4] 1 UINT16 1 1 °C or °F 45407 0x151E 5406 Exhaust Temperature from Power Cabinet [4] 1 UINT16 1 1 °C or °F 45408 0x151F 5407 Ambient Temperature from Power Cabinet [5] 1 UINT16 1 1 °C or °F 45409 0x1520 5408 Exhaust Temperature from Power Cabinet [5] 1 UINT16 1 1 °C or °F 45410 0x1521 5409 Ambient Temperature from Power Cabinet [6] 1 UINT16 1 1 °C or °F 45411 0x1522 5410 Exhaust Temperature from Power Cabinet [6] 1 UINT16 1 1 °C or °F 45412 0x1523 5411 Ambient Temperature from Power Cabinet [7] 1 UINT16 1 1 °C or °F 45413 0x1524 5412 Exhaust Temperature from Power Cabinet [7] 1 UINT16 1 1 °C or °F 45414 0x1525 5413 Power Cabinet Redundancy Status 1 UINT16 1 1 0 - 7 46401 0x1900 6400 Current L1 (parallel system mains input) 1 UINT16 1 1 amps 46402 0x1901 6401 Current L2 (parallel system mains input) 1 UINT16 1 1 amps 46403 0x1902 6402 Current L3 (parallel system mains input) 1 UINT16 1 1 amps 46404 0x1903 6403 Current L1 (parallel system bypass input) 1 UINT16 1 1 amps 46405 0x1904 6404 Current L2 (parallel system bypass input) 1 UINT16 1 1 amps 46406 0x1905 6405 Current L3 (parallel system bypass input) 1 UINT16 1 1 amps 46407 0x1906 6406 Current L1 (parallel system output) 1 UINT16 1 1 amps 46408 0x1907 6407 Current L2 (parallel system output) 1 UINT16 1 1 amps 46409 0x1908 6408 Current L3 (parallel system output) 1 UINT16 1 1 amps 46410 0x1909 6409 Total apparent power (parallel system output) 1 UINT16 1 1 kVA 46411 0x190A 6410 Total Percent load (parallel system) 1 UINT16 0.1 10 % 46412 0x190B 6411 Total active power (parallel system output) 1 UINT16 1 1 kW 46413 0x190C 6412 Apparent power percent L1 (parallel system output) 1 UINT16 0.1 10 % 46414 0x190D 6413 Apparent power percent L2 (parallel system output) 1 UINT16 0.1 10 % 46415 0x190E 6414 Apparent power percent L3 (parallel system output) 1 UINT16 0.1 10 % 46416 0x190F 6415 Reserved 46417 0x1910 6416 Reserved 46418 0x1911 6417 Reserved 46419 0x1912 6418 Reserved 46420 0x1913 6419 UPS Operation Modes 1 bit = 1, define current UPS operation mode Modicon Standard Register Number Absolute Starting Register Address, (Hexa-decimal) Absolute Starting Register Address, (Decimal) Bit Data Point Length # register s Data Type Multiply Reading By: Divide Reading By: Valid Response Scale 0 Initialize BOOLEAN 1 Normal Operation BOOLEAN 2 Battery Operation BOOLEAN 3 Battery test or Battery Discharge in Spot Mode BOOLEAN 4 Requested Static Bypass BOOLEAN 5 Forced Static Bypass BOOLEAN 6 Maintenance Bypass BOOLEAN 7 Off BOOLEAN 8 Emergency Static Bypass BOOLEAN 9 Static Bypass Standby BOOLEAN 10 Inverter standby BOOLEAN 11 Power Saving mode BOOLEAN 12 Inverter SPoT Mode BOOLEAN 13 ECO mode BOOLEAN 14 ECOnvertion Mode mode BOOLEAN 15 Charger SPoT Mode BOOLEAN 46421 0x1914 6420 System Mode 1 bit = 1, define current System mode 0 Inverter BOOLEAN 1 Requested Static Bypass BOOLEAN 2 Forced Static Bypass BOOLEAN 3 Off BOOLEAN 4 Maintenance Bypass BOOLEAN 5 ECO mode BOOLEAN 6 ECOnversion mode BOOLEAN 7 Static Bypass Standby Operation BOOLEAN 8 Reserved BOOLEAN 9 Reserved BOOLEAN 10 Reserved BOOLEAN 11 Reserved BOOLEAN 12 Reserved BOOLEAN 13 Reserved BOOLEAN 14 Reserved BOOLEAN 15 Reserved BOOLEAN 46422 0x1915 6421 Reserved 1 UINT16 1 1 46423 0x1916 6422 Reserved 1 UINT16 1 1 46424 0x1917 6423 Reserved 1 UINT16 1 1 46425 0x1918 6424 Reserved 1 UINT16 1 1 46426 0x1919 6425 Reserved 1 UINT16 1 1 46427 0x191A 6426 Reserved 1 UINT16 1 1 46428 0x191B 6427 Reserved 1 UINT16 1 1 46429 0x191C 6428 Reserved 1 UINT16 1 1 46430 0x191D 6429 Reserved 1 UINT16 1 1 46431 0x191E 6430 Sensor temperature in sensor 1 1 UINT16 0.1 10 °C or °F 46432 0x191F 6431 Sensor temperature in sensor 2 1 UINT16 0.1 10 °C or °F 46433 0x1920 6432 Sensor humidity in sensor 1 1 UINT16 0.1 10 % 46434 0x1921 6433 Sensor humidity in sensor 2 1 UINT16 0.1 10 % 46435 0x1922 6434 Sensor (AP9810) input contact status 1 Bit mask For each bit, 0 = open, 1 =closed 0 Sensor dry contact A in sensor 1 BOOLEAN 1 Sensor dry contact B in sensor 1 BOOLEAN 2 Sensor dry contact A in sensor 2 BOOLEAN 3 Sensor dry contact B in sensor 2 BOOLEAN 4 Reserved BOOLEAN 5 Reserved BOOLEAN 6 Reserved BOOLEAN 7 Reserved BOOLEAN 8 Reserved BOOLEAN 9 Reserved BOOLEAN 10 Reserved BOOLEAN 11 Reserved BOOLEAN 12 Reserved BOOLEAN 13 Reserved BOOLEAN 14 Reserved BOOLEAN 15 Reserved BOOLEAN 46449 0x1930 6448 User interface - Input Pictogram 1 UINT16 1 1 Inoperable (Red) = 4 Ok and operating (Green) = 2 None of the above (Black) = 0 Modicon Standard Register Number Absolute Starting Register Address, (Hexa-decimal) Absolute Starting Register Address, (Decimal) Bit Data Point Length # register s Data Type Multiply Reading By: Divide Reading By: Valid Response Scale 46450 0x1931 6449 User interface - PFC Pictogram 1 UINT16 1 1 Inoperable (Red) = 4 Ok and operating (Green) = 2 None of the above (Black) = 0 46451 0x1932 6450 User interface - Battery Pictogram 1 UINT16 1 1 Inoperable (Red) = 4 Ok and operating (Green) = 2 None of the above (Black) = 0 46452 0x1933 6451 User interface - Inverter Pictogram 1 UINT16 1 1 Inoperable (Red) = 4 Ok and operating (Green) = 2 None of the above (Black) = 0 46453 0x1934 6452 User interface - Output Pictogram 1 UINT16 1 1 Inoperable (Red) = 4 Ok and operating (Green) = 2 None of the above (Black) = 0 46454 0x1935 6453 User interface - Bypass Input Pictogram 1 UINT16 1 1 Inoperable (Red) = 4 Ok and operating (Green) = 2 None of the above (Black) = 0 46455 0x1936 6454 User interface - Static Bypass Pictogram 1 UINT16 1 1 Inoperable (Red) = 4 Ok and operating (Green) = 2 None of the above (Black) = 0 46456 0x1937 6455 Status for mimic animation 1 UINT16 1 1 0 Aggregated Battery circuit breaker status BOOLEAN 0 = open, 1 =closed 1 Reserved BOOLEAN 2 Reserved BOOLEAN 3 Reserved BOOLEAN 4 Reserved BOOLEAN 5 Reserved BOOLEAN 6 Reserved BOOLEAN 7 Reserved BOOLEAN 8 Reserved BOOLEAN 9 Reserved BOOLEAN 10 Reserved BOOLEAN 11 Reserved BOOLEAN 12 Reserved BOOLEAN 13 Reserved BOOLEAN 14 Reserved BOOLEAN 15 Reserved BOOLEAN 46457 0x1938 6456 Power Cabinet status for UPS detailled view animation 1 UINT16 1 1 0 Warning alarm present in Power Cabinet 1 BOOLEAN 1 = warning alarm present in Power Cabinet 1 (Orange) 1 Critical alarm present in Power Cabinet 1 BOOLEAN 1 = critical alarm present Power Cabinet 1 (Red) 2 Warning alarm present in Power Cabinet 2 BOOLEAN 1 = warning alarm present in Power Cabinet 2 (Orange) 3 Critical alarm present in Power Cabinet 2 BOOLEAN 1 = critical alarm present Power Cabinet 2 (Red) 4 Warning alarm present in Power Cabinet 3 BOOLEAN 1 = warning alarm present in Power Cabinet 3 (Orange) 5 Critical alarm present in Power Cabinet 3 BOOLEAN 1 = critical alarm present Power Cabinet 3 (Red) 6 Warning alarm present in Power Cabinet 4 BOOLEAN 1 = warning alarm present in Power Cabinet 4 (Orange) 7 Critical alarm present in Power Cabinet 4 BOOLEAN 1 = critical alarm present Power Cabinet 4 (Red) 8 Warning alarm present in Power Cabinet 5 BOOLEAN 1 = warning alarm present in Power Cabinet 5 (Orange) 9 Critical alarm present in Power Cabinet 5 BOOLEAN 1 = critical alarm present Power Cabinet 5 (Red) 10 Warning alarm present in Power Cabinet 6 BOOLEAN 1 = warning alarm present in Power Cabinet 6 (Orange) 11 Critical alarm present in Power Cabinet 6 BOOLEAN 1 = critical alarm present Power Cabinet 6 (Red) 12 Warning alarm present in Power Cabinet 7 BOOLEAN 1 = warning alarm present in Power Cabinet 7 (Orange) 13 Critical alarm present in Power Cabinet 7 BOOLEAN 1 = critical alarm present Power Cabinet 7 (Red) 14 Reserved BOOLEAN 15 Reserved BOOLEAN 46458 0x1939 6457 Power Cabinet status for UPS detailled view animation 1 UINT16 1 1 0 informational alarm present in Power Cabinet 1 BOOLEAN 1 = informational alarm present in Power Cabinet 1 1 informational alarm present in Power Cabinet 2 BOOLEAN 2 = informational alarm present in Power Cabinet 2 2 informational alarm present in Power Cabinet 3 BOOLEAN 3 = informational alarm present in Power Cabinet 3 3 informational alarm present in Power Cabinet 4 BOOLEAN 4 = informational alarm present in Power Cabinet 4 4 informational alarm present in Power Cabinet 5 BOOLEAN 5 = informational alarm present in Power Cabinet 5 5 informational alarm present in Power Cabinet 6 BOOLEAN 6 = informational alarm present in Power Cabinet 6 6 informational alarm present in Power Cabinet 7 BOOLEAN 7 = informational alarm present in Power Cabinet 7 7 Reserved BOOLEAN 8 Reserved BOOLEAN 9 Reserved BOOLEAN 10 Reserved BOOLEAN 11 Reserved BOOLEAN 12 Reserved BOOLEAN 13 Reserved BOOLEAN Modicon Standard Register Number Absolute Starting Register Address, (Hexa-decimal) Absolute Starting Register Address, (Decimal) Bit Data Point Length # register s Data Type Multiply Reading By: Divide Reading By: Valid Response Scale 14 Reserved BOOLEAN 15 Reserved BOOLEAN Configuratio n Data 48193 0x2000 8192 RESERVED 3 48196 0x2003 8195 RESERVED 1 48198 0x2005 8197 RESERVED 48199 0x2006 8198 RESERVED 48200 0x2007 8199 Breaker settings 1 bit = 1, breaker is present 0 breaker Q1 (UIB) BOOLEAN 1 breaker Q2 (UOB) BOOLEAN 2 Q3 (MBB) BOOLEAN 3 Q4 (SIB) BOOLEAN 4 Q5 (SSIB) BOOLEAN 5 BB1 BOOLEAN 6 BB2 BOOLEAN 7 BB3 BOOLEAN 8 BB4 BOOLEAN 9 BF2 BOOLEAN 10 Reserved BOOLEAN 11 Reserved BOOLEAN 12 Reserved BOOLEAN 13 Reserved BOOLEAN 14 Reserved BOOLEAN 15 Reserved BOOLEAN 48201 0x2008 8200 Temperature unity 1 ENUM 0 = Celcius 1 = Fahrenheit 48202 0x2009 8201 UPS environment settings 1 0 Input transformer presence BOOLEAN bit = 1, transformer is present 1 Output transformer presence BOOLEAN bit = 1, transformer is present 2 AC wiring configuration BOOLEAN bit = 0, input cabling 3 wires bit = 1, input cabling 4 wires 3 UPS mains supply by single input BOOLEAN bit = 1, mains supply input is single 4 UPS mains supply by dual input BOOLEAN bit = 1, mains supply input is dual 5 Reserved BOOLEAN 6 Reserved BOOLEAN 7 Reserved BOOLEAN 8 Reserved BOOLEAN 9 Reserved BOOLEAN 10 Reserved BOOLEAN 11 Reserved BOOLEAN 12 Reserved BOOLEAN 13 Reserved BOOLEAN 14 Reserved BOOLEAN 15 Reserved BOOLEAN 48203 0x200A 8202 SIB breaker label 2 ASCII 4 bytes string = 2 registers, Default value "SIB " 48205 0x200C 8204 UIB breaker label 2 ASCII 4 bytes string = 2 registers, Default value UIB " 48207 0x200E 8206 SSIB breaker label 2 ASCII 4 bytes string = 2 registers, Default value "SSIB" 48209 0x2010 8208 MBB breaker label 2 ASCII 4 bytes string = 2 registers, Default value "MBB " 48211 0x2012 8210 UOB breaker label 2 ASCII 4 bytes string = 2 registers, Default value "UOB " 48213 0x2014 8212 BF2 breaker label 2 ASCII 4 bytes string = 2 registers, Default value "BF2 " 48215 0x2016 8214 BB breaker label 2 ASCII 4 bytes string = 2 registers, Default value "BB " 48217 0x2018 8216 UPS Name 9 ASCII 18 bytes string = 8 registers 48449 0x2100 8448 Low Battery Alarm Threshold 1 UINT16 1 1 Seconds 48450 0x2101 8449 Battery Type 1 ENUM 1 1 0=VRLA 1=Open Cell 2=Lithium-Ion 3=NiCd 6=NiZn 48451 0x2102 8450 Battery Solution 1 ENUM 1 1 0=None 1=Classic 2=NA 3=Unknown 48452 0x2103 8451 Deep Discharge Allowed 1 ENUM 1 1 0=No 1=Yes 48453 0x2104 8452 Total Battery Capacity 1 UINT16 1 1 Ah 48454 0x2105 8453 Reserved 1 UINT16 1 1 48455 0x2106 8454 Number of battery bank for Classical battery 1 UINT16 1 1 Unitless Modicon Standard Register Number Absolute Starting Register Address, (Hexa-decimal) Absolute Starting Register Address, (Decimal) Bit Data Point Length # register s Data Type Multiply Reading By: Divide Reading By: Valid Response Scale 48705 0x2200 8704 Nominal Output Voltage 1 ENUM 1 1 0=380V 1=400V 2=415V 3=480V 4=440V 48706 0x2201 8705 Transfer to Static Bypass Disable 1 ENUM 1 1 0=Disable 1=Enable 48707 0x2202 8706 Reserved 1 ENUM 1 1 48708 0x2203 8707 Automatic Battery Disconnect 1 ENUM 1 1

0=No 1=Yes 48709 0x2204 8708 High Efficiency Mode 1 ENUM 1 1 0=Disable 1=ECO mode 2=ECOnversion 3=ECOnversion Harmonics Compensator 48710 0x2205 8709 Reserved 1 1 1 48711 0x2206 8710 Number of UPS installed in a parallel installation 1 UINT16 48712 0x2207 8711 Number of redundant UPS installed in a parallel installatio 1 UINT16 48713 0x2208 8712 Number of redundant Power Cabinet installed in a UPS 1 UINT16 48714 0x2209 8713 UPSs presence in parallel installation 1 0 UPS 1 presence BOOLEAN bit = 0, UPS 1 not present bit = 1, UPS 1 is present 1 UPS 2 presence BOOLEAN bit = 0, UPS 2 not present bit = 1, UPS 2 is present 2 UPS 3 presence BOOLEAN bit = 0, UPS 3 not present bit = 1, UPS 3 is present 3 UPS 4 presence BOOLEAN bit = 0, UPS 4 not present bit = 1, UPS 4 is present 4 UPS 5 presence BOOLEAN bit = 0, UPS 5 not present bit = 1, UPS 5 is present 5 Reserved BOOLEAN 6 Reserved BOOLEAN 7 Reserved BOOLEAN 8 Reserved BOOLEAN 9 Reserved BOOLEAN 10 Reserved BOOLEAN 11 Reserved BOOLEAN 12 Reserved BOOLEAN 13 Reserved BOOLEAN 14 Reserved BOOLEAN 15 Reserved BOOLEAN 48715 0x220A 8714 Frequency Converter Mode 1 ENUM 1 1 0=Disable 1=Enable 48716 0x220B 8715 Energy Storage Type 1 ENUM 1 1 0=None 1=Battery 2=Flywheel48717 0x220C 8716 Number Power Cabinet on the left of IO Cabinet 1 UINT16 1 1 48718 0x220D 8717 Continuous Overload Mode Setting 1 UINT16 1 1 % Worldwide Customer Support Customer support for this or any other product is available at no charge in any of the following ways: * Visit the Schneider Electric Web site to access documents in the Schneider Electric Knowledge Base and to submit customer support requests. – www.schneider-electric.com (Corporate Headquarters) Connect to localized Schneider Electric Web sites for specific countries, each of which provides customer support information. – www.schneider-electric.com/support/ Global support searching Schneider Electric Knowledge Base and using e-support. * Contact the Schneider Electric Customer Support Center by telephone or e-mail. – Local, country-specific centers: go to www.schneider-electric.com > Support > Operations around the world for contact information. SCHN-01185-V01.01-EN - PEP ECOPASSPORT®- Galaxy VX UPS System Product Environmental Profile Galaxy VX UPS System #Internal ENVPEP2311001_V2 - SCHN-01185-V01.01-EN 2024/4/23 SCHN-01185-V01.01-EN - PEP ECOPASSPORT®- Galaxy VX UPS System 3600 kg Plastics Metals Others 22.70% General information Reference product Galaxy VX 1250kVA, 400V, Start up 5x8 - GVX1250K1250NHS Constituent materials This document provides environmental impact and performance of the product based on Life Cycle Assessment (LCA), from cradle to grave (materials, manufacturing, distribution, installation, use and end of life). Reference product mass including the product, its packaging and additional elements and accessories 4.80% 72.50% Description of the product The Galaxy VX is a scalable, highly efficient 500 - 1500KVA 3 phase Uninterruptible Power Supply (UPS) system that provides seamless power protection for large sized data centers, industrial and facilities applications. Description of the range Galaxy VX UPS System The representative product is 1250 kW rating (5 Power Cabinets) with 1250 kW I/O Cabinet (GVX1250K1250NHS). The environmental impacts of this referenced product are representative of the impacts of the other products of the range which are developed with a similar technology. Meanwhile, environmental details of other kVA ratings are available in supplementary information at the end of this document. Functional unit To protect the load of 1250 kW against input power failure during 15 years and switch to the energy storage system to avoid power outage. Steel - 42% Copper - 16.6% Aluminium - 12.8% Tin - 0.5% Ferrous alloys - 0.3% Brass - 0.3% Electronic components - 16.6% Wood - 3.6% Cardboard - 1.3% Miscellaneous - 0.4% Various - 0.8% PC Polycarbonate - 2.6% UP Polyester - 0.5% PE Polyethylene - 0.5% PA Polyamide - 0.4% Diverse Thermosetting Plastics - 0.4% ABS Acrylonitrile Butadiene Styrene - 0.4% #Internal ENVPEP2311001_V2 - SCHN-01185-V01.01-EN 2024/4/23 SCHN-01185-V01.01-EN - PEP ECOPASSPORT®- Galaxy VX UPS System RoHS compliance REACH compliance Battery Directive compliance End Of Life 76% Use scenario Power consumption conforms to the requirements in PSR0010-ed1.1-EN-2015_10_16_UPS: The referent UPS can operate in 2 modes. It has an average energy efficiency of 95.8% in Double Conversion mode and 98.6% in eConversion mode. Total energy losses are calculated to be 3418454 kWh in Double Conversion and 1047094 kWh in eConversion after 15 years. Geographical representativeness Europe Energy model used [A1 - A3] [A5] [B6] [C1 - C4] Electricity Mix; Production mix; Low voltage; IN Electricity Mix; Production mix; Low voltage; UE-27 Electricity Mix; Production mix; Low voltage; UE-27 Electricity Mix; Production mix; Low voltage; UE-27 Technological representativeness The Modules of Technologies such as material production, manufacturing process and transport technology used in this PEP analysis (LCA- EIME in this case) are Similar and representative of the actual type of technologies used to make the product in production. Environmental impacts Reference service life time 15 years Installation elements The disposal of the packaging materials is accounted for 6% during the installation phase (including transport to disposal). Substance assessment Details of ROHS and REACH substances information are available on the

