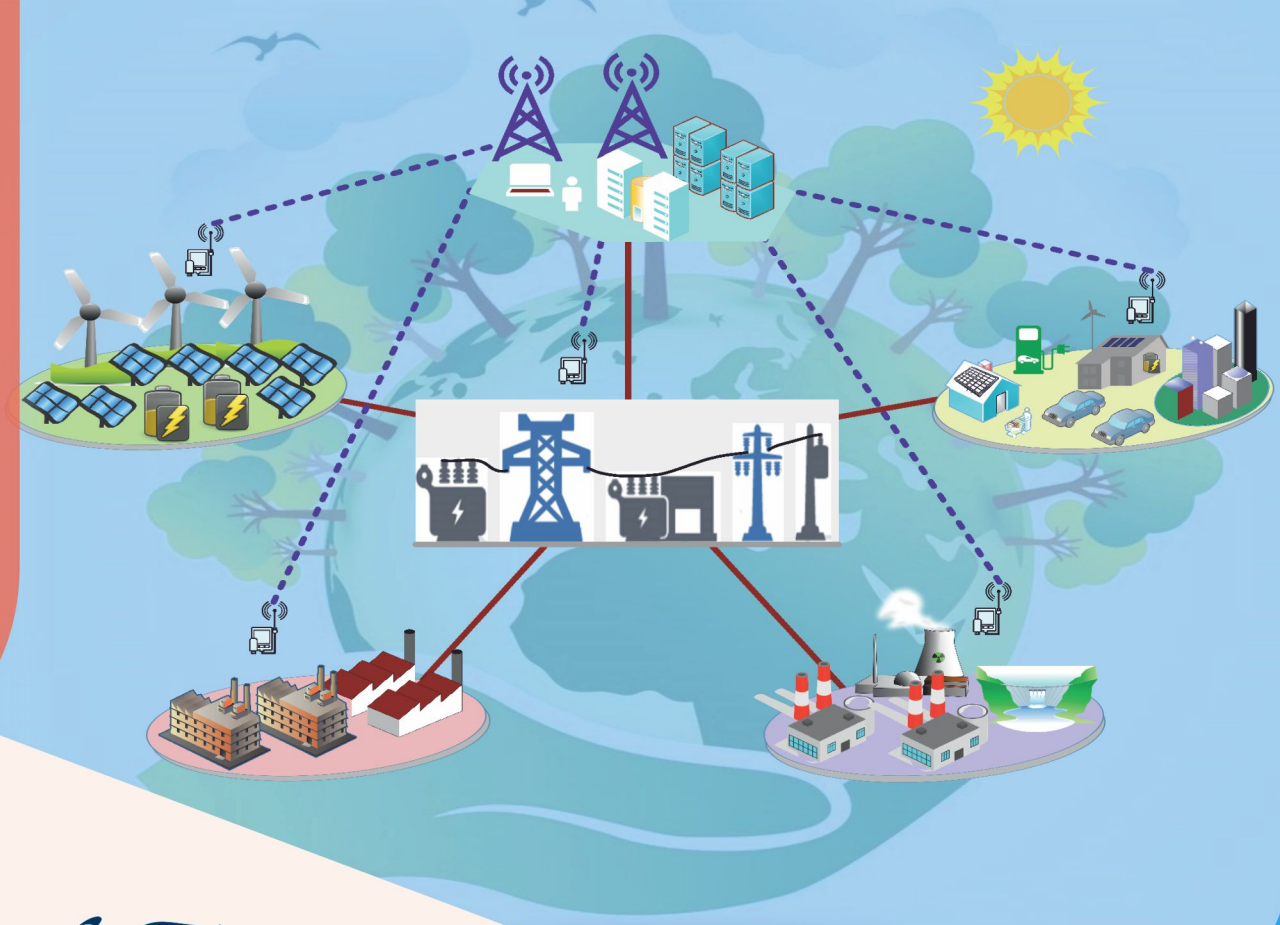

Book of Abstracts

ICPS 2021

9th International Conference on Power Systems (ICPS) 2021

December 16-18, 2021

Development towards Inclusive Growth for Sustainable and Resilient Grid

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Department of Electrical Engineering
and
School of Energy Science & Engineering