Schneider-Electric Green Premium website https://www.se.com/ww/en/work/support/green-premium/ Additional environmental information Recyclability potential: Recyclability rate has been calculated based on REEECY'LAB tool developed by Ecosystem, for components/materials not covered by the tool, data from the “ECO’DEEE recyclability and recoverability calculation method” was taken. If no data was found a conservative assumption was used (0% recyclability). Products of this range are designed in conformity with the requirements of the RoHS directive (European Directive 2011/65/EU of 8 June 2011) on restriction of lead, mercury, cadmium, hexavalent chromium or flame retardants -PBB&PBDE or phthalates-DEHP, BBP, DBP, DIBP. Products of this range are designed in conformity with the requirements of the REACH 1907/2006 regulation and its latest updates. The battery within this product range are designed in conformity with the requirements of the Battery and Accumulator Directive (European Directive 2006/66/EC of 26 September 2006).Average energy efficiency Electricity consumption (kWh over 15 years) Average energy efficiency Electricity consumption (kWh over 15 years) 500 kW with 1250 kW I/O Cabinet 95.6% 1.45E+06 98.6% 4.52E+05 625 kW with 1250 kW I/O Cabinet 95.6% 1.81E+06 98.2% 6.78E+05 750 kW with 1250 kW I/O Cabinet 95.6% 2.17E+06 98.4% 7.51E+05 800 kW with 1250 kW I/O Cabinet 95.7% 2.23E+06 98.3% 8.02E+05 1000 kW with 1250 kW I/O Cabinet 95.8% 2.76E+06 98.6% 8.71E+05 1100 kW with 1250 kW I/O Cabinet 95.9% 2.98E+06 98.6% 9.58E+05 1250 kW with 1250 kW I/O Cabinet 95.8% 3.42E+06 98.6% 1.05E+06 500 kW with 1500 kW I/O Cabinet 96.4% 1.19E+06 99.0% 3.20E+05 750 kW with 1500 kW I/O Cabinet 96.2% 1.90E+06 98.9% 5.05E+05 1000 kW with 1500 kW I/O Cabinet 96.0% 2.65E+06 98.9% 6.73E+05 1250 kW with 1500 kW I/O Cabinet 96.2% 3.20E+06 99.0% 7.60E+05 1500 kW with 1500 kW I/O Cabinet 96.2% 3.84E+06 99.0% 9.12E+05 Type (400V UPS system) Double conversion eConversionAverage energy efficiency Electricity consumption (kWh over 15 years) Average energy efficiency Electricity consumption (kWh over 15 years) 500 kW with 1250 kW I/O Cabinet 95.7% 1.38E+06 98.0% 5.83E+05 625 kW with 1250 kW I/O Cabinet 95.9% 1.61E+06 98.2% 6.78E+05 750 kW with 1250 kW I/O Cabinet 95.9% 1.98E+06 98.4% 7.51E+05 800 kW with 1250 kW I/O Cabinet 95.9% 2.08E+06 98.3% 8.02E+05 1000 kW with 1250 kW I/O Cabinet 96.1% 2.51E+06 98.6% 8.46E+05 1100 kW with 1250 kW I/O Cabinet 96.2% 2.68E+06 98.5% 9.67E+05 1250 kW with 1250 kW I/O Cabinet 96.2% 3.08E+06 98.6% 1.06E+06 500 kW with 1500 kW I/O Cabinet 96.2% 1.23E+06 98.9% 3.20E+05 750 kW with 1500 kW I/O Cabinet 96.3% 1.80E+06 98.9% 5.05E+05 1000 kW with 1500 kW I/O Cabinet 96.3% 2.37E+06 98.9% 6.73E+05 1250 kW with 1500 kW I/O Cabinet 96.4% 2.92E+06 99.0% 7.60E+05 1500 kW with 1500 kW I/O Cabinet 96.3% 3.58E+06 99.0% 9.12E+05 Type (480V UPS system) Double conversion eConversionLoad rate 25% 50% 75% 100% Proportion of time at specified load 0.25 0.5 0.25 0 #Internal ENVPEP2311001_V2 - SCHN-01185-V01.01-EN 2024/4/23 SCHN-01185-V01.01-EN - PEP ECOPASSPORT®- Galaxy VX UPS System Detailed results, including all the optional indicators mentioned in PCRed4, and the split of the Use Phase (B1 to B7), are available in the LCA report and on demand in a digital format - Country Customer Care Center - http://www.schneider-electric.com/contact kg CO2 eq kg CO2 eq kg CO2 eq kg CO2 eq kg CFC-11 eq mol H+ eq kg $(PO4)^{3-}$ eq kg N eq mol N eq kg COVNM eq kg Sb eq MJ m3 eq Additional indicators for the French regulation are available as well MJ MJ MJ MJ MJ MJ kg MJ MJ m^3 Contribution to use of non renewable secondary fuels Contribution to net use of freshwater 0.00E+00 2.56E+03 3.77E+02 1.23E+00 1.76E+00 1.15E+03 1.03E+03 -6.12E+03 0.00E+00 0* 0* 0* 0* 0* Contribution to total use of renewable primary energy resources 6.88E+06 2.29E+04 0* 0* 6.85E+06 0* -9.45E+03 3.68E+07 7.30E+05 1.26E+04 0* 3.57E+07 3.52E+05 -8.62E+06 0.00E+00 0.00E+00 0* 0* 0* 0* 0* 0.00E+00 1.27E+00 1.27E+00 0* 0* 0* 0*Contribution to use of secondary material Contribution to total use of non-renewable primary energy resources Contribution to use of renewable secondary fuels 3.17E+03 -1.91E+05 Contribution to use of renewable primary energy resources used as raw material 3.89E+03 3.89E+03 0* 0* 0* 0* -7.67E+03 Contribution to use of renewable primary energy excluding renewable primary energy used as raw material 6.88E+06 1.90E+04 0* 0* 6.85E+06 Contribution to use of non renewable primary energy resources used as raw material 1.19E+04 1.19E+04 0* 0* 0* 3.17E+03 -1.99E+05 Contribution to use of non renewable primary energy excluding non renewable primary energy used as raw material 3.68E+07 7.18E+05 1.26E+04 0* 3.57E+07 3.52E+05 -8.61E+06 Inventory flows Indicators Galaxy VX UPS System - GVX1250K1250NHS Inventory flows Unit Total Manufact. Distribution Installation Contribution to water use 1.06E+05 1.62E+04 5.26E+01 7.58E+01 4.96E+04 Use End of Life Benefits [A1 - A3] [A4] [A5] [B1 - B7] [C1 - C4] [D] 1.26E-01 -1.07E+02 Contribution to resource use, fossils 3.68E+07 7.30E+05 1.26E+04 0* 3.57E+07 3.52E+05 -8.62E+06 Contribution to resource use, minerals and metals 7.93E+00 7.70E+00 0* 0* 1.02E-01 3.99E+04 -2.63E+05 Contribution to eutrophication marine 1.01E+03 9.22E+01 2.07E+00 1.66E-01 9.08E+02 7.38E+00 -2.70E+02 Contribution to eutrophication, freshwater 8.49E+00 1.77E-01 0* 2.19E-03 3.84E+00 6.43E+01 -3.10E+03 Contribution to photochemical ozone formation - human health 3.26E+03 3.15E+02 7.36E+00 4.29E-01 2.92E+03 1.94E+01 -1.20E+03 Contribution to eutrophication, terrestrial 1.49E+04 1.18E+03 2.25E+01 0* 1.36E+04 1.08E-04 -7.02E-02 Contribution to acidification 8.89E+03 8.50E+02 4.51E+00 0* 8.00E+03 3.55E+01 -5.07E+03 Contribution to ozone depletion 1.99E-02 1.29E-02 9.16E-04 8.90E-06 5.99E-03 4.48E+00 -9.84E-01 Contribution to climate change-fossil 1.50E+06 9.24E+04 1.04E+03 2.89E+02 1.40E+06 6.12E+03 -4.38E+05 Contribution to climate change 1.50E+06 9.31E+04 1.04E+03 2.18E+02 1.40E+06 1.31E+02 -7.38E+03 Contribution to climate change-land use and land use change 2.27E-03 5.00E-05 0* 1.20E-04 0* 2.10E-03 0.00E+00 Contribution to climate change-biogenic 2.60E+03 6.69E+02 0* 0* 1.87E+03 Impact indicators Unit Total Manufacturing Distribution Installation Use End of Life Benefits [A1 - A3] [A4] [A5] [B1 - B7] [C1 - C4] [D] 6.25E+03 -4.46E+05 Mandatory Indicators Galaxy VX UPS System - GVX1250K1250NHS *Net benefits and loads beyond the system boundaries stage (module D): potential for reuse, recovery and/or recycling, expressed as net benefits and impacts. #Internal ENVPEP2311001_V2 - SCHN-01185-V01.01-EN 2024/4/23 SCHN-01185-V01.01-EN - PEP ECOPASSPORT®- Galaxy VX UPS System kg kg kg kg kg kg MJ kg de C kg de C Referent product 500 625 750 800 1000 1100 1250 500 750 1000 1250 1500 1 1 1 1 1 1 1 1 1 1 1 1 2 3 3 4 4 5 5 2 3 4 5 6 1920 2480 2480 3040 3040 3600 3600 2180 2740 3300 3860 4420 6.37E+05 8.00E+05 9.48E+05 9.86E+05 1.20E+06 1.31E+06 1.50E+06 5.42E+05 8.46E+05 1.17E+06 1.41E+06 1.68E+06 8.86E-03 1.15E-02 1.21E-02 1.42E-02 1.52E-02 1.76E-02 1.99E-02 9.37E-03 1.26E-02 1.59E-02 1.89E-02 2.21E-02 3.79E+03 4.76E+03 5.61E+03 5.87E+03 7.12E+03 7.76E+03 8.89E+03 3.26E+03 5.05E+03 6.93E+03 8.34E+03 9.97E+03 3.74E+00 4.82E+00 5.23E+00 5.96E+00 6.56E+00 7.48E+00 8.49E+00 3.78E+00 5.25E+00 6.76E+00 8.05E+00 9.44E+00 4.30E+02 5.41E+02 6.37E+02 6.68E+02 8.09E+02 8.83E+02 1.01E+03 3.71E+02 5.74E+02 7.88E+02 9.49E+02 1.13E+03 6.35E+03 7.98E+03 9.42E+03 9.84E+03 1.20E+04 1.30E+04 1.49E+04 5.44E+03 8.45E+03 1.16E+04 1.40E+04 1.67E+04 1.39E+03 1.75E+03 2.05E+03 2.15E+03 2.61E+03 2.85E+03 3.26E+03 1.20E+03 1.85E+03 2.54E+03 3.06E+03 3.66E+03 3.61E+00 4.75E+00 4.76E+00 5.90E+00 5.91E+00 7.05E+00 7.93E+00 4.14E+00 5.29E+00 6.44E+00 7.59E+00 8.74E+00 1.85E+07 2.32E+07 2.77E+07 2.86E+07 3.52E+07 3.81E+07 3.68E+07 1.55E+07 2.44E+07 3.39E+07 4.09E+07 4.91E+07 4.66E+04 6.00E+04 6.52E+04 7.42E+04 8.19E+04 9.33E+04 1.06E+05 4.68E+04 6.52E+04 8.42E+04 1.00E+05 1.18E+05 2.29E+05 3.36E+05 3.66E+05 4.01E+05 4.29E+05 4.79E+05 5.26E+05 1.83E+05 2.72E+05 3.55E+05 4.04E+05 4.80E+05 500 625 750 800 1000 1100 1250 500 750 1000 1250 1500 1 1 1 1 1 1 1 1 1 1 1 1 2 3 3 4 4 5 5 2 3 4 5 6 1920 2480 2480 3040 3040 3600 3600 2180 2740 3300 3860 4420 6.09E+05 7.18E+05 8.72E+05 9.27E+05 1.10E+06 1.19E+06 1.35E+06 5.57E+05 8.03E+05 1.05E+06 1.29E+06 1.58E+06 8.74E-03 1.12E-02 1.18E-02 1.40E-02 1.47E-02 1.71E-02 1.78E-02 9.44E-03 1.24E-02 1.55E-02 1.84E-02 2.16E-02 3.62E+03 4.29E+03 5.17E+03 5.53E+03 6.54E+03 7.07E+03 7.99E+03 3.35E+03 4.80E+03 6.28E+03 7.67E+03 9.37E+03 3.66E+00 4.60E+00 5.02E+00 5.80E+00 6.29E+00 7.15E+00 7.59E+00 3.82E+00 5.13E+00 6.45E+00 7.73E+00 9.15E+00 4.12E+02 4.88E+02 5.88E+02 6.29E+02 7.44E+02 8.03E+02 9.09E+02 3.81E+02 5.46E+02 7.13E+02 8.72E+02 1.06E+03 6.07E+03 7.18E+03 8.68E+03 9.26E+03 1.10E+04 1.18E+04 1.34E+04 5.58E+03 8.03E+03 1.05E+04 1.29E+04 1.57E+04 1.33E+03 1.58E+03 1.90E+03 2.03E+03 2.40E+03 2.59E+03 2.93E+03 1.23E+03 1.76E+03 2.30E+03 2.81E+03 3.43E+03 Contribution to hazardous waste disposed Contribution to radioactive waste disposed Contribution to non hazardous waste disposed 0* 0.00E+00 * represents less than 0.01% of the total life cycle of the reference flow Life cycle assessment performed with EIME version v5.9.4, database version 2022-01 in compliance with ISO14044. Detailed results, including all the optional indicators mentioned in PCRed4, and the split of the Use Phase (B1 to B7), are available in the LCA report and on demand in a digital format - Country Customer Care Center - http://www.schneider-electric.com/contact ** Net benefits and loads beyond the system boundaries stage (module D): potential for reuse, recovery and/or recycling, expressed as net benefits and impacts. Not accounted in the Total. Environmental indicators- 'Total' of Life Cycle Phases (UPS in eConversion mode) Contribution to climate change (kg CO2 eq) 480V UPS system Galaxy VX UPS (kVA) with 1250 kW I/O Cabinet Galaxy VX UPS (kVA) with 1500 kW I/O Cabinet Product type Product information I/O Cabinet Power Cabinets (250 kW/3U) Weight with Packaging (kg) Compulsory environmental indicators - 'Total' of Life Cycle Phases (UPS in Double conversion mode) Contribution to materials for energy recovery 4.30E-07 4.30E-07 0* 0* 0* 0* 0.00E+00 Please note that the values given above are only valid within the context specified and cannot be used directly to draw up the environmental assessment of an installation. Extrapolated data 400V UPS system Galaxy VX UPS (kVA) with 1250 kW I/O Cabinet Galaxy VX UPS (kVA) with 1500 kW I/O Cabinet Product type Product information I/O Cabinet Power Cabinets (250 kW/3U) Weight with Packaging (kg) 0* 0.00E+00 Contribution to biogenic carbon content of the product 0.00E+00 0* 0* 0* 0* 0* 0.00E+00 Contribution to exported energy 9.26E+01

8.71E+00 0* 8.39E+01 0* Contribution to biogenic carbon content of the associated packaging 0.00E+00 0* 0* 0* 0* -2.72E+02 Contribution to components for reuse 0.00E+00 0* 0* 0* 0* 0* 0.00E+00 8.72E+01 4.47E+01 2.06E-01 4.74E-02 4.22E+01 3.11E-02 2.66E+03 0.00E+00Contribution to materials for recycling 2.78E+03 2.87E+00 0* 1.18E+02 0* -8.73E+06 2.33E+05 3.07E+04 0* 4.30E+02 2.02E+05 1.86E+02 -4.45E+05 3.04E+05 2.75E+05 0* 0* 2.62E+04 3.11E+03 Contribution to climate change (kg CO2 eq) Contribution to Ozone depletion (kg CFC11 eq) Contribution to Acidification (mol H+ eq) Contribution to eutrophication, freshwater (kg PO43- eq) Contribution to eutrophication marine (kg N eq) Contribution to eutrophication, terrestrial (mol N eq) Contribution to photochemical ozone formation - human health (kg COVNM eq) Contribution to resource use, minerals and metals (kgSbeq) Total use of primary energy (MJ) Contribution to water use (m3 eq) Compulsory environmental indicators - 'Total' of Life Cycle Phases (UPS in Double conversion mode) Contribution to climate change (kg CO2 eq) Contribution to Ozone depletion (kg CFC11 eq) Contribution to Acidification (mol H+ eq) Contribution to eutrophication, freshwater (kg PO43- eq) Contribution to eutrophication marine (kg N eq) Contribution to eutrophication, terrestrial (mol N eq) Contribution to photochemical ozone formation - human health (kg COVNM eq) #Internal ENVPEP2311001_V2 - SCHN-01185-V01.01-EN 2024/4/23 SCHN-01185-V01.01-EN - PEP ECOPASSPORT®- Galaxy VX UPS System 3.61E+00 4.74E+00 4.76E+00 5.89E+00 5.90E+00 7.04E+00 7.05E+00 4.14E+00 5.29E+00 6.44E+00 7.58E+00 8.74E+00 1.76E+07 2.07E+07 2.54E+07 2.68E+07 3.21E+07 3.44E+07 3.93E+07 1.59E+07 2.31E+07 3.05E+07 3.74E+07 4.59E+07 4.56E+04 5.71E+04 6.25E+04 7.21E+04 7.83E+04 8.90E+04 9.47E+04 4.73E+04 6.37E+04 8.02E+04 9.62E+04 1.14E+05 2.83E+05 3.36E+05 3.66E+05 4.01E+05 4.19E+05 4.83E+05 5.20E+05 1.83E+05 2.72E+05 3.55E+05 4.05E+05 4.81E+05 Internal External 5 years 2024/4/23 CS 30323 F- 92500 Rueil Malmaison Cedex RCS Nanterre 954 503 439 Capital social 896 313 776 € www.se.com Published by Schneider Electric Schneider Electric Industries SAS Country Customer Care Center http://www.schneider-electric.com/contact 35, rue Joseph Monier ©2023 - Schneider Electric – All rights reserved Independent verification of the declaration and data, in compliance with ISO 14025 : 2010 X The PCR review was conducted by a panel of experts chaired by Julie ORGELET (DDemain) PEP are compliant with XP C08-100-1 :2016 or EN 50693:2019 The elements of the present PEP cannot be compared with elements from another program. Document in compliance with ISO 14025 : 2010 « Environmental labels and declarations. Type III environmental declarations » Date of issue 2024/4/23 Information and reference documents Registration number : SCHN-01185-V01.01-EN Drafting rules PEP-PCR-ed4-2021 09 06 Verifier accreditation N° VH08 Supplemented by www.pep-ecopassport.org Validity period PSR-0010-ed1.1-2015 10 16 Environmental indicators- 'Total' of Life Cycle Phases (UPS in eConversion mode) Contribution to climate change (kg CO2 eq) Other Additional information Operating the Galaxy VX in eConversion mode results in significantly reduced environmental impact, in particular Carbon emissions (up to 65% reduction) compared to operation in Double Conversion mode. This is mainly due to an improved energy efficiency in eConversion of 98.6% (average) compared to an efficiency of 95.8% (average) in Double Conversion mode. For details about eConversion, consult the Schneider-Electric eConversion page: https://www.se.com/ww/en/work/products/product-launch/econversion-high-efficiency-ups- mode/ Compulsory environmental indicators - 'Total' of Life Cycle Phases (UPS in Double conversion mode) Contribution to resource use, minerals and metals (kgSbeq) Total use of primary energy (MJ) Contribution to water use (m3 eq) #Internal ENVPEP2311001_V2 - SCHN-01185-V01.01-EN 2024/4/23 No reply 12:32 PM (7 minutes ago) to me Dear Tshingombe fiston, Please find your configuration My Configuration created with the Modicon PLC Configurator application. Your configuration ID: 08b93f14-4d65-41cf-9f4a-a8d9670e17e7 Bill of Material Build No Reference Description Quantity 1 EALBTP23 licence, Ecostruxure Automation Expert, standard engineering buildtime, v23 1 2 EALBFP23 license, EcoStruxure Automation Expert, professional engineering, buildtime, v23 1 Run No Reference Description Quantity 3 EALDSP license, EcoStruxure Automation Expert, standard device runtime, add on, v23 6 4 EALDHP license, EcoStruxure Automation Expert, high availability option, runtime, add on, v23 7 5 EALADP license, EcoStruxure Automation Expert, run time, application, permanent, 1 user, for ATV dPac 1 6 EALAMP license, EcoStruxure Automation Expert, run time, application, permanent, 1 user, for M251, M262 dPAC 2 7 EALASP license, EcoStruxure Automation Expert, run time, application, permanent, 1 user, for M580 dPAC 1 8 EALALP license, EcoStruxure Automation Expert, run time, application, permannet, 1 user, for M580 dPAC with extensions 1 Run Add-on No Reference Description Quantity 9 EALH1P license, EcoStruxure Automation Expert, run time, HMI, permanent, 1 user, for Harmony ST6 1 10 EALH2P license, EcoStruxure Automation Expert, run time, HMI, permanent, 1 user, for Harmony iPC 1 Service plan No Reference Description Quantity 11 ECAUTESEAE Service plan for EcoStruxure Automation Expert - Essential 294 ... Software license configurator 1. Software selectionDone License selectorDone 3. Finalize and shareDone Bill of materials My Configuration Verification No Reference Description Quantity 1 CEGVER01AN license, EcoStruxure Control Engineering, verification, basic, node locked, 1 shot 1 Documentation No Reference Description Quantity 2 CEGDOC01AN license, EcoStruxure Control Engineering, documentation, basic, node locked, 1 shot 1 Software license configurator 1. Software selectionDone License selectorDone Service plansDone 4. Finalize and shareDone Bill of materials My Configuration Regular No Reference Description Quantity 1 CEXSPUCZSSPAZZ Control Expert S single e-licence 1 2 CEXSPMCZXTPAZZ License, EcoStruxure Control Expert, Topology Manager & M580 safety add-on for XL, team floating (10 users), digital 1 Service plan No Reference Description Service plan size 3 ECAUTESECE Service plan for EcoStruxure Control Expert - Essential 283 Your configuration has been saved! Copy the configuration ID to your clipboard Send by email Add to my project Export (1) Export the bill of material in XLS .xls Documentation (2) Product Data Sheet .zip Catalog Configuration Name : My Configuration Configuration ID : f9d295b2-90b2-4164-b665-04551a1f2f54 Date : Sun Mar 09 10:52:15 UTC 2025 Operation Server No Reference Description Quantity 1 EUSOPECZZSPEZZ SW PE OPER SERVER LIC 6 Operation Client No Reference Description Quantity 2 EUSLCCCZZSPEZZ SW PE CTRL CLIENT LIC 1 3 EUSVCCCZZSPEZZ SW PE VIEW CLIENT LIC 1 4 EUSLRCCZZSPEZZ SW PE RED CTRL CLIENT LIC 1 5 EUSVRCCZZSPEZZ SW PE RED VIEW CLIENT LIC 1 Service plan No Reference Description Quantity 6 ECAUTESEPE Service plan for EPE - Essential 608 Product Selector Tool This tool is designed to assist you through the product selection process. Try our Product Selector Content Training Installed Base Programs Overview Product Configurators PLC Your products have been added to a New Project/BOM View BOM Select your location Tshingombe fiston Software license configurator 1. Software selectionDone License selectorDone Service plansDone 4. Finalize and shareDone Bill of materials Perpetual My Configuration Design & Build No Reference Description Quantity 1 EALBTP23 licence, Ecostruxure Automation Expert, standard engineering buildtime, v23 1 2 EALBFP23 license, EcoStruxure Automation Expert, professional engineering, buildtime, v23 1 Operate & Maintain No Reference Description Quantity 3 EALDSP license, EcoStruxure Automation Expert, standard device runtime, add on, v23 6 4 EALDHP license, EcoStruxure Automation Expert, high availability option, runtime, add on, v23 7 5 EALADP license, EcoStruxure Automation Expert, run time, application, permanent, 1 user, for ATV dPac 1 6 EALAMP license, EcoStruxure Automation Expert, run time, application, permanent, 1 user, for M251, M262 dPAC 2 7 EALASP license, EcoStruxure Automation Expert, run time, application, permanent, 1 user, for M580 dPAC 1 8 EALALP license, EcoStruxure Automation Expert, run time, application, permannet, 1 user, for M580 dPAC with extensions 1 Run Add-on No Reference Description Quantity 9 EALH1P license, EcoStruxure Automation Expert, run time, HMI, permanent, 1 user, for Harmony ST6 1 10 EALH2P license, EcoStruxure Automation Expert, run time, HMI, permanent, 1 user, for Harmony iPC 1 Service plan No Reference Description Service plan size 11 ECAUTESEAE Service plan for EcoStruxure Automation Expert - Essential 294 Your configuration has been saved! Copy the configuration ID to your clipboard Send by email Add to my project Export (1) Export the bill of material in XLS .xls Documentation (2) Product Data Sheet .zip Catalog pdf Feedback Back Go to start page Back Go to start page mySchneider Terms of Use Privacy Policy Cookie Notice Change your cookie settings ©2025, Schneider Electric mySchneider Design & Build;;; No;Reference;Description;Quantity 1;EALBTP23;licence Ecostruxure Automation Expert standard engineering buildtime v23;1 2;EALBFP23;license EcoStruxure Automation Expert professional engineering buildtime v23;1 Operate & Maintain;;; No;Reference;Description;Quantity 3;EALDSP;license EcoStruxure Automation Expert standard device runtime add on v23;6 4;EALDHP;license EcoStruxure Automation Expert high availability option runtime add on v23;7 5;EALADP;license EcoStruxure Automation Expert run time application permanent 1 user for ATV dPac;1 6;EALAMP;license EcoStruxure Automation Expert run time application permanent 1 user for M251 M262 dPAC;2 7;EALASP;license EcoStruxure Automation Expert run time application permanent 1 user for M580 dPAC;1 8;EALALP;license EcoStruxure Automation Expert run time application permannet 1 user for M580 dPAC with extensions;1 Run Add-on;;; No;Reference;Description;Quantity 9;EALH1P;license EcoStruxure Automation Expert run time HMI permanent 1 user for Harmony ST6;1 10;EALH2P;license EcoStruxure Automation Expert run time HMI permanent 1 user for Harmony iPC;1 Service plan;;; No;Reference;Description;Quantity 11;ECAUTESEAE;Service plan for EcoStruxure Automation Expert - Essential;294 Direct Starter EcoStruxure™ Motor Control Configurator 1. Voltage440 V Motor detailsIE3-55 kW AdjustDone OptionsDone 5. Save & ShareDone My Configuration Technology: direct starter Supply Voltage: 440 V Standard: IEC (kW) Motor power: 55 kW Coordination type: Coordination type 1 Number of product: 2 products Range: 664 Starter type: Direct

Online PLC Control: no Breaking performance Iq: 50 kA Coil Type: Standard Coil voltage: 230 V AC - 50/60 Hz Power terminal connection: Screw Clamp Motor efficiency class: IE3 Breaker GV4P115N Motor circuit breaker, TeSys GV4, 3P, 115A, Icu 50kA, thermal magnetic, Everlink terminals Accessories GV4AE11 Auxiliary contact, TeSys GV4, 690VAC, 1 NO/NC GV4AE11 Auxiliary contact, TeSys GV4, 690VAC, 1 NO/ NC Contactor LC1D115P7 Contactor, TeSys Deca, 3P(3NO), AC-3/AC-3e, Show options (2) Contactor LC1D115P7 Contactor, TeSys Deca, 3P(3NO), AC-3/AC-3e, Show options (1) Your configuration has been saved! Copy the configuration ID to your clipboard dc5b40a4-bb0a-4e45-b277-b7fa55863d6a Please find a summary of Energy Savings delivered for Drive instead of a fixed speed solution This data is to be considered with assemption Export (2) Print Export Bill of Material (.xls) .xls Documentation (6) Product Data Sheet Bill of Material - My Configuration - 6b546e9d-8a2e-424f-af3c-939ea886fdcd - Schneider Electric Inbox No reply 12:45 PM (14 minutes ago) to me Dear Tshingombe fiston, Please find your configuration My Configuration created with the Modicon PLC Configurator application. Your configuration ID: 6b546e9d-8a2e-424f-af3c-939ea886fdcd Bill of Material Verification No Reference Description Quantity 1 CEGVER01AN license, EcoStruxure Control Engineering, verification, basic, node locked, 1 shot 1 Documentation No Reference Description Quantity 2 CEGDOC01AN license, EcoStruxure Control Engineering, documentation, basic, node locked, 1 shot 1 Service plan No Reference Description Quantity ... [Message clipped] View entire message Bill of Material - My Configuration - 577e9790-a49e-4c0c-9307-f56f18a5ab60 - Schneider Electric Inbox No reply 12:50 PM (10 minutes ago) to me Dear Tshingombe fiston, Please find your configuration My Configuration created with the Modicon PLC Configurator application. Your configuration ID: 577e9790-a49e-4c0c-9307-f56f18a5ab60 Bill of Material Regular No Reference Description Quantity 1 CEXSPUCZSSPAZZ License, EcoStruxure Control Expert, service pack base, small S, 1 user, node locked, digital license 1 2 CEXSPMCZXTPAZZ License, EcoStruxure Control Expert, with Topology Manager and M580 safety, for XL, node locked, 10 users, digital 1 Service plan No Reference Description Quantity 3 ECAUTESECE Service plan for EcoStruxure Control Expert - Essential 283 ... [Message clipped] View entire message Bill of Material - My Configuration - f9d295b2-90b2-4164-b665-04551a1f2f54 - Schneider Electric Inbox No reply 12:54 PM (6 minutes ago) to me Dear Tshingombe fiston, Please find your configuration My Configuration created with the Modicon PLC Configurator application. Your configuration ID: f9d295b2-90b2-4164-b665-04551a1f2f54 Bill of Material Operation Server No Reference Description Quantity 1 EUSOPECZZSPEZZ SW PE OPER SERVER LIC 6 Operation Client No Reference Description Quantity 2 EUSLCCCZZSPEZZ SW PE CTRL CLIENT LIC 1 3 EUSVCCCZZSPEZZ SW PE VIEW CLIENT LIC 1 4 EUSLRCCZZSPEZZ SW PE RED CTRL CLIENT LIC 1 5 EUSVRCCZZSPEZZ SW PE RED VIEW CLIENT LIC 1 Service plan No Reference Description Quantity 6 ECAUTESEPE Service plan for EPE - Essential 608 ... Bill of Material - My Configuration - dc5b40a4-bb0a-4e45-b277-b7fa55863d6a - Schneider Electric Inbox tshingombe tshitadi 12:58 PM (2 minutes ago) to me Dear tshingombe tshitadi, Please find your configuration created from: EcoStruxureTM Motor Control Configurator Configuration link: My Configuration Your configuration ID: dc5b40a4-bb0a-4e45-b277-b7fa55863d6a Motor Starter parameters selected Technology: Direct Start Standard: IEC Supply Voltage: 440 V V Motor Power: 55 kW Motor efficiency class: IE3 Breaker Breaking performance Iq: 50 kA Contactor Coil voltage: 230 V AC - 50/60 Hz Power terminal connection: Screw Clamp Coil Type: Standard Bill of Material Devices Options Description Quantity: Breaker GV4P115N Motor circuit breaker, TeSys GV4, 3P, 115A, Icu 50kA, thermal magnetic, Everlink terminals 1 GV4AE11 Auxiliary contact, TeSys GV4, 690VAC, 1 NO/NC Auxiliary Contact Block > Front Function Sd > 1 NO + 1 NC - SD function 1 GV4AE11 Auxiliary contact, TeSys GV4, 690VAC, 1 NO/NC Auxiliary Contact Block > Front Function On/off > 1 NO + 1 NC - OF function 1 Contactor LC1D115P7 Contactor, TeSys Deca, 3P(3NO), AC-3/AC-3e, Front Clip Position 1 > 10180 s - 1 NO + 1 NC 1 LX1D8P7 Spareparts Voltage440 V Motor detailsIE3-55 kW AdjustDone OptionsDone 1. Save & ShareDone My Configuration Technology: soft starter Supply Voltage: 440 V Standard: IEC (kW) Motor power: 132 kW Segment and process: Machine Manufacturing Application: Standard Machines Service duty: Normal duty Coordination type: Coordination type 1 Range: 5745 Communication module: Modbus SL (embedded) Motor Softstarter connection: In line Integrated bypass: yes With trip unit: yes Breaking capacity: 50 kA Coil Type: without coil Breaker C40H31M320 Circuit breaker, ComPacT NSX400H, 70kA/415VAC, 3 poles, MicroLogic 1.3M trip unit 320A Contactor LC1F265 Contactor body,TeSys F,3P(3NO)-AC-3, <=440V 265A without coil Accessories LADN01 Auxiliary contact block, TeSys Deca, 1NC, front mounting, screw clamp terminals LADN11 Auxiliary contact block, TeSys Deca, 1NO+1NC, front mounting, screw clamp terminals LADN13 Auxiliary contact block, TeSys Deca, 1NO+3NC, front mounting, screw clamp terminals Soft starter ATS22C25Q soft starter for asynchronous motor, Altistart 22, control 230V, 230 to 440V, 75 to 132kW My Configuration ZA Add to My

Products Technology: soft starter Supply Voltage: 440 V Standard: IEC (kW) Motor power: 132 kW Segment and process: Machine Manufacturing Application: Standard Machines Service duty: Normal duty Coordination type: Coordination type 1 Range: 5745 Communication module: Modbus SL (embedded) Motor Softstarter connection: In line Integrated bypass: yes With trip unit: yes Breaking capacity: 50 kA Coil Type: without coil Breaker C40H31M320 Circuit breaker, ComPacT NSX400H, 70kA/415VAC, 3 poles, MicroLogic 1.3M trip unit 320A Contactor LC1F265 Contactor body,TeSys F,3P(3NO)-AC-3, Show options (3) Soft starter ATS22C25Q soft starter for asynchronous motor, Altistart 22, control 230V, 230 to 440V, 75 to 132kW Your configuration has been saved! Copy the configuration ID to your clipboard 98d8730c-cef0-4fd3-8fbe-b6f8b3c1d66b Please find a summary of Energy Savings delivered for Drive instead of a fixed speed solution This data is to be considered with assemption Export (2) Print Export Bill of Material (.xls) .xls Documentation (6) Product Data Sheet .zip Variable Speed Drive EcoStruxure™ Motor Control Configurator My Configuration Technology: variable speed drive Supply Voltage: 480 V Standard: IEC (kW) Motor power: 132 kW Segment and process: Machine Manufacturing Application: Standard Machines Service duty: Heavy duty Range: 63124 Communication module: Modbus SL Installation type: wall mounted Protection level: IP21 With braking unit: yes With trip unit: yes Breaking capacity: 50 kA Coil Type: without coil Breaker C40H31M320 Circuit breaker, ComPacT NSX400H, 70kA/415VAC, 3 poles, MicroLogic 1.3M trip unit 320A Accessories 29452 Low level auxiliary contact, circuit breaker status OF/SD/SDE/SDV, 1 changeover contact type 29452 Low level auxiliary contact, circuit breaker status OF/SD/SDE/SDV, 1 changeover contact type 29452 Low level auxiliary contact, circuit breaker status OF/SD/SDE/SDV, 1 changeover contact type Contactor LC1F265 Contactor body,TeSys F,3P(3NO)-AC-3, Show options (3) Contactor LC1F265 Contactor body,TeSys F,3P(3NO)-AC-3, Show options (3) Drive ATV930C16N4 variable speed drive, Altivar Process ATV900, ATV930, 160kW, 380 to 480V, with braking unit, IP20 Your configuration has been saved! Copy the configuration ID to your clipboard 96d5a340-770b-4927-bab7-5c538288d832 This data is to be considered with assemption Export (2) Print Export Bill of Material (.xls) .xls Documentation (6) Product Data Sheet .zip CAD files Modicon PLC 1. HomeDone PLC selectionDone Graphical editorDone Power supplyDone AccessorizeSkipped 6. Finalize and shareDone My Configuration Range Pacdrive LMC Power supply 24 Vdc Field bus protocols EtherNet/IP; Sercos Bill of materials Add to Favorites Controller + I/O No Reference Description Quantity 1 LMC216CAA10000 Motion controller LMC216 16 axis - Acc kit - Basic 1 2 ABL8WPS24200 Regulated switch power supply, modicon power supply, 3 phases, 380 to 500V AC, 24V, 20A 1 3 GV2ME06 Motor circuit breaker, TeSys Deca, 3P, 1 to 1.6A, thermal magnetic, screw clamp terminals, button control 1 4 ABL8BBU24200 battery control module, phaseo ABL7 ABL8, 24 to 28.8V DC, phaseo ABL7 ABL8, 24V, 20A, for regulated SMPS 1 5 ABL8BBU24400 battery control module, phaseo ABL7 ABL8, 24 to 28.8V DC, phaseo ABL7 ABL8, 24V, 40A, for regulated SMPS 1 6 BVS480XDPDR Easy UPS control module, 24V DC-DC, DIN Rail, Industrial, 20A 1 7 XB005XPDR Easy UPS battery module, 24V DC-DC, DIN Rail, Industrial, 4.5Ah 1 Your configuration has been saved! Copy the configuration ID to your clipboard Send by email Add to my project Export (5) Export to EcoStruxure Machine Expert .py Export PNG picture .zip Export the bill of material in XLS .xls Export project in PDF .pdf Export architecture in PDF .pdf Documentation (6) Product Data Sheet .zip CAD .zip Instruction Sheet .zip User guide .zip Certificate .zip Catalog .zip Feedback Bill of Material - My Configuration - 98d8730c-cef0-4fd3-8fbe-b6f8b3c1d66b - Schneider Electric Inbox tshingombe 1:09 PM (12 minutes ago) to me Dear tshingombe, Please find your configuration created from: EcoStruxureTM Motor Control Configurator Configuration link: My Configuration Your configuration ID: 98d8730c-cef0-4fd3-8fbe-b6f8b3c1d66b Motor Starter parameters selected Technology: Soft Starter Standard: IEC Supply Voltage: 440 V V Motor Power: 132 kW Segment and Process: Machine Manufacturing Application: Standard machines Heavy Duty selection: no Breaker Breaking capacity: 50 kA With trip unit: yes Contactor Coil voltage: n/a Coil Type: without coil Soft Starter Integrated bypass: yes Bill of Material Devices Options Description Quantity: Breaker C40H31M320 Circuit breaker, ComPacT NSX400H, 70kA/415VAC, 3 poles, MicroLogic 1.3M trip unit 320A 1 LV432513 Spareparts 1 Contactor LC1F265 Contactor body,TeSys F,3P(3NO)-AC-3, Right > 1 NC 1 LADN11 Auxiliary contact block, TeSys Deca, 1NO+1NC, front mounting, screw clamp terminals Auxiliary Contact For Standard Environment > Front Clip Position 1 > 1 NO + 1 NC 1 LADN13 Auxiliary contact block, TeSys Deca, 1NO+3NC, front mounting, screw clamp terminals Auxiliary Contact For Standard Environment > Front Clip Position 1 > 1 NO + 3 NC 1 Soft Starter ATS22C25Q soft starter for asynchronous motor, Altistart 22, control 230V, 230 to 440V, 75 to 132kW 1 Bill of Material - My Configuration - 96d5a340-770b-4927-bab7-5c538288d832 - Schneider Electric Inbox tshingombefiston 1:12 PM (9 minutes ago) to me Dear tshingombefiston, Please find your configuration created from: EcoStruxureTM Motor Control Configurator