Indian Institute of Technology Kharagpur

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Developments towards Inclusive growth for Sustainable and Resilient Grid

IIT Kharagpur

16th - 18th December, 2021

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Tutorial Sessions

RE Rich Microgrid: Operation and Control

Tutorial-IA

Date: Thursday, Dec 16, 2021 **Time: 02:00 PM-04:00 PM**

Speaker: Sukumar Mishra, Professor, Department of Electrical Engineering, IIT Delhi, India

Abstract:

Distributed energy resources (DERs), mostly solar and wind farms, are getting prime interest of the power system operators to overcome shortage of fossil fuels and for sustainable growth of the grid. It is necessary to understand the behaviour of voltage source inverters (VSIs) due to its importance in integrating DERs in the microgrids. Additionally, good understanding of transition from synchronous generators to the VSIs is required to achieve smart operation and control of the power network. There are several methods available for effective operation of the VSIs, which are mostly categorized in three modes. Firstly, grid following (GFL) operation of VSIs to meet the voltage and frequency of the grid at the local point of common coupling. Secondly, VSIs operate in grid supporting (GS) mode. Some of the popular GS functionalities are frequency, reactive, inertial and voltage support. Power regulatory authority of different countries impose grid codes for the operation of generating units comprising of DER in the distribution system. The DER operator adheres to the grid codes to maintain operation of the VSI in GFL and GS mode. Last but not the least, grid forming (GFM) operation of the VSIs, which is effective in autonomous micro-grid. The DERs in the micro-grid are operated in conventional droop to handle active and reactive power flows to maintain demand and generation balance of the system. The widely used conventional droops are P-f and Q-V droop which are used in power sharing among the DERs. The choice of droop coefficient of the DERs is a critical task as it is highly motivated by the economics of the plant as well as the network parameters.

The tutorial will discuss all the detailed mathematical formulations, controller design and their working philosophy.

Generation Capacity Addition and Dispatch Modelling

Tutorial-IB

Date: Thursday, Dec 16, 2021 **Time: 02:00 PM-04:00 PM**

Speakers: Sreekumar Nhalur and Srihari Dukkipati, Member, Energy Group, Prayas, Pune, India

Abstract:

Over the last decade, renewable generation, mostly wind and solar, has displaced coal-based generation as the cheapest source of electricity in generation cost terms. It is also desirable to add as much renewables as the system can absorb, for local and global ecological reasons. Given this, and the strong policy push, the share of renewables in the Indian electricity grid has been increasing rapidly in recent years, with installed capacity of renewable power generation crossing 100GW.

Traditionally, power generation planning has been focussed on ensuring baseload capacity to meet demand in a reliable and cost-effective manner. This approach is increasingly insufficient to deal with the increased variability and intermittency of generation due to the high proportion of renewable generation in the power grid. Since solar and wind have no fuel costs, it is desirable to curtail them as little as possible, while ensuring system reliability. Battery storage costs have seen huge reductions in recent years and they are expected to continue to drop. This and the modular nature of battery storage, makes it an attractive option to manage diurnal variability and reduce curtailment of renewable generation. In addition, there are various initiatives such as the agriculture solar feeder scheme to shift load to times when generation cost is the lowest. With the advent of smart meters and ICT infrastructure, demand side management options such as time-of-day tariffs and demand response measures are becoming more feasible. Capacity planning and system operation need to consider all these aspects in order to arrive at a least-cost, reliable system.

The tutorial will present a modelling-based approach to optimise capacity addition and dispatch, while ensuring supply reliability. Case studies from the Indian power system will be discussed using results from models built in an open source power sector modelling platform named GridPath.

This tutorial would be of interest to industry and utility professionals, researchers, policy makers, regulators and planners.