Configuration link: My Configuration Your configuration ID: 96d5a340-770b-4927-bab7-5c538288d832 Motor Starter parameters selected Technology: Variable Speed Drive Standard: IEC Supply Voltage: 480 V V Motor Power: 132 kW Segment and Process: Machine Manufacturing Application: Standard machines Heavy Duty selection: no Breaker Breaking capacity: 50 kA With trip unit: yes Contactor Coil voltage: n/a Coil Type: without coil Drive Installation type: wall mounted With braking unit: yes Protection level: IP21 Bill of Material Devices Options Description Quantity: Breaker C40H31M320 Circuit breaker, ComPacT NSX400H, 70kA/415VAC, 3 poles, MicroLogic 1.3M trip unit 320A 1 29452 Low level auxiliary contact, circuit breaker status OF/SD/SDE/SDV, 1 changeover contact type Add-on Auxiliary Contact-low Level > Front Function Sde > SDE function 1 29452 Low level auxiliary contact, circuit breaker status OF/SD/SDE/SDV, 1 changeover contact type Add-on Auxiliary Contact-low Level > Front Function Sd > SD function 1 29452 Low level auxiliary contact, circuit breaker status OF/SD/SDE/SDV, 1 changeover contact type Add-on Auxiliary Contact-low Level > Front Function On/off > ON/OFF 1 LV432513 Spareparts 1 Contactor LC1F265 Contactor body,TeSys F,3P(3NO)-AC-3, Clip On Rail Mounting > 127240 V AC 1 LADT0 Time delay auxiliary contact block, TeSys Deca, 1NO+1NC, on delay 0.3-3s, front, screw clamp terminals Time On Delay > Front Clip Position 1 > 0.13 s - 1 NO + 1 NC 1 LADT2 Time delay contact block,TeSys Deca,1NO+1NC,on-delay 1-30s,front Time On Delay > Front Clip Position 1 > 0.130 s - 1 NO + 1 NC 1 LA5FH431 Spareparts 1 Drive ATV930C16N4 variable speed drive, Altivar Process ATV900, ATV930, 160kW, 380 to 480V, with braking unit, IP20 1 Bill of Material - My Configuration - 36455ef8-f6c2-460a-91c3-15d69cf9452f - Schneider Electric Inbox No reply 1:16 PM (6 minutes ago) to me Dear Tshingombe fiston, Please find your configuration My Configuration created with the Modicon PLC Configurator application. Your configuration ID: 36455ef8-f6c2-460a-91c3-15d69cf9452f Bill of Material Bom level Position Reference Description Quantity My Configuration 1 LMC216CAA10000 Motion controller LMC216 16 axis - Acc kit - Basic 1 My Configuration 2 ABL8WPS24200 Regulated switch power supply, modicon power supply, 3 phases, 380 to 500V AC, 24V, 20A 1 My Configuration 3 GV2ME06 Motor circuit breaker, TeSys Deca, 3P, 1 to 1.6A, thermal magnetic, screw clamp terminals, button control 1 My Configuration 4 ABL8BBU24200 battery control module, phaseo ABL7 ABL8, 24 to 28.8V DC, phaseo ABL7 ABL8, 24V, 20A, for regulated SMPS 1 My Configuration 5 ABL8BBU24400 battery control module, phaseo ABL7 ABL8, 24 to 28.8V DC, phaseo ABL7 ABL8, 24V, 40A, for regulated SMPS 1 My Configuration 6 BVS480XDPDR Easy UPS control module, 24V DC-DC, DIN Rail, Industrial, 20A 1 My Configuration 7 XB005XPDR Easy UPS battery module, 24V DC-DC, DIN Rail, Industrial, 4.5Ah 1 ... Bill of Material - My Configuration - 9988cbd9-4fe8-473c-927f-c3473aaf67af - Schneider Electric Inbox No reply 1:21 PM (1 minute ago) to me Dear Tshingombe fiston, Please find your configuration My Configuration created with the Modicon PLC Configurator application. Your configuration ID: 9988cbd9-4fe8-473c-927f-c3473aaf67af Bill of Material Bom level Position Reference Description Quantity My Configuration 1 TM171ODM22R Controller, Modicon M171/M172/M173, optimized display 22 IO, Modbus 1 My Configuration 2 TM171ACB4OI1M Modicon M171 Optimized LV Connector 1m cable 2 My Configuration 3 TM171ACB4OAO1M Modicon M171 Optimized AO Connector 1m cable 1 My Configuration 4 TM171ACB4OAO2M Modicon M171 Optimized AO Connector 2m cable 1 My Configuration 5 TM171DLED Modicon M171 Optimized Display LED 1 My Configuration 6 TM171DLCD2U Modicon M171 Optimized Display LCD 1 My Configuration 7 TM171DWAL2U Modicon M171 Optimized Wall thermostat without backlight 1 My Configuration 8 TM1STNTCRN52015 NTC 1,5m IP68 5x20 -50+110°C Grey 1 My Configuration 9 TM1STNTCRN5201P NTC 1,5m IP68 5x20 -50+110°C Grey 1 My Configuration 10 TM1STNTCRN52030 NTC 3,0m IP68 5x20 -50+110°C Grey 1 My Configuration 11 TM171VEVA2 EEV Driver, Actuator 1 My Configuration 12 TM171VEVD4 EEV Driver, Autonomous & Hardwired 1 My Configuration 13 TM171VEVM4 EEV Driver, Autonomous & Modbus 1 ... [Message clipped] View entire message www.se.com Catalog | July 2024 Software-defined Automation Software version v24.0 EcoStruxure™ Automation Expert Industrial Automation systems Find your catalog > With just 3 clicks, you can access the Industrial Automation and Control catalogs, in both English and French > Consult digital automation catalogs at Digi-Cat Online Select your training > Find the right Training for your needs on our Global website > Locate the training center with the selector tool, using this link Quick access to product information Get technical information about your product Each commercial reference presented in a catalog contains a hyperlink. Click on it to obtain the technical information of the product: – Characteristics, Dimensions and drawings, Mounting and clearance, Connections and schemas, Performance curves – Product image, Instruction sheet, User guide, Product certifications, End of life manual • Up-to-date catalogs • Embedded product selectors, 360° pictures • Optimized search by commercial references General contents EcoStruxure™ Automation Expert b General presentation v EcoStruxure Automation

Expert... page 2 v Feature overview .... page 3 b Presentation v Software - EcoStruxure Automation Expert engineering .... page 4 - EcoStruxure Automation Expert - HMI .... page 5 - EcoStruxure Automation Expert - Archive .... page 5 - EcoStruxure Automation Expert - AVEVA System Platform integration.. page 5 - EcoStruxure Automation Expert - Libraries .... page 5 - System requirements.. page 9 v Hardware - Software dPAC .... page 10 - Edge Controller..page 11 - Altivar and Modicon dPAC .... page 11 - Selection Guide .... page 14 - Architecture .... page 17 v Licenses - EcoStruxure Automation Expert – Perpetual licensing .... page 20 - EcoStruxure Automation Expert – Subscription-based licensing .... page 21 - EcoStruxure Automation Expert Licensing – Architecture .... page 21 b Compatibility v List of X80 hardware compatible with Modicon M580 dPAC .... page 28 v List of TM3 hardware compatible with ModiconM251 dPAC and M262 dPAC .... page 30 v Altivar hardware and Altivar ATV dPAC compatibility .... page 31 b References v Modicon M580 dPAC .... page 32 v Modicon M251 dPAC .... page 36 v Modicon M262 dPAC .... page 37 v Altivar ATV dPAC .... page 38 b Services... page 40 b Product reference index.. page 42 1 2 EcoStruxure™ Automation Expert Industrial automation systems EcoStruxure Automation Expert General presentation Libraries Operator Station Automation Expert HMI Runtime Modicon dPAC Engineering Automation Expert Communications X80 TM3 I/O & Enc M580 dPAC M2xx dPAC ATV dPAC Soft dPAC Linux/HA Soft dPAC Windows Automation ExpertHistorization Automation Expert Archive Control Room AVEVA System Platform CRD + X80 EcoStruxure Automation Expert consists of a suite of integrated hardware and software solutions: > EcoStruxure Automation Expert build time - engineering, monitoring, and management environment > Distributed Programmable Automation Controller (dPAC) platforms with the Universalautomation.org Shared Source Runtime engine: b ATV dPAC for Altivar b Modicon M251 dPAC/TM3 I/O b Modicon M262 dPAC/TM3 I/O b Modicon M580 dPAC/X80 I/O > Plus, innovative new software-based controllers: b Soft dPAC for Linux™, for standalone and high availability configurations b Soft dPAC for Windows™ , for standalone configurations > EcoStruxure Automation Expert - HMI, a fully integrated, object-oriented industrial visualization solution > EcoStruxure Automation Expert - Archive, a centralized solution for the historization of process data, alarms, and trends > Schneider Electric Libraries, a comprehensive set of hardware-independent libraries, ranging from basic functions up to segment solutions > Asset Link for Bulk Engineering to extract data from engineering tools for automated application generation > Asset Link for AVEVA OMI to create application objects (AppObjects) in the AVEVA System Platform in an automated workflow Note: UniversalAutomation.org is an independent, non-for-profit association managing the implementation of an industrial automation shared source runtime execution engine, based on the IEC 61499 standard that is an object-oriented further development of IEC 61131 with the cyclical execution model of IEC 61131 replaced by an event-based model. This new level of shared technology provides the basis for an ecosystem of portable, interoperable, “plug and produce” solutions and creates an entirely new category within industrial automation. EcoStruxure Automation Expert is a software-defined industrial automation system, a new category of industrial automation that leverages innovative technology to enable industrial operators to realize a step-change improvement over traditional process control systems and deliver significant advancement in productivity, quality, flexibility, and security throughout the entire lifecycle of industrial assets. 3 Feature overview EcoStruxure Automation Expert represents a new approach to designing, building, operating, and maintaining industrial automation systems that offers a unique technology mix to define a new category of integrated automation systems. Complexity mastered Systems, devices, services, and assets are natively represented as ready-to-use software objects called composite automation types (CATs) that encapsulate internal behaviour and simplify functional interfaces. An object-oriented approach promotes code reuse, standardization on best practice, and helps manage complexity while providing the fundamental building blocks for the creation of state-of-the-art cyber-physical systems.

CAT objects follow a type/instance relation and can be combined to create new objects that encapsulate: b Control logic b HMI/SCADA visualization b I/O and device communications b Simulation and test rigging b Documentation Decoupling the application from implementation EcoStruxure Automation Expert addresses full automation system engineering and extends the best features of classic PLC and DCS control approaches to a new generation of automation system that completely decouples the application design from runtime deployment, enabling automation professionals to focus on these tasks independently in their project lifecycle. Applications are portable, reusable, and interoperable across runtime platforms, meaning deployment decisions are made just in time and on the fly, enabling exceptional system agility. Efficient engineering EcoStruxure Automation Expert build time provides a single, modular engineering environment for all tasks for engineering, monitoring, and managing the complete automation system including hardware and software, control, and visualization. It automates low value engineering and integration tasks, reducing engineering effort and sources of error by Asset Link to perform digital engineering. Complex functions can be encapsulated into manageable objects, enabling non-technical users to understand and manage complex systems. Cross communications are transparent and implicit regardless of physical location, requiring zero engineering consideration. Common runtime environment Through the implementation of the shared source Runtime engine provided by universalautomation.org across hardware and software platforms, exceptional re-usability, scalability, and architectural flexibility are now available. Application portability provides cost savings through the decoupling of the lifecycles of software and hardware systems. Simple system orchestration EcoStruxure Automation Expert was designed with the complete lifecycle of an automation system in mind, with functions to facilitate management and monitoring of multiple assets and devices at scale. With a single user environment covering the entire system scope including third-party devices, orchestration of complex, heterogenous systems becomes simpler. Native IT integration Modern automation systems generate increased value when coupled with business information and hence wider IT ecosystems. EcoStruxure Automation Expert provides an expandable platform for Industry 4.0 solutions with support for high-level programming, modular systems design, and open standards. Thanks to event-driven execution and object-oriented design, EcoStruxure Automation Expert applies to IT programming language standards. Cybersecurity EcoStruxure Automation Expert includes robust support for cybersecurity including credential management and secure communications. User and device credentials are managed by the EcoStruxure Automation Expert build time environment, and secure communications are available between controllers, HMI, SCADA, and third-party devices. Industrial automation systems EcoStruxure Automation Expert General presentation (continued) 4 EcoStruxure Automation Expert Software The EcoStruxure Automation Expert software offer includes: b The EcoStruxure Automation Expert engineering environment, with add-ons for integration of AVEVA Engineering and AVEVA System Platform software b EcoStruxure Automation Expert HMI Runtime b EcoStruxure Automation Expert Archive b Asset-oriented application libraries EcoStruxure Automation Expert engineering EcoStruxure Automation Expert is an asset-based, fully-integrated engineering environment that allows portable, IEC 61499-standard-based automation systems to be managed within a single environment. EcoStruxure Automation Expert provides the capability to: b Design and manage asset-based applications using object libraries based on multifaceted models (asset logic, operating modes, HMI symbols and faceplates (including alarms and trends), I/O interface, and asset documentation) b Design the process based on asset-oriented objects with single line connections b Create rich process displays to monitor and control the process from the control room or line terminal by dragging and dropping asset-based objects b Manage a single solution independently of the number of controllers and HMI stations b Design the application solution independently of the hardware configuration b Test and simulate the control and HMI for the whole solution b Create and modify procedural automation CATs based on S88 state model with graphical editor b Support multi-user change management through SVN client integration b Design, configure, and manage network and device topologies b Flexibly deploy applications to multiple hardware or software platforms based on a common runtime b Automatically discover and diagnose compatible runtime devices b Automate bulk generation of asset instances from AVEVA Engineering or DEXPI files b Automate bulk generation of asset instances for AVEVA System Platform b Embedded AVEVA industrial graphic editor in EcoStruxure Automation Expert build time to create new AVEVA industrial graphics or to reuse graphics from existing applications b Secure the automation system by managing authentication with encrypted communication and security certificates at solution and devices level EcoStruxure Automation Expert V24.0 build time Industrial automation systems EcoStruxure Automation Expert Software Presentation 5 EcoStruxure Automation Expert Software EcoStruxure Automation Expert – HMI EcoStruxure Automation Expert HMI is a tightly integrated human-machine interface designed for EcoStruxure Automation Expert applications. Its features include: b Compatibility with WindowsTM OS/LinuxTM OS hardware or Schneider Electric Harmony ST6 b Seamless management of controller and HMI communication b Support for single/ multi operator stations with cloning b User management for access control b Multi-language application b Monitoring of runtime connections The EcoStruxure Automation Expert HMI Client for WindowTM/LinuxTM operating system can be installed on various hardware such as Workstations, Industrial PCs, and Edge Boxes, provided they meet the minimum system requirements. It ensures high-performance, seamless management of controller and HMI communication. Furthermore, the EcoStruxure Automation Expert HMI Client for Harmony ST6 is compatible with HMIST6200, HMIST6400, HMIST6500, HMIST6600, HMIST6700, HMISTM6400, and HMISTM6200 touch panel screens. It offers seamless management of controller and automatic HMI communication, particularly ideal for a small number of assets. EcoStruxure Automation Expert – Archive EcoStruxure Automation Expert Archive operates as a highly integrated local data historian, providing minimal engineering effort historization and retrieval of live process data, alarms, and events within Automation Expert HMI and the capability to integrate with larger enterprise data storage systems by Structured Query Language (SQL). It is compatible with Windows 10, Windows 11, and Linux operating system. EcoStruxure Automation Expert – AVEVA System Platform integration EcoStruxure Automation Expert includes native support for System Platform - AVEVA's real-time operations control platform for supervisory, HMI, SCADA, and IIoT applications. EcoStruxure Automation Expert is capable of auto-generating OPC UA-based secure communications between platforms and generate AVEVA System Platform-compatible graphics for clean integration. Furthermore, it now embeds the AVEVA Industrial Graphics editor so that users no longer need to move from EcoStruxure Automation Expert buildtime to AVEVA buildtime, providing unpreceeded integration. Automation Expert version Library compatibile version Platform version for Asset Link Version for Asset Link and AVEVA Industrial Graphics V23.0 AVEVA System Platform 2020 R2 SP1 AVEVA System Platform 2020 R2 SP1 or later No AVEVA Industrial Graphics support V23.1 AVEVA System Platform 2023 AVEVA System Platform 2020 R2 SP1 or later (New Galaxy creation is possible only with Library compatible version)* AVEVA System Platform 2023 or later V24.0 AVEVA System Platform 2023 or R2 SP1 AVEVA System Platform 2020 R2 SP1 or later (New Galaxy creation is possible only with AVEVA System Platform 2023 R2 SP1)* AVEVA System Platform 2023 or later (New Galaxy creation is possible only with AVEVA System Platform 2023 R2 SP1)* *Only Select Existing Galaxy from the configurator is possible if Library compatible version is not available with the user. Embedded AVEVA industrial graphic editor in EcoStruxure Automation Expert build time Industrial automation systems EcoStruxure Automation Expert Software Presentation (continued) 6 EcoStruxure Automation Expert Software (continued) EcoStruxure Automation Expert – Libraries EcoStruxure Automation Expert includes a set of application libraries with generic process and control modules such as motors / valves and segment-based libraries with equipment modules that include multiple facets – logic, Automation Expert HMI, AVEVA System Platform template, and documentation within a single package to minimize the engineering time. EcoStruxure Automation Expert also includes a hardware library for easier integration of the most common Schneider Electric and Technical Partner's field devices through Modbus TCP / Ethernet IP that provides the mapping, HMI, and documentation to be used in the application. With version 24.0 release, the free libraries included are: b Field Device b Base and common process b Sequence management and Phase Management b Liquid food b Water & Wastewater (including desalination) b Single line power monitoring b Conveying These libraries include HMI objects that are compatible with Windows and Linux Ubuntu native HMI runtime, including the Harmony HMIST6xxx and HMISTM6xxx panels. Additionally, Universal Automation vendors provide specific hardware libraries to deploy EcoStruxure Automation Expert applications to their offer. Industrial automation systems EcoStruxure Automation Expert Software Presentation (continued) With this release the library updates include: b Elementary blocks with easier customization covering basic application functions like alarms, conditions, owners, and signal conditioning that are used by other application CATs – SE.App2Base. b Library of application CATs with easier customization to address common process assets or functions like digital I/O, analog I/O, motors, valves, and flowcontrol. There are multiple layers of each object available which can be used and customized for various application purposes – SE.App2CommonProcess. b State management functionality for generic application (State Manager) as well as ISA-88 based application (Phase Manager). Phase Manager also includes a phase logical interface that accepts commands from external batching interfaces such as AVEVA Batch Management and returns the phase manager status – SE.App2StateManagement. Example of HWCAT symbol and faceplate on EcoStruxure Automation Expert HMI Example of Application CAT symbol and faceplate on AVEVA OMI Application – Common Process Setpoint, Signal Processing, Motors, Valves, Process Control, Flow Control, Pump Set M580 dPAC CPU, X80 I/O Modules M251 dPAC CPU, TM3 I/O Modules M262 dPAC CPU, TM3 I/O Modules ATV dPAC Soft dPAC I/O Modbus Read/Write registers Field Device Modbus/TCP ATV, ATS, Lexium, PowerMeter Gateways Modbus Gateway, UDP Gateway HARDWARE SPECIALIZED APPLICATION GENERAL APPLICATION Application – Base Deviation Alarm, Limit Alarm, Range of Change Alarm, State Alarm Conditions, Owner Application 2 – Base Deviation Alarm, Limit Alarm, Range of Change Alarm, State Alarm Conditions, Owner Application – Sequence Sequence Step, Sequence Action Application 2 – Common Process Setpoint, Signal Processing, Motors, Valves, Process Control, Flow Control, Pump Set Segment Applications WWW, Single Line Power Monitoring, Conveying, Liquid Food, State Management Segment Applications 2 State Management 7 Industrial automation systems EcoStruxure Automation Expert Software Presentation (continued) EcoStruxure Automation Expert Software (continued) EcoStruxure Automation Expert – Libraries (continued) EcoStruxure Automation Expert libraries Library name Short description Extended description Runtime.Base Standard blocks This library contains the basic function blocks to be used for: b Runtime management b Arithmetic functions b Logic functions b Format conversion b Event management b etc. SE.AppBase Elementary block of the application Library of application CATs covering basic application functions like alarms, conditions, owners, and signal conditioning that are used by other application CATs like the ones from SE.AppCommonProcess SE.App2Base Elementary blocks of the application SE.AppBase objects are redesigned to make customization easier. These objects will be used by other redesigned libraries. SE.AppSequence Sequence control This library has a set of application CATs that allows you to create sequential control algorithms with steps and transitions to command control modules. This library works with both SE.AppCommonProcess and SE.App2CommonProcess. SE.AppCommonProcess Common process applications Library of application CATs to address common process assets or functions like digital I/O, analog I/O, motors, valves, flow control, etc. These types of object can be used in any industrial application as well as in process control in manufacturing applications SE.App2CommonProcess Common process application SE.AppCommonProcess objects are redesigned to make customization easier. There are multiple layers of each object available, which can be used and customized for various application purposes. SE.AppConveying Conveying Library of application CATs to address common equipment such as conveyors, sorters, transfer tables, and turntables, typically used in logistic hubs and distribution centers SE.AppLiquidFood Liquid and Food This library has an application CAT to control the seats of mixproof valves used in Liquid and Food applications SE.SingleLinePowerMonitoring Low and medium power monitoring This library includes templates with common functions for electrical objects such as busbars, sources, infeeds, and loads that can be connected to energy management hardware CATs SE.AppStateManagement State management This library is used to monitor and manage interface states of the machine: b receiving control commands and providing machine information b managing acting state sequence and transitions SE.App2StateManagement State management This library is used to provide state management functionality for generic application (State Manager) as well as ISA-88 based application (Phase Manager). Phase Manager also includes a phase logical interface that accepts commands from external batching interfaces such as AVEVA Batch Management and returns the Phase Manager status. SE.AppProcedure Procedure control This library is used to monitor and manage phases based on ISA-88 associated with sequences in coordination with sequence control blocks from SE.AppSequence. It also includes a phase logical interface that accepts commands from external batching interfaces such as AVEVA Batch Management and returns the phase manager status. SE.AppWWW Waste and wastewater This library contains blocks used to monitor and manage control sequences like aeration and dual media filter for Water and Wastewater applications SE.DPAC dPAC hardware controllers Library containing the dPAC device types AVEVA.IndustrialGraphicsLibrary Industrial graphics library Industrial Graphics are vector-based graphics that can be scaled, animated, embedded into application objects, and deployed. The library contains common industrial equipment. You can modify graphics or add graphics to the library by creating new graphics using the Industrial Graphic Editor. SE.EAEPortal AVEVA System Platform Device type The AVEVA System Platform device type is required by Asset Link for establishing communication and creating the application objects automatically in AVEVA System Platform SE.FieldDevice Field device hardware CATs This library has ready-to-use hardware CATs for motor control, energy management, machine safety, and weighing from Schneider Electric, allowing dPAC communication with these devices by Modbus TCP or Ethernet IP depending on the device SE.HwCommon Common hardware CAT functions Library of functions used by the various hardware CAT libraries SE.IoATV Variable speed drive I/O services for ATV dPAC Library of hardware CATs for Altivar I/O (local and modules) used for the Altivar dPAC module hardware configuration 8 Industrial automation systems EcoStruxure Automation Expert Software Presentation (continued) EcoStruxure Automation Expert Software (continued) EcoStruxure Automation Expert – Libraries (continued) EcoStruxure Automation Expert libraries (continued) Library name Short description Extended description SE.IoNet UDP gateway Library of hardware CATs to enable UDP communication SE.IoTMx TM I/O services for M251d/M262d Library of hardware CATs for TMp I/O modules used for M251d and M262d hardware configuration SE.IoX80 X80 I/O services for M580d Library of hardware CATs for X80 I/O modules used for M580d hardware configuration SE.ModbusGateway Standard Modbus gateway Library of hardware CATs to enable Modbus TCP communication with import of data description file SE.Standard EcoStruxure Automation Expert HMI device type Library with EcoStruxure Automation Expert HMI device type Standard.IoEtherNetIP Standard Ethernet IP scanner functions Library of hardware CATs used for EIP scanner configuration (Implicit use by the EcoStruxure Automation Expert system when using the EIP scanner and also to add custom EIP connections) Standard.IoModbus Standard Modbus functions Library of hardware CATs to enable Modbus client communication Standard.IoModbusSlave Standard Modbus server functions Library of hardware CATs to enable Modbus server communication Standard.OPCUAClient Standard OPC UA client functions Functions to enable OPC UA client connection, monitor, read, and write data Definitions: b CAT object: A composite automation type (CAT) function block includes objects with multiple facets: v Logic to define its operating modes v I/O interfaces to exchange data/events with its environment v Symbols/faceplates for control and monitoring in the HMI v Documentation that is implicitly part of the project online help b Application CAT: representing application assets or functions b Hardware CAT: representing hardware devices that can be added to the hardware configuration, for device monitoring and control 9 Industrial automation systems EcoStruxure Automation Expert Software Presentation (continued) EcoStruxure Automation Expert Software (continued) System requirements Windows – Engineering, HMI, and Archive System requirements Minimum Performance Engineering HMI Archive Engineering HMI Archive Processor 1 GHz 2 GHz or higher RAM (1) 2 GB 2 GB 2 GB 4 GB 4 GB 4 GB Hard disk free space (1) 1 GB 1 GB 1 GB 10 GB 10 GB 10 GB Display resolution 1280x1024 1920x1080 or higher Pointing device Mouse or compatible Network access One Ethernet interface Operating system Microsoft Windows 10 Professional (64-bit) Version 1903 and later, Microsoft Windows 11 Professional Version 21H2 and later, and Microsoft Server Version 2019 (1809 and later) .NET framework .NET 4.8 .NET 4.8 or higher (1) Requirement is indicated for each software package. More than one software package can be installed on the same device. In this case, you need to add the respective RAM and hard disk free space requirements together. For example, if you install the HMI and Archive software packages on the same device, the minimum RAM required is 4 GB (2 GB + 2 GB). 10 Industrial automation systems EcoStruxure Automation Expert Hardware Presentation (continued) EcoStruxure Automation Expert Distributed Programmable Automation Controller (dPAC) Platforms EcoStruxure Automation Expert consists of several hardware components working together to create a complete automation system. Soft dPAC Soft dPAC is an edge computing controller designed to execute an application and interact with field devices. This hardware-agnostic controller is versatile, capable of installation on various hardware such as servers, workstations, industrial PCs, or microcomputers, provided they meet the necessary hardware and software requirements. Soft dPAC supports both LinuxTM and WindowsTM operating systems: v The Linux SoftdPAC is ideal for real-time control when installed in conjunction with a Linux real-time patch. v The Windows SoftdPAC is best suited for non-critical applications that do not demand real-time control. In a Linux environment, multiple instances of Soft dPAC can be seamlessly installed on a single host machine, allowing tasks like line expansions to be completed without disrupting ongoing processes. This capability minimizes downtime, thereby enhancing productivity and profitability. For Windows, one Soft dPAC instance can be installed per host machine. High Availability Soft dPAC High Availability Soft dPAC (HA Soft dPAC) represents a software-based high availability industrial automation system meticulously engineered to operate in a redundant configuration, offering resilience against hardware failures and ensuring continuous operations. This capability effectively minimizes process downtime, making it ideal for demanding applications where uninterrupted process flows are critical. The integration of the high-availability system with EcoStruxure Automation Expert software plays a pivotal role in enhancing productivity by significantly reducing process downtime. High Availability Soft dPAC is compatible with the following hardwares: v Schneider Electric Harmony P6 iPC v ASRockTM iEP-5000G Series Industrial IoT Controller v For compatibility with other iPC, please contact your Schneider Electric representative for additional information. Moreover, High Availability Soft dPAC seamlessly integrates with Modicon X80 IOs using the BMECRD0100 Remote I/O module, ensuring comprehensive compatibility and functionality within industrial automation setups. Essential Edge Controller Essential Edge Controller is part of the Harmony iPC range and runs at the Edge of EcoStruxure. Essential Edge Controller provides customers the flexibility and versatility in products to be used in control and compute applications and helps to enhance the customer's experience by reducing the time to market and improving the cybersecurity of the solution. Product reference: HMIBX1A0NDA Essential Edge Controller is a versatile and open-to-application edge terminal running Linux Operating software. It is a simple edge device, capable of bringing solid values for and beyond industrial use cases. v Pre-installed EcoStruxure Automation Expert Soft dPAC, HMI for immediate deployment v Capability to run third-party applications on the same hardware The Essential Edge controller has no embedded I/O; it supports Remote I/O on Modicon TM3, X80 expansion modules with up to 32 devices connected via Modbus TCP/IP or Ethernet IP communication. Performance Edge Controller Performance Edge Controller is part of the Harmony iPC range and runs at the Edge of EcoStruxure. A cutting-edge iPC-based Edge controller with more performance, designed to revolutionize industrial automation. Equipped with pre-installed Soft dPAC, HMI, and Archive, this powerhouse of a controller offers seamless integration and unparalleled flexibility. With the ability to install third-party applications on the same hardware, it empowers you to customize and expand functionality to suit your specific needs. Performance Edge Controller operates on the robust and secure Linux operating system, helps to provide a stable and efficient platform for industrial automation. Linux OS contributes to maintaining consistent performance, enhanced security, and seamless integration with a wide range of industrial applications. Product Reference: HMIP6CTO It is a configure-to-order product, where the user can choose the processor type (Celeron / i3), Memory size, and accessories. The Performance Edge controller has no embedded I/O; it supports Remote I/O on Modicon TM3, X80 expansion modules with up to 200 devices connected via Modbus TCP/IP or Ethernet IP communication. This innovative Performance Edge controller is an all-in-one solution, streamlining operations and maximizing efficiency. NOTE: Please contact your Schneider Electric representative for additional information. HMIBX1A0NDA HMIP6CTO 11 Industrial automation systems EcoStruxure Automation Expert Hardware Presentation (continued) EcoStruxure Automation Expert Distributed Programmable Automation Controller (dPAC) Platforms (continued) HA Edge Controller Designed for high availability applications, this HA Edge controller running on Linux OS helps to maintain a continuous operation, offering a platform for critical industrial processes. Whether in manufacturing, energy management, or process automation, the versatility of our controller combined with Linux OS opens a world of possibilities, improving seamless and efficient operations in demanding industrial environments. Product Reference: HMIP6CTO It is a configure-to-order product, where the user can choose the processor type (Celeron / i3), Memory size, and accessories. v Pre-installed EcoStruxure Automation Expert HA soft dPAC for immediate deployment v Robust performance for diverse industrial applications The HA Edge controller has no embedded I/O; it supports Remote I/O on Modicon X80 expansion modules with up to 200 devices connected via Modbus TCP/IP communication. NOTE: Please contact your Schneider Electric representative for additional information. Modicon M580 dPAC A high-performance, rugged distributed field controller based on the widely successful Modicon M580 ePAC platform with up to 64 MB ECC RAM for programs and data. The Modicon M580 dPAC supports the robust, high-performance Modicon X80 I/O catalog(1) and is available in standard and conformal coated versions. Product references: b BMED581020: Modicon M580 dPAC (standard) b BMED581020C: Modicon M580 dPAC (conformal coated) BMED581020 and BMED581020C controllers support: v Up to 1,024 discrete I/O channels(2) v Up to 256 analog I/O channels(2) v Up to 4 racks of local I/O Modicon M251 dPAC A cost-optimized, low-footprint distributed controller based on the machine-specialized Modicon M251 Logic Controller platform. The Modicon M251 dPAC provides a single Ethernet port for fieldbus, switched dual Ethernet ports for peer communications, and supports the field-proven TM3 I/O system(1). Product reference: b TM251MDESE: Modicon M251 dPAC The TM251MDESE controller has no embedded I/O; it supports Modicon TM3 I/O expansion modules: v Up to 448 discrete I/O channels(2) v Up to 112 analog I/O channels(2) v Up to 14 Modicon TM3 expansion modules (7 local modules + 7 remote modules) with Modicon TM3 bus expansion modules (transmitter module and receiver module) It is possible to control up to 4 TeSys U and TeSys D motor starters by connecting a TM3XTYS4 TM3 module to the Modicon M251 dPAC. Modicon M262 dPAC This is the controller for performance machines. It is powered with a non-isolated 24 V DC power supply, has a built-in overload protection, embeds a dual-core processor and a 256 MB memory capacity and supports RSTP protocol. Product reference: b TM262L01MDESE8T: Modicon M262 dPAC The TM262L01MDESE8T controller has no embedded I/O; it supports Modicon TM3 I/O expansion modules: v Up to 448 discrete I/O channels(2) v Up to 112 analog I/O channels(2) v Up to 14 Modicon TM3 expansion modules (7 local modules + 7 remote modules) with Modicon TM3 bus expansion modules (transmitter module and receiver module) It is possible to control up to 4 TeSys U and TeSys D motor starters by connecting a TM3XTYS4 TM3 module to the Modicon M262 dPAC. (1) Expert/specialist modules are not supported in this release. Please refer to the compatibility list on page 28. (2) These values are theoretical limits; the device limits are highly dependent on the event load of the user application. BMED581020 TM251MDESE TM262L01MDESE8T 12 Industrial automation systems EcoStruxure Automation Expert Hardware Presentation (continued) EcoStruxure Automation Expert Distributed Programmable Automation Controller (dPAC) Platforms (continued) Altivar ATV dPAC module The ATV dPAC module is part of the EcoStruxure Automation Expert distributed controller solution platform, with 12 MB memory for programs and data. It is intended to be used as a slide-in option for ATV600, ATV900, and ATV340 variable speed drive (VSD) families(1). The Altivar ATV dPAC module is powered by the drive and provides dual Ethernet sockets for connection to peer controllers, distributed I/O, or remote secondary devices. Product references: b VW3A3530D: Altivar ATV dPAC module b VW3A1111: Graphic display terminal The VW3A3530D dedicated controller has no embedded I/O. However, all standard I/O on the respective Altivar Process and Altivar Machine drives can be used and extended with I/O modules: b Up to 23 discrete I/O b Up to 7 analog I/O b Encoder interfaces (ATV900 and ATV340) It is possible to control up to 8 Modbus TCP devices, such as Altivar drives and soft starters, TeSys motor starters, remote I/O using a TM3BCEIP bus coupler, PowerLogic meters, or Harmony Hub wireless sensors. For more information about the input/output capability, refer to Altivar dPAC Module VW3A3530D user guide. (1) For details, please refer to the compatibility table on page 31. VW3A3530D Altivar Process drives slots 13 Industrial automation systems EcoStruxure Automation Expert Hardware Presentation (continued) EcoStruxure Automation Expert Distributed Programmable Automation Controller (dPAC) Platforms (continued) Information Technology (IT)/Operational Technology (OT) Communication Protocols Platform Soft dPAC High Availability (Linux) Simplex Soft dPAC (Linux) Simplex Soft dPAC (Windows OS) M580 dPAC M262 dPAC M251 dPAC ATV dPAC OPCUA Client – – – – – Server MQTT Pub/Sub – – – – – Modbus TCP Client Server – Modbus RTU Client – – – – – Server – – – – – EtherNet/IP Scanner (Client) – – – PROFIBUS DP Client Through Modbus TCP third party gateway Through Modbus TCP third party gateway Through Modbus TCP third party gateway Through Modbus TCP third party gateway Through Modbus TCP third party gateway Through Modbus TCP third party gateway Through Modbus TCP third party gateway ASi-5 / ASi-3 Through Modbus TCP third party gateway Through Modbus TCP third party gateway Through Modbus TCP third party gateway Through Modbus TCP third party gateway Through Modbus TCP third party gateway Through Modbus TCP third party gateway Through Modbus TCP third party gateway HART – – – – – Open TCP/IP – 14 15 Presentation (continued) EcoStruxure Automation Expert Distributed Programmable Automation Controller (dPAC) Platforms Selection guide EcoStruxure Automation Expert consists of several hardware components working together to create a complete automation system. High Availability Soft dPAC Simplex Soft dPAC (Linux OS) Simplex Soft dPAC (Windows OS) Modicon M580 dPAC Modicon M262 dPAC Modicon M251 dPAC Altivar dPAC Applications Type Virtualized device Virtualized device Virtualized device Embedded device Embedded device Embedded device Embedded device Specification For critical applications For real time applications For non-real time applications For robust process application For performance modular machines For small modular machines For distributed or Variable Speed Drive centric applications, including mini modular machines Max Application size (Mbytes) Scalable(10) Scalable(10) Scalable(10) 100MB 100MB 20MB 12MB Commmunication fieldbus and network performance Embedded OPCUA Server (20000 variables) Modbus TCP Client (60 devices)(1) OPCUA Server (20000 variables) OPCUA Client EtherNet/IP (32 devices @20ms RPI)(1) Modbus TCP Client (60 devices)(1) Modbus TCP Server (800 variables)(1) OPCUA Server (20000 variables) Modbus TCP Client (60 devices)(1) Modbus TCP Server (800 variables)(1) OPCUA Server (5000 variables) EtherNet/IP (16 devices @20ms RPI)(1) Modbus TCP Client (16 devices)(1) Modbus TCP Server (800 variables)(1) OPCUA Server (5000 variables) EtherNet/IP (16 devices @20ms RPI)(1) Modbus TCP Client (16 devices)(1) Modbus TCP Server (800 variables)(1) Modbus RTU 56kbps OPCUA Server (1000 variables) EtherNet/IP (8 devices @20ms RPI)(1) Modbus TCP Client (16 devices)(1) Modbus TCP Server (800 variables)(1) Modbus RTU 56kbps OPCUA Server (200 variables) OPCUA Client Modbus TCP Client (8 devices)(1) Modbus TCP Server (50 variables)(1) Optional Profibus DP through Modbus TCP third party gateway Asi-5/Asi-3 through Modbus TCP third party gateway Profibus DP through Modbus TCP third party gateway Asi-5/Asi-3 through Modbus TCP third party gateway Profibus DP through Modbus TCP third party gateway Asi-5/Asi-3 through Modbus TCP third party gateway Profibus DP through Modbus TCP third party gateway Asi-5/Asi-3 through Modbus TCP third party gateway Profibus DP through Modbus TCP third party gateway Asi-5/Asi-3 through Modbus TCP third party gateway Profibus DP through Modbus TCP third party gateway – Connectivity services – MQTT Pub/Sub Open TCP/IP MQTT Pub/Sub Open TCP/IP Open TCP/IP Open TCP/IP Open TCP/IP I/O Discrete I/O channels 1750(3) 1750(3) – 352(2) 112(2) 112(2) Up to 23 (depending on drive reference) Analog I/O channels 1750(3) 1750(3) – 72 112 112 Up to 7 (depending on drive reference) Compatible expansion I/O module ranges(5) Extension I/O – – – 4 Modicon X80 backplane 14 Modicon TM3 14 Modicon TM3 – Remote I/O 16 Modicon X80 backplane(4) 16 Modicon X80 backplane(4) – – – – – References Hardware agnostic(8) Hardware agnostic(8) Hardware agnostic(9) BMED581020 / BMED581020C TM262L01MDESE8T TM251MDESE VW3A3530D(6) / VW3A1111(7) (1) Recommended limit (2) Typical architecture – I/O can increase or decrease depending on the I/O scan rate or change rate, and the auxiliary application load with connected devices, such as Modbus. (3) I/O count can increase or decrease depending on the CPU version used on the host iPC, I/O scan rate or change rate, and the auxiliary application load with connected devices, such as Modbus. The host iPC processor speed greatly affects the performance capabilities of the controller. The performance limits can be increased when using more powerful iPC processors, such as the Intel i5/i7 offerings. (4) BMECRD0100: Ethernet Remote I/O drop adapter for Automation Expert High Availability (5) Consult the DIA3ED2140109EN and DIA6ED2131203EN catalog for additional information on the I/O compatibility. (6) Altivar ATV dPAC module (7) Graphic display terminal for Altivar ATV340 (8) Reference value based on the Harmony P6 Celeron (2 cores) (9) Minimum requirements available in the section Windows – Software dPAC (page 13). (10) Maximum application size can increase or decrease depending on the CPU version on the host iPC. Industrial automation systems EcoStruxure Automation Expert Hardware 16 Presentation (continued) Industrial automation systems EcoStruxure Automation Expert Hardware EcoStruxure Automation Expert Distributed Programmable Automation Controller (dPAC) Platforms (continued) System requirements Linux – Software dPAC System requirements Minimum Performance Required for RT control OS Debian 10.3, Ubuntu 18.04 and 20.04, or Raspbian 32- or 64-bit Ubuntu 20.04 with low-latency patch or other distribution with PREEMPT-RT patch Docker Docker 19.03.8 and above CPU X86/ARM 1 GHz or higher Multi-core X86/ARM 1 GHz or higher Dedicated cores RAM 256 MB 1 GB HDD/SSD 16 GB 32 GB Network interface At least one Network Interface Card (NIC) Two NICs to isolate control and device networks One NIC per container for RT fieldbuses Time synchronization NTPv4 client NTPv4 client support with monotonic and drift compensation Linux – Software dPAC, High Availability(1) System requirements Description Note Processor PC Celeron 4305UE, 2 Core, 2 Threads Need Multi-core X86 processor. ARM is not supported for v24.0 RAM SO-DIMM RAM 4 GB Minimum 4GB. ECC support is optional. Memory M.2 SSD Standard Endurance 128 GB 128 GB is not required. However, it is the lowest that was tested. Network interface RJ45 GbE Ethernet NIC Three NICs are needed for redundant network configuration. • One 1 GB speed NIC for interlink connection • Two 100MB for device network Operating system Linux Ubuntu 20.04 (Harmony P6)/22.04 (ASRock) tested (1) A set of 2 manageable switches compatible with RSTP and having at least 6 physical ports is also needed. Windows – Software dPAC System requirements Minimum Performance Processor 1 GHz 2 GHz or higher RAM(1) 2 GB 4 GB Hard disk free space(1) 1 GB 10 GB Display resolution 1280x1024 1920x1080 or higher Pointing device Mouse or compatible Network interface One Ethernet interface Operating system Microsoft Windows 10 Professional (64-bit) Version 1903 and later, Microsoft Windows 11 Professional Version 21H2 and later, and Microsoft Server Version 2019 (1809 and later) .NET framework .NET 4.8 .NET 4.8 or higher (1) Requirement is indicated for each software package. More than one software package can be installed on the same device. In this case, you need to add the respective RAM and hard disk free space requirements together. For example, if you install the HMI and Archive software packages on the same device, the minimum RAM required is 4 GB (2 GB + 2 GB). 17 Industrial automation systems EcoStruxure Automation Expert Architecture Presentation (continued) Types of standard architectures EcoStruxure Automation Expert breaks the dependency between the application software and the hardware platform it runs. Together with its distribution capabilities, EcoStruxure Automation Expert is a unique automation solution to be used in any kind of architecture, from small machines up to complex process architecture. Example of Soft dPAC standard architecture The EcoStruxure Automation Expert architecture for small machines increases engineering efficiency by using the Automatically generated network transparent communications between controller and HMI objects with many-to-many connectivity and communication protocol for field devices. Example of distributed standard architecture The openness and scalability of the EcoStruxure Automation Expert makes it ready for IT/OT with connectivity AI model by HTTP and apps & analytics in an architecture with distributed controllers. EcoStruxure Automation Expert HMI Switch Field Device Soft dPAC Apps and Analytics Edge M251 dPAC Connected Devices M262 dPAC Distributed IO XPSMCM TM3 TM5 STB ATV320 ATV340 ATV320WS ATV320 (Flex center) TeSys Island 3rd party roller drives Vision system AS-i Gateway Weighing system Barcode reader Motor Control Sensors 3rd Party Products M580 dPAC AS-i Safety Safety Ethernet/IP Harmony P6 PacDrive M580 CIP safety CIP Safety IO 3rd Party PCHMIBSC HMIBMU EcoStruxure

Automation Expert Orchestrated AVEVA Automation Expert HMI ATV dPACCRD 18 Industrial automation systems EcoStruxure Automation Expert Architecture Presentation (continued) Example of complex standard architecture The complex architecture below illustrates the extensive possibilities of distributed application for the EcoStruxure Automation Expert solution among the different dPACs. This example is focused on a combination of Modicon M580d and Altivar ATVd dPACs. Control Network ATVd Pumps (6) ATVd Motors (4) ATVd Pumps (2) ATVd Pumps (7) ATVd Motors (2) ATVd Pumps (7) Control Room Standard PC x 1 EAE Embedded HMI x 1 EcoStruxure Automation Expert 19 Industrial automation systems EcoStruxure Automation Expert Architecture Presentation (continued) Types of high-availability architectures The EcoStruxure Automation Expert high-availability system is used for more demanding applications in terms of the availability of the control/ command system where no interruption of the process can be tolerated. The high-availability system with EcoStruxure Automation Expert software helps increase productivity by minimizing process downtime. High-availability Soft dPAC based on Ethernet RIO architecture The high-availability configuration comprises two identical iPCs (industrial computers), each hosting a High-Availability Soft dPAC, and configured to run in a Pair where one instance (a Partner) is driving the process while the other Partner is ready to take over control, if the first one stops working. The two Partners check each other's availability by communicating over two links: • A dedicated cable (the HA Interlink), and • The device network, which also carries commands and diagnostics. In a high-availability Soft dPAC topology based on an Ethernet RIO architecture, devices are hardwired on remote I/O over Ethernet by BMECRD1020 (RIO drop adapter for Modicon X80 I/Os modules). This high-availability system is used for sensitive processes that require a bumpless I/O control takeover time. 1. Linux-based iPC pair, each hosting an instance of High Availability Soft dPAC 2. HA Interlink: 1GB/s Network Interface Card (NIC)/connection 3. Redundant network: 100MB/s with NIC bonding 4. Linux-based standalone iPC, hosting an instance of non-redundant Soft dPAC 5. Non-redundant Modicon X80 I/O drop with BMECRD0100 RIO drop adapter and redundant power supplies 6. Non-redundant Modicon X80 I/O drop with BMECRD0100 RIO drop adapter and redundant power supplies 7. Remote I/O RSTP - enabled ring network 8. Workstation running EcoStruxure Automation Expert build time, RSTP configuration software 9. Workstation running AVEVA System Platform (ASP), AVEVA Operation Management Interface (OMI), and AVEVA historian. Communication is over OPC UA 10. Workstation running EcoStruxure Automation Expert Runtime HMI 11. Managed switches, for example, Modicon switch 20 Industrial automation systems EcoStruxure Automation Expert Architecture Presentation (continued) Components of a high-availability system High-Availability Soft dPAC pair At the heart of a high-availability architecture are two iPCS - Preferred Primary and Non-Preferred Primary, with identical hardware configurations, based on Linux software connected via a high-speed (1 Gbps) communication link. The Preferred Primary device executes the application program and controls the I/Os located in Modicon X80 drops. The Non-Preferred Primary remains in the background. In the event of a detected error affecting the Primary device, the Standby system switches over automatically, changing over the execution of the application program and control of the I/O to the Standby device with an up-to-date data context. Once the changeover is complete, the Standby device becomes the Primary device while the former Primary device is being cleared from the detected error: when clearance is done, the device reconnects to the standby system and acts as the Standby device. The changeover from Primary to Standby is performed smoothly at the outputs and is completely transparent to the process. Modicon X80 Redundant power supplies and compatible backplanes For high-availability applications, two BMXCPS●●02 redundant power supplies can be used on the same rack to increase the availability of power supply. They are supported by 6-slot BMEXBP0602 backplane and 10-slot BMEXBP1002 backplane equipped with dual slots marked CPS1 and CPS2. On CPS1 slot, the power supply is initially set as Primary and on CPS2 slot, as Standby. When power stops being supplied in accordance with expected rate, they switch roles so that power can be continuously delivered. See Modicon X80 modules catalog for more details. Example of complex high-availability architecture The complex architecture illustrates the extensive possibilities of the High-Availability Soft dPAC in terms of cross-communication, RIO and DIO networks: 1. Linux-based iPC pair, each hosting an instance of High Availability Soft dPAC 2. HA Interlink: 1GB/s NIC/connection 3. Redundant network: 100MB/s with NIC bonding 4. Remote I/O RSTP enabled ring network 5. Non-redundant X80 I/O drop with: - BMECRD0100 RIO drop adapter - Redundant power supplies on the main backplane - Extended main backplane 6. Distributed I/O connected to field devices (sensors, actuators) 7. Non-redundant Modicon X80 I/O drop with BMECRD0100 RIO drop adapter 8. BMEAHI0812/ BMEAHO0412 Hart I/O modules 9. Modbus TCP devices in an Intelligent power and motor control center (including PM5500 power meter series and MasterPact MTZ) connected to TeSysT motor controllers and Altivar processors 10. Managed switches 11. Workstation running AVEVA System Platform (ASP), AVEVA

Operation Management Interface (OMI), and AVEVA historian Communication is over OPC UA 12. Workstation running EcoStruxure Automation Expert Runtime HMI 13. Cross-communication with Altivar ATVdPAC for motor control 21 Industrial automation systems EcoStruxure Automation Expert Licenses Presentation, references EcoStruxure Automation Expert – Perpetual licensing The EcoStruxure Automation Expert offer provides a simplified approach to the software licensing model. The offer has two categories of licenses – Build and Run. EcoStruxure Automation Expert – Build license The Build software requires a license per seat to create Automation Expert based applications. The Build engineering license provides the capability to create, configure, and manage UAO runtime control applications, HMI, archive, and network/device topologies. The Build licenses can be perpetual or subscription-based(1) and are available in four types: b Trial: The engineering software includes a full function demo mode for 42 days unlicensed. b Lite: A basic set of features is included to focus on machine and small process applications. This license allows the use of machine controller platforms and restricted process control platforms. The limitations of this type of license will be included in future release version 24.1. b Standard: A basic set of features included and can be extended by buying add on licenses to extend functionalities. The add ons that are available with EcoStruxure Automation Expert Standard licenses are: v Asset Link for AVEVA OMI v High Availability Engineering v Asset Link for Bulk Engineering is already included in the Standard engineering license v24.0 b Professional: This type of license includes all currently available features. Any new features available in future releases within the first year following the activation date will be included for the software updates. Each commercial license provides: b The capability to design, develop, simulate with HMI, and commission a complete system b Collaborative engineering (SVN client) plugin b Physical topology editor b Free software updates, within the first 12 months from the activation date b Support desk from 9 am to 5pm b Access to private communities on exchange.se.com for p2p support, libraries, project samples, training material, TVDAs, and so on. (1) For more information, refer to EcoStruxure Automation Expert – Subscription-based licensing Build license compatibility Supported platforms Lite Standard Professional Soft dPAC 1 Max Soft dPAC High Availability 1 Max ATV dPAC M251 dPAC M262 dPAC M580 dPAC 1 Max Add-ons (per seat) Asset Link for Bulk Engineering – Asset Link for AVEVA OMI – Optional High Availability Engineering Optional Optional BUILD Perpetual Lite License (Incl. Asset Link for Bulk Engineering add-on) Basic features High Availability add-on Asset Link for AVEVA OMI add-on (Incl. Asset Link for Bulk Engineering + Asset link for AVEVA OMI + High Availability add-ons) HMI - Panel add-on HMI - Operator Station add-on Standard License Professional License Application License for dPAC RUN Perpetual Application License for Soft dPAC Device Small Micro Large Simplex €/Tiered-pack €/Controller €/User €/User €/Device Version Tiered devices packs *Only for Build = Lite HA 10 Devices* 100 Devices 1000 Devices 5000 Devices 22 Industrial automation systems EcoStruxure Automation Expert Licenses Presentation, references (continued) EcoStruxure Automation Expert – Perpetual licensing (continued) Engineering license references The Build engineering licenses are available in different types: Lite, Standard, or Professional. Standard and Professional licenses can be perpetual or subscription-based(1) and are currently offered for single seat use only. Reference Description EALBTEP24 Lite Engineering License EALBTC Standard Engineering License EALBFC Professional Engineering License EALUAOC Engineering license for UAO vendor The standard engineering license includes the "Asset Link for Bulk Engineering" add-on and allows for the addition of the following add-ons: Reference Description EALBATC Add-on for Asset Link for AVEVA OMI EALBAHC Add-on for High Availability 23 Industrial automation systems EcoStruxure Automation Expert Licenses Presentation, references (continued) EcoStruxure Automation Expert – Perpetual licensing (continued) EcoStruxure Automation Expert – Run licenses In addition to the Build engineering license that is required to create EcoStruxure Automation Expert applications, for the operation and maintenance of the application, each hardware should have a Run license. The Run licenses will be based on the control type of Schneider Electric dPAC controllers and the number of devices connected for the Soft dPAC PC-based control. The Run application licenses are available in perpetual and subscription-based model. For more information, refer to EcoStruxure Automation Expert – Subscription-based licensing. For exact calculation of the number of devices and controller type for the application license, a software license configurator for EcoStruxure Automation Expert is available on our website. Run license compatibility Available Licenses Lite Standard Professional Device Micro Small Large 10 Pack – – 100 Pack – 1000 Pack – 5000 Pack – The available application licenses for dPAC controllers are: Reference Description EALADP Application license for one dPAC runtime instance, DEVICE EALANP Application license for one dPAC runtime instance, NANO EALAMP Application license for one dPAC runtime instance, MICRO EALASP Application license for one dPAC runtime instance, SMALL EALALP Application license for one dPAC runtime instance, LARGE Run Application (A+B+C)

Control Control Applicaton A SE or UAO Hardware Select type of controller Devices connected via hardwired or any communication protocols (Modbus, EtherNet/IP, OPC-UA, Profibus) Devices connected via any communication protocols (Modbus, EtherNet/IP, OPC-UA, Profibus) In case of Orchestration or Secondary sensing use cases, EAE Device license = 0.3 * no. of connected devices Control Applicaton B IPC hardware IPC hardware Other Controllers and/or Gateways Control Applicaton C Orchestration DEVICE ATV dPAC M251 dPAC, M262 dPAC M580 dPAC (Ext.Backplane) M580 dPAC (Single Backplane) MICRO SMALL LARGE Tiered devices pack 10 devices* 100 devices 1000 devices 5000 devices EALDXP and EALDHAXP, are only available with Automation Expert Lite Build time EALDXP* EALDCP EALDMP EALDVMP EALDHAXP* EALDHACP EALDHAMP EALDHAVMP Simplex version High Availability version 24 Industrial automation systems EcoStruxure Automation Expert Licenses Presentation, references (continued) EcoStruxure Automation Expert – Perpetual Licensing (continued) The Automation Expert HMI license includes rights to both HMI and Archive runtimes. All runtime licenses are perpetual. Different license types are required depending on the platform on which the runtime is installed, as per the following table: EcoStruxure Automation Expert – HMI license Automation Expert Runtime Platform License type HMI(1) Harmony ST6 HMI range 1 license per HMI runtime instance HMI(1) PC-type HMI (Windows 10/ Linux) 1 license per HMI runtime instance (1) Each license includes both Automation Expert HMI and Automation Expert Archive runtime rights. The Automation Expert HMI Runtime licenses are: Reference Description EALH1P Automation Expert HMI Runtime - Panel (ST6) EALH2P Automation Expert HMI Runtime - Operator (iPC) For exact calculation of the number of devices and controller type for the application license, a software license configurator for Automation Expert is available on se.com. Run application license references Reference Description EALDXP(1) Application Standard 10 Devices EALDCP Application Standard 100 Devices EALDMP Application Standard 1000 Devices EALDVMP Application Standard 5000 Devices EALDHAXP(1) Application High Availability 10 Devices EALDHACP Application High Availability 100 Devices EALDHAMP Application High Availability 1000 Devices EALDHAVMP Application High Availability 5000 Devices (1) Only available with Automation Expert Lite build time. Download the HMIBMI, HMIBMO, and HMIP6 ranges catalog 25 Industrial automation systems EcoStruxure Automation Expert Licenses Presentation, references (continued) EcoStruxure Automation Expert – Subscription-based licensing To provide customers with more business and economic model flexibility and reduced obsolescence risk, both Build and Run licenses are available under a subscription-based model consisting of 1-year termed subscriptions. The subscription-based licenses model is available for project business with end-users. Each commercial license provides: b The capability to design, develop, simulate with HMI, and commission a complete system b Collaborative engineering (SVN client) plugin b Physical topology editor b Free software updates b Support desk from 9 am to 5pm b Access to private communities on exchange.se.com for p2p support, libraries, project samples, training material, TVDAs, and so on. Build subscription-based licenses The Build subscription–based licenses are available in three different types: b Trial: The engineering software includes a full function demo mode for 42 days unlicensed. b Standard: A basic set of features equivalent to Standard perpetual-based license. b Professional: this version includes all available features, including: v Asset Link for AVEVA OMI v High Availability Engineering The Build subscription-based licenses are offered for single-seat use only. A license is needed per user. Reference Description EALBTS1 Build - Standard Engineering Yearly EALBTS2 Build - Professional Engineering Yearly Run subscription-based licenses The Run subscription-based licenses are available in two different types: b Standard: for simplex applications. b High Availability: for high availability applications. The Run subscription-based licenses are sized per device. A license is needed per device. To know how to measure the number of devices of your application, refer to the EcoStruxure Automation Expert – Perpetual Licensing. Reference Description EALOMD1 Run - Standard Device Yearly EALOMD2 Run – High Availability Device Yearly Please contact your Schneider Electric representative for additional information. In addition to the advantages included in Perpetual licenses, subscription-based licenses include: b Access to upcoming software releases and features in the scope of your license b Customer adoption support plan, with a Trusted Advisor that will support you to reduce your time to value with each new release and its features, recommend the appropriate evolutions, and support you on license lifecycle and renewal process. Build Subscription (1-year term license, per user) Software Standard License Application Design Service Onsite Training, Lifecycle Consulting, Engineering Service Block of Support Service EAE Configuration Training Cybersecurity Assessment Service Application for Standard Device Professional License (including all options) Included in all packages: Customer Support Plan, Software Assurance, Customer Adoption Management Application for High Availability Device Yearly Services Ad hoc Run Subscription (1-year term license, per device) 26 Presentation, references (continued) Industrial automation systems EcoStruxure Automation Expert Licenses - Example EcoStruxure Automation Expert Licensing – Architecture Example of single high-availability architecture Build license Reference Description No. of Seats EALBTEP24 Lite Engineering License 1 Reference Description No. of Licenses EALBAHC Add-on for High Availability 1 Run license Unit 1 - High Availability Control 50 devices Reference Description No. of Licenses EALBAHC Application High Availability 10 Devices 5 Reference Description No. of Licenses EALH2P Automation Expert HMI Runtime Operator 1 50 Field Devices High Availability 27 Industrial automation systems EcoStruxure Automation Expert Licenses - Example EcoStruxure Automation Expert Licensing – Architecture Example of complex high-availability architecture Build license Reference Description No. of Seats EALBFC Professional Engineering License 1 Run license Unit 1 – High Availability Control 100 devices Reference Description No. of Seats Application High Availability 100 Devices 1EALDHACP Unit 2 – 1 M262d Control 50 devices Reference Description No. of Licenses EALAMP Application license for one dPAC runtime instance, MICRO 1 Unit 3 – Simplex Control 100 devices Reference Description No. of Licenses EALDCP Application Standard 100 Devices 1 100 Field Devices 100 Field Devices 50 Field Devices High Availability M262d Simplex Control Presentation, references (continued) 28 Compatibility Industrial automation systems EcoStruxure Automation Expert Product compatibility according to dPAC platform List of Modicon X80 hardware compatible with Modicon M580 dPAC, Modicon CRD for Simplex/High Availability Soft dPAC (Linux OS) Type Reference Description Compatibility with Modicon M580 dPAC Compatibility with Modicon CRD for Simplex/High Availability Soft dPAC (Linux OS) Rack BMEXBP0400 4-slot Ethernet backplane Yes Yes Rack BMEXBP0400H Ruggedized 4-slot Ethernet backplane Yes Yes Rack BMEXBP0602 6-slot Ethernet backplane redundant PS Yes Yes Rack BMEXBP0602H Ruggedized 6-slot Ethernet backplane redundant PS Yes Yes Rack BMEXBP0800 8-slot Ethernet backplane Yes Yes Rack BMEXBP0800H Ruggedized 8-slot Ethernet backplane Yes Yes Rack BMEXBP1002 10-slot Ethernet backplane redundant PS Yes Yes Rack BMEXBP1002H Ruggedized 10-slot Ethernet backplane redundant PS Yes Yes Rack BMEXBP1200 12-slot Ethernet backplane Yes Yes Rack BMEXBP1200H Ruggedized 12-slot Ethernet backplane Yes Yes Rack BMXXBC008K Backplane extension cable 0.8 m/2.6 ft Yes Yes Rack BMXXBC015K Backplane extension cable 1.5 m/4.9 ft Yes Yes Rack BMXXBC030K Backplane extension cable 3 m/9.8 ft Yes Yes Rack BMXXBC050K Backplane extension cable 5 m/16.4 ft Yes Yes Rack BMXXBC120K Backplane extension cable 12 m/39 ft Yes Yes Rack BMXXBE1000 Standard backplane extender Yes Yes Rack BMXXBE1000H Ruggedized standard backplane extender Yes Yes Rack BMXXBE2005 Backplane extender kit Yes Yes Rack BMXXBP0400 4-slot backplane Yes Yes Rack BMXXBP0400H Ruggedized 4-slot backplane Yes Yes Rack BMXXBP0600 6-slot backplane Yes Yes Rack BMXXBP0600H Ruggedized 6-slot backplane Yes Yes Rack BMXXBP0800 8-slot backplane Yes Yes Rack BMXXBP0800H Ruggedized 8-slot backplane Yes Yes Rack BMXXBP1200 12-slot backplane Yes Yes Rack BMXXBP1200H Ruggedized 12-slot backplane Yes Yes SD card BMXRMS004GPF Optional M580 SD card 4 GB Yes No Analog I/O BMXAMI0410 4 voltage/ current isolated high-speed analog inputs Yes Yes Analog I/O BMXAMI0410H Ruggedized 4 voltage/current isolated high-level analog inputs Yes No Analog I/O BMXAMI0800 8 voltage/current non-isolated fast analog inputs Yes No Analog I/O BMXAMI0810 8 voltage/current isolated fast analog inputs Yes Yes Analog I/O BMXAMI0810H Ruggedized 8 voltage/current isolated fast analog inputs Yes Yes Analog I/O BMXAMO0410 4 voltage/current isolated analog outputs Yes Yes Analog I/O BMXAMO0410H Ruggedized 4 voltage/current isolated analog outputs Yes Yes Analog I/O BMXAMO0802 8 current non-isolated analog outputs Yes Yes Analog I/O BMXAMM0600 4 analog inputs - 2 analog outputs Yes No Analog I/O BMXAMM0600H Ruggedized 4 analog inputs - 2 analog outputs Yes No Analog I/O BMXAMO0210 2 isolated analog outputs Yes No Analog I/O BMXAMO0210H Ruggedized 2 voltage/current isolated analog outputs Yes No Analog I/O BMXART0814 8 isolated TC/RTD inputs Yes Yes Analog I/O BMXART0814H Ruggedized 8 isolated TC/RTD inputs Yes Yes Analog I/O BMEAHI0812 8 current isolated analog inputs, HART No Yes Analog I/O BMEAHO0412 4 current isolated high-level analog outputs, HART No Yes Power BMXCPS2000 Standard AC power supply Yes Yes Power BMXCPS2010 Standard isolated DC power supply Yes Yes Power BMXCPS3020 High-power isolated 24 to 48 V DC power supply Yes Yes Power BMXCPS3020H Ruggedized high-power isolated 24 to 48 V DC power supply Yes Yes Power BMXCPS3500 High-power AC power supply Yes Yes Power BMXCPS3500H Ruggedized high-power AC power supply Yes Yes Power BMXCPS3522 Redundant 125 V DC power supply Yes Yes Power BMXCPS3540T High-power 125 V DC power supply Yes Yes Power BMXCPS4002 Redundant AC power supply Yes Yes Power BMXCPS4022 Redundant 24 to 48 V DC power supply Yes Yes Discrete I/O BMXDDI1602 16x 24 V DC sink discrete inputs Yes Yes Discrete I/O BMXDDI1602H Ruggedized 16x 24 V DC sink discrete inputs Yes Yes Discrete I/O BMXDDI3202K 32x 24 V DC sink discrete inputs Yes No

Discrete I/O BMXDDI6402K 64x 24 V DC sink discrete inputs Yes Yes Discrete I/O BMXDDM16025 8x 24 V DC discrete inputs, 8x discrete relay outputs Yes No Discrete I/O BMXDDM16025H Ruggedized 8x 24 V DC discrete inputs, 8x discrete relay outputs Yes No Discrete I/O BMXDDO1602 16 transistor source 0.5 A discrete outputs Yes Yes 29 Compatibility (continued) Industrial automation systems EcoStruxure Automation Expert Product compatibility according to dPAC platform List of Modicon X80 hardware compatible with Modicon M580 dPAC, Modicon CRD for Simplex/High Availability Soft dPAC (Linux OS) Type Reference Description Compatibility with Modicon M580 dPAC Compatibility with Modicon CRD for Simplex/High Availability Soft dPAC (Linux OS) Discrete I/O BMXDDO1602H Ruggedized 16 transistor source 0.5 A discrete outputs Yes Yes Discrete I/O BMXDDO6402K 64 transistor source 0.1 A discrete outputs Yes Yes Discrete I/O BMXDRA0815 8 isolated relay outputs Yes No Discrete I/O BMXDRA0815H Ruggedized 8 isolated relay outputs Yes No Discrete I/O BMXDRA1605 16 discrete relay outputs Yes No Discrete I/O BMXDRA1605H Ruggedized 16 discrete relay outputs Yes No Discrete I/O BMXDAI0814 8x 100...120 V AC isolated inputs Yes No Discrete I/O BMXDAI1604 16x 100...120 V AC capacitive inputs Yes No Discrete I/O BMXDAI1604H Ruggedized 16x 100...120 V AC capacitive inputs Yes No Discrete I/O BMXDAO1605 16x 100...240 V AC triac outputs Yes No Discrete I/O BMXDAO1605H Ruggedized 16x 100...240 V AC triac outputs Yes No Discrete I/O BMXDDM16022 8 inputs - 24 V DC - 8 outputs - solid state Yes No Discrete I/O BMXDDM16022H 8 inputs - 24 V DC - 8 outputs - solid state- severe environment Yes No Discrete I/O BMXDDM3202K 16x 24 V DC inputs - 16x solid state outputs Yes No Other BMXNRP0200 Fiber converter MM/LC 2-channel, 100 m/328 ft Yes No Other BMXNRP0201 Fiber converter SM/LC 2-channel, 100 m/328 ft Yes No Expert BMXEHC0800 8 high-speed counter channels Yes No Expert BMXEHC0800H Ruggedized 8 high-speed counter channels Yes No Expert BMXEAE0300 3-channel SSI encoder interface module Yes No Expert BMXEAE0300H Ruggedized 3-channel SSI encoder interface module Yes No 30 List of TM3 hardware compatible with Modicon M251 dPAC and M262 dPAC Type Reference Description Discrete I/O TM3DI16/TM3DI16G 16 discrete inputs Discrete I/O TM3DI32K 32 discrete inputs, HE10 connection Discrete I/O TM3DI8/TM3DI8A/TM3DI8G 8 discrete inputs Discrete I/O TM3DQ8T/TM3DQ8TG 8x 0.5 A transistor source discrete outputs Discrete I/O TM3DQ16T/TM3DQ16TG 16x 0.5 A transistor source discrete outputs Discrete I/O TM3DQ16R/TM3DQ16RG 16x 2 A discrete relay outputs Discrete I/O TM3DQ32TK 32x 0.1 A transistor source discrete outputs, HE10 connection Discrete I/O TM3DQ8U/TM3DQ8UG 8x 0.3 A transistor sink discrete outputs Discrete I/O TM3DQ16U/TM3DQ16UG 16x 0.3 A transistor sink discrete outputs Discrete I/O TM3DQ32UK 32x 0.4 A transistor sink discrete outputs, HE10 connection Analog I/O TM3AI2H/TM3AI2HG 2 high-resolution analog inputs, +-10 V, 0-10 V, 0-20 mA, 4-20 mA, 16-bit, 1 ms Analog I/O TM3AI4/TM3AI4G 4 analog inputs, +-10 V, 0-10 V, 0-20 mA, 4-20 mA, 12-bit, 1 ms Analog I/O TM3AI8/TM3AI8G 8 analog inputs, +-10 V, 0-10 V, 0-20 mA, 4-20 mA, 12-bit, 1 ms Analog I/O TM3AQ2/TM3AG2G 2 analog outputs, +-10 V, 0-10 V, 0-20 mA, 4-20 mA, 12-bit, 1 ms Analog I/O TM3AQ4/TM3AQ4G 4 analog outputs, +-10 V, 0-10 V, 0-20 mA, 4-20 mA, 12-bit, 1 ms Safety I/O TM3SAC5R/TM3SAC5RG CAT3 Safety, 1 function, max. PL d/SIL3, 3 outputs 6 A relays Safety I/O TM3SAF5R/TM3SAF5RG CAT4 Safety, 1 function, max. PL e/SIL3, 3 outputs 6 A relays Safety I/O TM3SAFL5R/TM3SAFL5RG CAT3 Safety, 2 functions, max. PL d/SIL3, 3 outputs 6 A relays Safety I/O TM3SAK6R/TM3SAK6RG CAT4 Safety, 3 functions, max. PL e/SIL3, 3 outputs 6 A relays Mixed analog I/O TM3AM6/TM3AM6G 4 analog outputs, 2 analog inputs, +-10 V, 0-10 V, 0-20 mA, 4-20 mA, 12-bit, 1 ms Thermocouple mixed TM3TM3/TM3TM3G 2 temperature inputs + 1 analog output TC (J, K, R, S, B, T, N, E, C, L) RTD (NI100, NI1000, PT100, PT1000) (+-10 V, 0-10 V) (0-20 mA, 4-20 mA) 16-bit, 100 ms Thermocouple input TM3TI4/TM3TI4G 4 temperature inputs TC (J, K, R, S, B, T, N, E, C, L) RTD (NI100, NI1000, PT100, PT1000), (+-10 V, 0-10 V) (0-20 mA, 4-20 mA) 16-bit, 100 ms Thermocouple input TM3TI8T/TM3TI8TG 8 temperature inputs, NTC, PTC, and TC (J, K, R, S, B, T, N, E, C, L), 16-bit 100 ms Relay I/O TM3DM8R/TM3DM8RG 8x 2 A relay outputs Relay I/O TM3DM24R/TM3DM24RG 24x 2 A relay outputs Relay I/O TM3DQ8R/TM3DQ8RG 8x 2 A relays outputs Other TM3XREC1 TM3 remote receiver module Other TM3XTRA1 TM3 remote transmitter module Other TM3XTYS4 TM3 parallel interface for 4 Tesys motor starters Expert TM3XHSC202/TM3XHSC202G High-speed counting, 2 HSC channels, 10 inputs, 8 outputs Compatibility (continued) Industrial automation systems EcoStruxure Automation Expert Product compatibility according to dPAC platform 31 Compatibility (continued) Industrial automation systems EcoStruxure Automation Expert Product compatibility according to dPAC platform List of Altivar hardware compatible with Altivar ATV dPAC Type Reference Description Compatible Drive ATV340●●●N4 Altivar Machine drives Yes Drive ATV340●●●N4E ≤ D22 Altivar Machine drives No Drive ATV340●●●N4E ≥ D30 Altivar Machine drives Yes Drive ATV630●●●●● ATV630●●●●●F Altivar Process drives Yes Drive ATV650●●●●● ATV650●●●●●E ATV650●●●●●F Altivar Process drives Yes Drive ATV930●●●●●

ATV930●●●●●C ATV930●●●●●F Altivar Process drives Yes Drive ATV950●●●●● ATV950●●●●●E ATV950●●●●●F Altivar Process drives Yes Drive ATV660●●●●● ATV680●●●●● Altivar Process drive systems Yes Drive ATV960●●●●● ATV980●●●●● Altivar Process drive systems Yes Drive ATV99●●●●● Altivar Process drive systems Yes Drive ATV6A0●●●●● ATV6B0●●●●● Altivar Process Modular drives Yes Drive ATV9A0●●●●● ATV9B0●●●●● Altivar Process Modular drives Yes Drive ATV6L0●●●●● ATV9L0●●●●● Altivar Process liquid-cooled drives Yes Other VW3A1111 Graphic display terminal Yes Other VW3A1112 Door mounting kit Yes Mixed I/O VW3A3203 Extended I/O module - 6 digital inputs/ 2 digital outputs/2 analog inputs Yes Mixed I/O VW3A3204 Extended relay module - 3 relay outputs Yes Encoder VW3A3420 Digital encoder interface module for Altivar 340 and Altivar 9pp variable speed drives Yes Encoder VW3A3422 Analog encoder interface module for Altivar 340 and Altivar 9pp variable speed drives Yes Encoder VW3A3423 Resolver interface module for Altivar 340 and Altivar 9pp variable speed drives Yes Encoder VW3A3424 HTL encoder interface module for Altivar 340 and Altivar 9pp variable speed drives Yes 32 References Modicon M580 dPAC Local I/O capacity Communication ports Service ports Reference Weight kg/lb Up to 1024 discrete I/O Up to 256 analog I/O 64 MB integrated memory 2 1 BMED581020 BMED581020C 0.848/ 1.872 Standards and certifications The Modicon M580 dPAC automation platform has been developed to comply with the principal national and international standards concerning electronic equipment for industrial automation systems. b Requirements specific to programmable controllers: functional characteristics, immunity, resistance, etc.: IEC/EN 61131-2 and IEC/ EN/UL/CSA 61010-2-201 b Requirements specific to power utility automation systems: IEC/EN 61000-6-5, IEC/EN 61850-3 (with installation restrictions) b Requirements specific to railway applications: EN 50155/ IEC 60571 (with installation restrictions) b Ex areas: v For USA and Canada: Hazardous location class I, division 2, groups A, B, C, and D v For other countries: CE ATEX (2014/34/EU) or IECEx in defined atmosphere Zone 2 (gas) and/or Zone 22 (dust) b Merchant navy requirements of the major international organizations: unified in IACS (International Association of Classification Societies) b Compliance with European Directives for CE marking: v Low voltage: 2014/35/EU v Electromagnetic compatibility: 2014/30/ EU v Machinery: 2006/42/EC Up-to-date information on which certifications have been obtained is available on our website. Modicon M580 dPACs are considered as open equipment and are designed for use in industrial environments, in pollution degree 2, overvoltage category II (IEC 60664-1), and in low-voltage installations, where the main power branch is protected on both wires by devices such as fuses or circuit breakers limiting the current to 15 A for North America and 16 A for the rest of the world. Industrial automation systems EcoStruxure Automation Expert Modicon M580 dPAC BMED581020 EAE_23643079_OPSPH20002 Characteristics Service conditions and recommendations relating to the environment Modicon M580 dPAC automation platform Modicon M580 dPAC harsh I/O platform Temperature Operation 0...60 °C/32...140 °F -25...+70 °C/-13...158 °F Storage -40...85 °C/-40...185 °F -40...85 °C/-40...185 °F Relative humidity (without condensation) Cyclical humidity 5...95% up to 55 °C/131 °F 5...95% up to 55 °C/131 °F Continuous humidity 5...93% up to 55 °C/131 °F 5...93% up to 60 °C/140 °F Altitude Operation 0…2,000 m/0...6,562 ft (full specification: temperature and isolation) 2,000...5,000 m/6,562...16,404 ft (temperature derating: approx. 1 °C/400 m (33.8 °F/1,312 ft), isolation 150 V/1,000 m (3,281 ft)) For accurate temperature derating calculation, refer to IEC 61131-2 Ed 4.0 Annex A Modicon X80 I/O power supply modules BMXCPS2010 BMXCPS3020 BMXCPS3020H BMXCPS3540T BMXCPS2000 BMXCPS3500 BMXCPS3500H BMXCPS4002 Supply voltage Nominal voltage 24 V c 24...48 V c 125 V c 100...240 V a 100...240 V a Limit voltages 18...31.2 V c 18...62.4 V c 100…150 V c 85...264 V a 85...264 V a Nominal frequencies – – – 50/60 Hz 50/60 Hz Limit frequencies – – – 47/63 Hz 47/63 Hz 33 Protective treatment of the Modicon M580 dPAC automation platform The Modicon M580 dPAC platform meets the requirements of “TC” treatment (treatment for all climates). For installations in industrial production workshops or environments corresponding to “TH” treatment (treatment for hot and humid environments), Modicon M580 dPAC must be embedded in enclosures with minimum IP54 protection. The Modicon M580 dPAC platform offers protection to IP20 level and protection against access to terminals (enclosed equipment) (1). They can therefore be installed without an enclosure in reserved-access areas that do not exceed pollution level 2 (control room with no dust-producing machine or activity). Pollution level 2 does not take account of more severe environmental conditions: air pollution by dust, smoke, corrosive or radioactive particles, vapors or salts, molds, insects, etc. (1) In cases where a slot is not occupied by a module, a BMXXEM010 protective cover must be installed. (e): Tests required by European directives (e) and based on IEC/EN 61131-2 standards. Environment tests Immunity to LF interference (e) (1) Name of test Standards Levels Voltage and frequency variations IEC/EN 61131-2; IEC/EN 61000-6-2; IEC 61000-4-11 0.85...1.10 Un - 0.94...1.04 Fn; 4 steps t = 30 min IACS E10; IEC 61000-4-11 0.80 Un...0.90 Fn; 1.20

Un...1.10 Fn; t = 1.5 s/5 s Direct voltage variations IEC/EN 61131-2; IEC 61000-4-29; IACS E10 (PLC not connected to charging battery) 0.85...1.2 Un + ripple: 5% peak; 2 steps t = 30 min Third harmonic IEC/EN 61131-2 H3 (10% Un), 0°/180°; 2 steps t = 5 min Voltage interruptions IEC/EN 61131-2; IEC/EN 61000-6-2; IEC 61000-4-11; IEC 61000-4-29; IACS E10 Power supply immunity: b 10 ms for a and c PS2 (20 ms DS criteria) b Check operating mode for longer interruptions up to 5 s, 85% Un b For IACS, 3 times 30 s in 5 min, 85% Un IEC/EN 61131-2; IEC/EN 61000-6-2; IEC 61000-4-11 For a PS2: b 20% Un, t0: ½ period b 40% Un, cycle 10/12 b 70% Un, cycle 25/30 b 0% Un, cycle 250/300 Voltage shut-down and start-up IEC/EN 61131-2 b Un…0…Un; t = Un/60 s b Umin…0…Umin; t = Umin/5 s b Umin…0.9 Udl…Umin; t = Umin/60 s Magnetic field IEC/EN 61131-2; IEC 61000-4-8 (for MV power stations: IEC 61000-6-5; IEC 61850-3) Power frequency: 50/60 Hz, 100 A/m continuous ...1,000 A/m; t = 3 s; 3 axes IEC 61000-4-10 Oscillatory: 100 kHz...1 MHz, 100 A/m; t = 9 s; 3 axes Conducted common mode disturbances range 0 Hz …150 kHz IEC 61000-4-16 (for MV power stations: IEC 61000-6-5; IEC 61850-3) For remote systems: b 50/60 Hz and c, 300 V, t = 1s b 50/60 Hz and c, 30 V, t = 1 min b 5 Hz…150 kHz, sweep 3 V…30 b For a: 10 V b For c: 10 V cont. or 100 V, t = 1 s Where: b PS1 applies to PLC supplied by battery, PS2 applies to PLC energized from a or c supplies b Un: nominal voltage; Fn: nominal frequency; Udl: detection level with power on (1) Devices must be installed, wired, and maintained in accordance with the instructions provided in the manual “Grounding and Electromagnetic Compatibility of PLC Systems”. (2) These tests are performed without an enclosure, with devices fixed on a metal grid and wired as per the recommendations in the manual “Grounding and Electromagnetic Compatibility of PLC systems”. (e): Tests required by European directives (e) and based on IEC/EN 61131-2 standards. References (continued) Industrial automation systems EcoStruxure Automation Expert Modicon M580 dPAC 34 References (continued) Modicon CRD, I/O bus over Ethernet for Simplex/High Availability Soft dPAC (Linux OS) RSTP Communication ports Service ports Reference Weight kg/lb 2 1 BMECRD0100 BMECRD0100C 0.848/1.872 Standards and certifications The Modicon CRD platform has been developed to comply with the principal national and international standards concerning electronic equipment for industrial automation systems. b Requirements specific to programmable controllers: functional characteristics, immunity, resistance, etc.: IEC/EN 61131-2 and IEC/EN/UL/CSA 61010-2-201 b Requirements specific to power utility automation systems: IEC/EN 61000-6-5, IEC/EN 61850-3 (with installation restrictions) b Requirements specific to railway applications: EN 50155/IEC 60571 (with installation restrictions) b Ex areas: v For USA and Canada: Hazardous location class I, division 2, groups A, B, C, and D v For other countries: CE ATEX (2014/34/EU) or IECEx in defined atmosphere Zone 2 (gas) and/or Zone 22 (dust) b Merchant navy requirements of the major international organizations: unified in IACS (International Association of Classification Societies) b Compliance with European Directives for CE marking: v Low voltage: 2014/35/EU v Electromagnetic compatibility: 2014/30/EU v Machinery: 2006/42/EC Up-to-date information on which certifications have been obtained is available on our website. Modicon CRD is considered as open equipment and are designed for use in industrial environments, in pollution degree 2, overvoltage category II (IEC 60664-1), and in low-voltage installations, where the main power branch is protected on both wires by devices such as fuses or circuit breakers limiting the current to 15 A for North America and 16 A for the rest of the world. Industrial automation systems EcoStruxure Automation Expert Modicon Ethernet Remote I/O BMECRD0100 BMECRD0100_main Characteristics Service conditions and recommendations relating to the environment Modicon CRD automation platform Modicon CRD harsh I/O platform Temperature Operation 0...60 °C/32...140 °F -25...+70 °C/-13...158 °F Storage -40...85 °C/-40...185 °F -40...85 °C/-40...185 °F Relative humidity (without condensation) Cyclical humidity 5...95% up to 55 °C/131 °F 5...95% up to 55 °C/131 °F Continuous humidity 5...93% up to 55 °C/131 °F 5...93% up to 60 °C/140 °F Altitude Operation 0…2,000 m/0...6,562 ft (full specification: temperature and isolation) 2,000...5,000 m/6,562...16,404 ft (temperature derating: approx. 1 °C/400 m (33.8 °F/1,312 ft), isolation 150 V/1,000 m (3,281 ft)) For accurate temperature derating calculation, refer to IEC 61131-2 Ed 4.0 Annex A Modicon X80 I/O power supply modules BMXCPS2010 BMXCPS3020 BMXCPS3020H BMXCPS3540T BMXCPS2000 BMXCPS3500 BMXCPS3500H BMXCPS4002 BMXCPS4002S BMXCPS4002H Supply voltage Nominal voltage 24 V c 24...48 V c 125 V c 100...240 V a 100...240 V a Limit voltages 18...31.2 V c 18...62.4 V c 100…150 V c 85...264 V a 85...264 V a Nominal frequencies – – – 50/60 Hz 50/60 Hz Limit frequencies – – – 47/63 Hz 47/63 Hz 35 Protective treatment of the Modicon CRD automation platform The Modicon CRD platform meets the requirements of “TC” treatment (treatment for all climates). For installations in industrial production workshops or environments corresponding to “TH” treatment (treatment for hot and humid environments), Modicon CRD must be embedded in enclosures with minimum IP54 protection. The Modicon CRD platform offers protection to IP20 level and protection against access to terminals (enclosed equipment) (1). They can therefore be installed without an enclosure in reserved-access areas that do not exceed pollution level 2 (control room with no dust-producing machine or activity). Pollution level 2 does not take account of more severe environmental conditions: air pollution by dust, smoke, corrosive or radioactive particles, vapors or salts, molds, insects, etc. (1) In cases where a slot is not occupied by a module, a BMXXEM010 protective cover must be installed. (e): Tests required by European directives (e) and based on IEC/EN 61131-2 standards. Environment tests Immunity to LF interference (e) (1) Name of test Standards Levels Voltage and frequency variations IEC/EN 61131-2; IEC/EN 61000-6-2; IEC 61000-4-11 0.85...1.10 Un - 0.94...1.04 Fn; 4 steps t = 30 min IACS E10; IEC 61000-4-11 0.80 Un...0.90 Fn; 1.20 Un...1.10 Fn; t = 1.5 s/5 s Direct voltage variations IEC/EN 61131-2; IEC 61000-4-29; IACS E10 (PLC not connected to charging battery) 0.85...1.2 Un + ripple: 5% peak; 2 steps t = 30 min Third harmonic IEC/EN 61131-2 H3 (10% Un), 0°/180°; 2 steps t = 5 min Voltage interruptions IEC/EN 61131-2; IEC/EN 61000-6-2; IEC 61000-4-11; IEC 61000-4-29; IACS E10 Power supply immunity: b 10 ms for a and c PS2 (20 ms DS criteria) b Check operating mode for longer interruptions up to 5 s, 85% Un b For IACS, 3 times 30 s in 5 min, 85% Un IEC/EN 61131-2; IEC/EN 61000-6-2; IEC 61000-4-11 For a PS2: b 20% Un, t0: ½ period b 40% Un, cycle 10/12 b 70% Un, cycle 25/30 b 0% Un, cycle 250/300 Voltage shut-down and start-up IEC/EN 61131-2 b Un…0…Un; t = Un/60 s b Umin…0…Umin; t = Umin/5 s b Umin…0.9 Udl…Umin; t = Umin/60 s Magnetic field IEC/EN 61131-2; IEC 61000-4-8 (for MV power stations: IEC 61000-6-5; IEC 61850-3) Power frequency: 50/60 Hz, 100 A/m continuous ...1,000 A/m; t = 3 s; 3 axes IEC 61000-4-10 Oscillatory: 100 kHz...1 MHz, 100 A/m; t = 9 s; 3 axes Conducted common mode disturbances range 0 Hz …150 kHz IEC 61000-4-16 (for MV power stations: IEC 61000-6-5; IEC 61850-3) For remote systems: b 50/60 Hz and c, 300 V, t = 1s b 50/60 Hz and c, 30 V, t = 1 min b 5 Hz…150 kHz, sweep 3 V…30 b For a: 10 V b For c: 10 V cont. or 100 V, t = 1 s Where: b PS1 applies to PLC supplied by battery, PS2 applies to PLC energized from a or c supplies b Un: nominal voltage; Fn: nominal frequency; Udl: detection level with power on (1) Devices must be installed, wired, and maintained in accordance with the instructions provided in the manual "Grounding and Electromagnetic Compatibility of PLC Systems". (2) These tests are performed without an enclosure, with devices fixed on a metal grid and wired as per the recommendations in the manual "Grounding and Electromagnetic Compatibility of PLC systems". (e): Tests required by European directives (e) and based on IEC/EN 61131-2 standards. References (continued) Industrial automation systems EcoStruxure Automation Expert Modicon Ethernet Remote I/O 36 Modicon M251 dPAC Local I/O capacity Device ports Service ports Reference Weight kg/lb No embedded I/O, supporting Modicon TM3 I/O expansion modules 2 1 TM251MDESE 0.848/ 1.872 Standards and certifications b Standards v IEC/EN 61131-2 (Edition 2 2007) v UL508 v ANSI/ISA 12.12.01-2007 v CSA C22.2 No. 213 and No. 142 b Certifications v e v cULus Listing Mark v RCM v Achilles v UKCA Environmental characteristics Service conditions and recommendations relating to the environment Temperature Operation Vertical installation: -10…35 °C/14…122 °F Horizontal installation: -10…55 °C/14…131 °F Storage -40…70 °C/-40…158 °F Relative humidity (without condensation) Operation 10...95% Storage Altitude Operation 0…2,000 m/0…6,562 ft: complete specification for temperature and exposure Storage 0…3,000 m (0…9,842 ft) Immunity to mechanical stress 1131 b Rail mounting: v 5…8.4 Hz (amplitude 3.5 mm/0.138 in.) v 8.4…150 Hz (acceleration 1 g) b Panel mounting: v 8.7…150 Hz (acceleration 3 g) Merchant Navy 2…13.2 Hz (amplitude 1.0 mm/0.039 in.) 13.2…100 Hz (acceleration 0.7 g) Supply charecteristics Power supply 24 V c Voltage limit Including ripple 19.2...28.8 V c Immunity to micro-cuts Class PS-2 10 ms Max. consumption 45 W References (continued) Industrial automation systems EcoStruxure Automation Expert Modicon M251 dPAC TM251MDESE EAE_23643079_OPSPH20005 37 Modicon M262 dPAC Local I/O capacity Device ports Service ports Reference Weight kg/lb No embedded I/O, supporting Modicon TM3 I/O expansion modules 2 1 TM262L01MDESE8T 0.655/ 1.444 Standards and certifications b Standards v IEC/EN 61131-2 (Edition 2 2007) v UL 61010-1, 61010-2-201 v ANSI/ISA 12.12.01-2007 v CSA C22.2 No. 213, No. 61010-1, No. 61010-2-201 b Certifications v e v cULus, cULus HazLoc Class I Division 2 CSA 22-2 No 213 v RCM v Achilles v KC v EAC Environmental characteristics Service conditions and recommendations relating to the environment Temperature Operation Vertical installation: -20…50 °C/-4…122 °F Horizontal installation: -20…60 °C/-4…140 °F Flat mounting: -20…45 °C/-4…113 °F Storage -40…85 °C/-40…185 °F Relative humidity (without condensation) Operation 5...95% Storage Altitude Operation 0…2,000 m/0…6,562 ft Storage 0…3,000 m (0…9,842 ft) Immunity to mechanical stress 3.5 mm at 2…8.4 Hz 1 gn at 8.4…200 Hz Supply charecteristics Power supply 24 V c (-15...20%) Voltage limit 20.4...28.8 V c Immunity to micro-cuts 0.01 ms Max. consumption 82 W References (continued) Industrial automation systems EcoStruxure Automation Expert Modicon M262 dPAC Modicon M262 dPAC module TM262L01MDESE8T_image 38 Altivar ATV dPAC ATV dPAC module Local I/O capacity Device ports

Service ports Reference Weight kg/lb Supporting Altivar Drives I/O embedded, expansion and encoder modules: b Up to 23 discrete I/O b Up to 7 analog I/O b 12 MB integrated memory 2 – VW3A3530D 0.020/ 0.044 Standards and certifications Depending on the specific drive type used for ATV dPAC integration, the standards and certifications must be checked in the corresponding ATV340/600/900 manual. b Standards v EN/IEC 61800-3 v EN/IEC 61800-5-1 v IEC 61000-3-12 v IEC 60721-3 v IEC 61508 v SEMI F47-0706 v UL508C and UL61800-5-1 v RoHS-2 according to EU directive 2002/95/EC v REACH according to EU regulation 1907/2006 b Certifications v CE v UL v CSA v RCM v EAC v ATEX v DNV-GL Environmental characteristics Altivar Process and Altivar Machine drives are designed to operate in a variety of environments, including harsh environments. The conditions stated below are general data and must be verified with the respective ATV600, ATV900, and ATV340 manuals for the specific drive type used. Service conditions and recommendations relating to the environment Temperature Operation As standard: -15...50 °C/+5...122 °F With derating: -15...60 °C/+5...140 °F Storage and transport -40…70 °C/-40…158 °F Relative humidity (without condensation) Operation 5...95% Storage Altitude Operation b 0…1,000 m/0… 3,281 ft without derating b 1,000…4,800 m/3,281…15,700 ft with derating of 1% per 100 m/328 ft Protection of drives IP20 to IP55 Withstand to harsh environment b Chemical class 3C3 conforming to IEC/EN 60721-3-3 b Mechanical class 3S3 conforming to IEC/EN 60721-3-3 b Printed circuit boards with protective coating Environmental characteristics Compliance with electromagnetic compatibility requirements has been incorporated into the design of Altivar Process and Altivar Machine drives. They are e marked according to the European EMC directive (2014/30/EU). Note: Depending on the specific drive type used for ATV dPAC integration, the EMC compliance values must be checked in the corresponding ATV340/600/900 manual. References (continued) Industrial automation systems EcoStruxure Automation Expert Altivar ATV dPAC VW3A3530D EAE_23643079_OPSPH20001 39 Graphic display terminal Description Reference Weight kg/lb To be used with ATV340 (ATV600 and ATV900 are equipped with the graphic display terminal as standard) Display 240 x 160 pixels, 8 lines Real-time clock with 10-year backup battery, to keep time when the drive is powered off Protection IP65 To be procured separately for ATV340 (delivered as standard with ATV600 and ATV900) VW3A1111 0.020/ 0.044 Remote mounting kit Description Reference Weight kg/ lb Remote mounting kit For remote mounting of graphic display terminal, suitable for ATV340, ATV600, and ATV900 families Protection IP65 VW3A1112 0.020/ 0.044 Remote mounting cordset Description Length (m/ ft) Reference Weight kg/lb Remote mounting cordset Equipped with 2 RJ45 connectors for connection of the graphic display terminal to the drive 1/ 3.28 VW3A1104R10 0.050/ 0.110 3/ 9.84 VW3A1104R30 0.150/ 0.331 5/ 16.4 VW3A1104R50 0.250/ 0.551 10/ 32.8 VW3A1104R100 0.500/ 1.102 Connector cable Description Length (m/ft) Reference Weight kg/lb USB/Mini B USB cable for connecting the display terminal to a PC – TCSXCNAMUM3P – VW3A1111 VW3A1112 PF130899PF130903 TCSXCNAMUM3P TCSXCNAMUM3P VW3A1104R10 EAE_23643079_OPSPH20003 References (continued) Industrial automation systems EcoStruxure Automation Expert Altivar ATV dPAC 40 Services Industrial automation systems Schneider Electric offers lifecycle services for your industrial automation systems based on EcoStruxure Automation Expert. Our lifecycle services include field and digital services. We believe, with our advanced processes and tools, we are your trusted expert in field and digital services to help you achieve greater functional safety, efficiency, sustainabilty, and resilience in your plant operations. We offer services that are designed to address your needs as you plan, install, operate, and optimize your industrial automation systems based on EcoStruxure Automation Expert. These include: b Consulting services b Maintenance and support services b Training Services b Migration Services For more information, visit our Industrial Automation Services page. Consulting services Consulting services are about bringing our expertise to help find solutions to some of your key operational challenges. Be it about maximizing the business value from your digital transformation initiatives, identifying improvement opportunities in your industrial automation system lifecycle management plans, or improving your cybersecurity posture and compliance, we can help. Take a look at some of our consulting offerings: Security consulting Our cybersecurity consultants will help you assess and review your EcoStruxure Automation Expert systems to detect gaps, identify risks, uncover any security malpractices, assess your staff's security competencies, provide emergency response services, and more. For more information, visit our Cybersecurity Services page. IA lifecycle consulting Audits performed by our service team provide insights and recommendations to help improve the maintenance plans of industrial automation assets. This service helps identify potential risks to the reliability and maintainability of these assets and plan mitigation actions. Watch the video to learn more about our IA Lifecyle Consulting Service. Maintenance and support services Our maintenance and support offerings help you quickly restore your operations in the event of an unplanned downtime incident. They can also help reduce the risk of occurrence and the associated costs. Take a look at some of our maintenance and support offerings: Extended warranty The extended warranty offer gives you the option to extend the warranty of selected Schneider Electric hardware by up to three years. Note: Please contact your Customer Care Center for offer availability. Spare parts, exchanges, and repairs These solutions help you to respond, in the most optimal manner, to requests for spare parts for your EcoStruxure Automation Expert system based on Schneider Electric hardware. Services include: b Parts management service: Onsite or shared spares inventory, managed by us, to help ensure parts availability, while optimizing costs. b Repair: Product repairs performed onsite when possible, or at our repair centers. b Exchange: A refurbished product is provided in exchange for a product returned with a detected fault. Note: Availability of these services may vary depending on the applicable Schneider Electric hardware. Please contact your Customer Care Center for offer availability. 41 Services (continued) Industrial automation systems Maintenance and support services (continued) Maintenance and support contracts Our Support and Maintenance Service Offers, are a simplified and modular annual support services agreements, designed to provide you with the right level of flexibility and confidence to meet your support and maintenance needs for your industrial automation systems based on EcoStruxure Automation Expert. Available as Advantage Service Plan (ASP) for Automation Control or as Customer FIRST (CF) Program for Automation Control, they offer a pre-packaged set of services relevant to operating & maintaining an EcoStruxure Automation Expert Systems. For further customization, a set of optional services are available. The following table provides a snapshot of the plan: Included Services Support Levels ASP CF Essential Primary Core Support and Services Priority Technical Support Access – NBH(a) SLA(b) SLA (b) mySchneider Portal Access – Premium support Yes Yes Software Version Update(c) Yes Yes Optional services(d) 24/7 Priority Technical Support – Phone Block of Support Hours (a) Normal Business Hours (b) Service Level Agreement (c) Excludes labor and hardware (d) Subject to local availability With the enhancements to EcoStruxure Automation Expert V24.0 licensing system, we will progressively offer a more digital experience for customers seeking to maintain the currency of their EcoStruxure Automation Expert software. With this experience, customers with our support and maintenance service offers, will be able to update, in a self-service mode, their EcoStruxure Automation Expert software installation, as and when installations are ready. Please contact your Customer Care Center for offer availability. Training services Our training services are designed for users to take maximum advantage of our industrial automation systems based on EcoStruxure Automation Expert. Our training catalog includes courses on: b Automation fundamentals b IEC 61499 concepts b EcoStruxure Automation Expert engineering and configuration For more information, please visit our Learning Services Home Page or send us an email. Modernization and migration services Over the years, we have been involved in migrating many major automation systems to Schneider Electric. Our migration services, based on this expertise and complemented by a set of dedicated tools, helps to minimize the risks and costs involved in such upgrades to an open EcoStruxure Automation Expert-based system. The available set of tools and services are outlined below: Tools and services Source platforms Tools and services Reverse engineering Application conversion service Wiring systems for Modicon X80 Schneider Electric Modicon Premium Yes 2023 Yes Rockwell Automation SLC 500 Yes Yes Yes PLC-5 Yes Yes Yes ControlLogix Yes 2023 _ In addition to the above, we can also offer project-specific solutions. Please contact your local service teams for more information. 42 Industrial automation systems EcoStruxure Automation Expert Product reference index Index A ATV340D11N4 31 ATV340D11N4E 31 ATV340D15N4 31 ATV340D15N4E 31 ATV340D18N4 31 ATV340D18N4E 31 ATV340D22N4 31 ATV340D22N4E 31 ATV340D30N4E 31 ATV340D37N4E 31 ATV340D45N4E 31 ATV340D55N4E 31 ATV340D75N4E 31 ATV340U07N4 31 ATV340U07N4E 31 ATV340U15N4 31 ATV340U15N4E 31 ATV340U22N4 31 ATV340U22N4E 31 ATV340U30N4 31 ATV340U30N4E 31 ATV340U40N4 31 ATV340U40N4E 31 ATV340U55N4 31 ATV340U55N4E 31 ATV340U75N4 31 ATV340U75N4E 31 ATV630C11N4 31 ATV630C11N4F 31 ATV630C13N4 31 ATV630C13N4F 31 ATV630C16N4 31 ATV630C16N4F 31 ATV630C20N4F 31 ATV630C22N4 31 ATV630C25N4 31 ATV630C25N4F 31 ATV630C31N4 31 ATV630C31N4F 31 ATV630D11N4 31 ATV630D15N4 31 ATV630D18N4 31 ATV630D22N4 31 ATV630D30N4 31 ATV630D37N4 31 ATV630D45N4 31 ATV630D55N4 31 ATV630D75N4 31 ATV630D90N4 31 ATV630U07N4 31 ATV630U15N4 31 ATV630U22N4 31 ATV630U30N4 31 ATV630U40N4 31 ATV630U55N4 31 ATV630U75N4 31 ATV650C11N4F 31 ATV650C13N4F 31 ATV650C16N4F 31 ATV650C20N4F 31 ATV650C25N4F 31 ATV650C31N4F 31 ATV650D11N4 31 ATV650D11N4E 31 ATV650D15N4 31 ATV650D15N4E 31 ATV650D18N4 31 ATV650D18N4E 31 ATV650D22N4 31 ATV650D22N4E 31 ATV650D30N4 31 ATV650D30N4E 31 ATV650D37N4 31 ATV650D37N4E 31 ATV650D45N4 31 ATV650D45N4E 31 ATV650D55N4 31 ATV650D55N4E 31 ATV650D75N4 31 ATV650D75N4E 31

ATV650D90N4 31 ATV650D90N4E 31 ATV650U07N4 31 ATV650U07N4E 31 ATV650U15N4 31
ATV650U15N4E 31 ATV650U22N4 31 ATV650U22N4E 31 ATV650U30N4 31 ATV650U30N4E 31
ATV650U40N4 31 ATV650U40N4E 31 ATV650U55N4 31 ATV650U55N4E 31 ATV650U75N4 31
ATV650U75N4E 31 ATV660C11Q4X1 31 ATV660C11T4X1 31 ATV660C13Q4X1 31 ATV660C13T4X1 31
ATV660C16Q4X1 31 ATV660C16T4X1 31 ATV660C20Q4X1 31 ATV660C20T4X1 31 ATV660C25Q4X1 31
ATV660C25T4X1 31 ATV660C31Q4X1 31 ATV660C31T4X1 31 ATV660C35Q4X1 31 ATV660C35T4X1 31
ATV660C40Q4X1 31 ATV660C40T4X1 31 ATV660C45Q4X1 31 ATV660C45T4X1 31 ATV660C50Q4X1 31
ATV660C50T4X1 31 ATV660C56Q4X1 31 ATV660C56T4X1 31 ATV660C63Q4X1 31 ATV660C63T4X1 31
ATV660C71Q4X1 31 ATV660C71T4X1 31 ATV660C80Q4X1 31 ATV660C80T4X1 31 ATV680C11Q4X1 31
ATV680C11T4X1 31 ATV680C13Q4X1 31 ATV680C13T4X1 31 ATV680C16Q4X1 31 ATV680C16T4X1 31
ATV680C20Q4X1 31 ATV680C20T4X1 31 ATV680C25Q4X1 31 ATV680C25T4X1 31 ATV680C31Q4X1 31
ATV680C31T4X1 31 ATV680C35Q4X1 31 ATV680C35T4X1 31 ATV680C40Q4X1 31 ATV680C40T4X1 31
ATV680C45Q4X1 31 ATV680C45T4X1 31 ATV680C50Q4X1 31 ATV680C50T4X1 31 ATV680C56Q4X1 31
ATV680C56T4X1 31 ATV680C63Q4X1 31 ATV680C63T4X1 31 ATV680C71Q4X1 31 ATV680C71T4X1 31
ATV680C80Q4X1 31 ATV680C80T4X1 31 ATV6A0C11N6 31 ATV6A0C11Q4 31 ATV6A0C11Q6 31
ATV6A0C11R4 31 ATV6A0C11S6 31 ATV6A0C11T4 31 ATV6A0C11T6 31 ATV6A0C13N6 31
ATV6A0C13Q4 31 ATV6A0C13Q6 31 ATV6A0C13R4 31 ATV6A0C13S6 31 ATV6A0C13T4 31
ATV6A0C13T6 31 ATV6A0C16N6 31 ATV6A0C16Q4 31 ATV6A0C16Q6 31 ATV6A0C16R4 31
ATV6A0C16S6 31 ATV6A0C16T4 31 ATV6A0C16T6 31 ATV6A0C20N6 31 ATV6A0C20Q4 31
ATV6A0C20Q6 31 ATV6A0C20R4 31 ATV6A0C20S6 31 ATV6A0C20T4 31 ATV6A0C20T6 31
ATV6A0C25N6 31 ATV6A0C25Q4 31 ATV6A0C25Q6 31 ATV6A0C25R4 31 ATV6A0C25T4 31
ATV6A0C25T6 31 ATV6A0C31N6 31 ATV6A0C31Q4 31 ATV6A0C31Q6 31 ATV6A0C31R4 31
ATV6A0C31T4 31 ATV6A0C31T6 31 ATV6A0C35Q4 31 ATV6A0C35R4 31 ATV6A0C35T4 31
ATV6A0C40N6 31 ATV6A0C40Q4 31 ATV6A0C40Q6 31 ATV6A0C40R4 31 ATV6A0C40T4 31
ATV6A0C40T6 31 ATV6A0C45Q4 31 ATV6A0C45R4 31 ATV6A0C45T4 31 ATV6A0C50N6 31
ATV6A0C50Q4 31 ATV6A0C50Q6 31 ATV6A0C50R4 31 ATV6A0C50T4 31 ATV6A0C50T6 31
ATV6A0C56Q4 31 ATV6A0C56R4 31 ATV6A0C56T4 31 ATV6A0C63N6 31 ATV6A0C63Q4 31
ATV6A0C63Q6 31 ATV6A0C63R4 31 ATV6A0C63T4 31 ATV6A0C63T6 31 ATV6A0C71Q4 31
ATV6A0C71R4 31 ATV6A0C71T4 31 ATV6A0C80N6 31 ATV6A0C80Q4 31 ATV6A0C80Q6 31
ATV6A0C80R4 31 ATV6A0C80T4 31 ATV6A0C80T6 31 ATV6A0M10N6 31 ATV6A0M10Q4 31
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automation systems EcoStruxure Automation Expert Product reference index Index (continued)
ATV6B0C20N6 31 ATV6B0C20Q4 31 ATV6B0C20Q6 31 ATV6B0C20R4 31 ATV6B0C20T4 31
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