Grid Resilience in the Presence of Renewable Generation

Tutorial-IIA

Date: Thursday, Dec 16, 2021 **Time: 05:20 PM-07:20 PM**

Speaker: Joydeep Mitra, Professor, Electrical and Computer Engineering, Michigan State University, USA

Abstract:

Since the beginning of this century we have witnessed an acceleration in the adoption of renewable energy resources and technologies. Various forces – social, political, economic, regulatory and technological – have driven the proliferation of numerous technologies that enable the conversion, control and integration of renewable energy resources. Despite their well-known benefits, these resources pose some challenges to grid operation. Concomitantly, there has been an emergence of factors such as extreme weather that also threaten reliability of electric service. These elements have contributed to an increased awareness of grid resilience. Resilience encompasses several diverse factors, and presents wide-ranging opportunities for innovation.

This tutorial will provide an introduction to grid resilience and its accompanying challenges and opportunities, particularly in the presence of renewable generation. It will discuss the fundamental aspects of resilience and traditional measures, both strategic and tactical, that are employed in modern grids to ensure resilience. It will discuss the impacts of renewable resources, particularly those resulting from the variability and the low-inertia characteristics of these resources, and illustrate these impacts with examples. It will present approaches for understanding and quantifying these impacts. It will explain how variability can be countered with systems and technologies ranging from storage and transmission expansion to demand response and “smart grid” control technologies. It will discuss the impacts on grid frequency regulation and the use of storage and operational strategies to mitigate them. The tutorial will conclude with a discussion of ongoing research toward ensuring grid resilience.

Practical Aspects for Design & Construction of High Voltage Semiconductor Power Modules

Tutorial-IIB

Date: Thursday, Dec 16, 2021 **Time: 05:20 PM-07:20 PM**

Speaker: Dipak Dutta, (Retired) AGM, Electronics Division, BHEL, Bangalore, India

Abstract:

Large amount of technical information is now available in the public domain in the form of books and technical papers on high voltage and high power modules & stacks used in Flexible AC Transmission Systems (FACTS) devices and Traction equipment.

But there is a dearth of information on the practical aspects of electrical and mechanical design and construction of these devices. One reason for this is that the manufacturers have developed their own techniques and designs which are different from each other even though the basic technology is the same.

This tutorial is about the practical aspects of design and construction of high voltage & high power switches used in FACTS, HVDC & Traction equipment restricting the discussion to only Thyristor and Silicon IGBT semiconductor power modules.

However most of the concepts presented will also hold good for equipment using Wide Band Gap (WBG) semiconductor devices too (e.g. Mosfets).

Introduction to a few FACTS equipment, classical & VSC-HVDC and Traction converters will also be covered in short without going into detailed theory of operation of these equipment. Thermal management and design of cooling systems (both Forced Air and Water) will also be covered during the tutorial.

Invited Talk Session

Smart Energy for Smart Cities

Date: Friday, Dec 17, 2021 **Time: 04:15 PM - 5:00 PM**

Speaker: Kunal Kumar, IAS, Joint Secretary & Mission Director (Smart Cities Mission), Ministry of Housing and Urban Affairs, Government of India

Abstract:

This talk will discuss about the India's urban landscape and its comparison in global prospective. It will also show the future projections for India's urban journey with the opportunities and challenges emerging from India's urbanization. The talk will be covering how the India's urban story interlink with its energy story and how is India's energy story shaping. Necessary requirement for improvement in current energy practices for cities in India considering different dimensions of smart energy will be discussed. This talk will illustrate the roadmap for cities to adopt smart energy and the necessary actions already initiated in this regard.

Keynote Sessions

PJM: Leading Reliable Operations, Competitive Markets and the Energy Transition

Inaugural Keynote

Date: Thursday, Dec 16, 2021 **Time: 10:00 AM-10:40 AM**

Speaker: Manu Asthana, President & CEO, PJM Interconnection, USA

Abstract:

This keynote address discusses about the PJM Interconnection, which oversees the largest power grid in North America and one of the largest electricity markets in the world. PJM Interconnection, founded in 1927, ensures the reliability of the high-voltage electric power system serving 65 million people in all or parts of 13 states of USA and the District of Columbia. PJM coordinates and directs the operation of the region's transmission grid, which includes over 85,103 miles of transmission lines; administers a competitive wholesale electricity market; and plans regional transmission expansion improvements to maintain grid reliability and relieve congestion. Asthana will talk about the organization's operations, markets and planning divisions and how they work together to make sure the system provides reliable electricity at least cost for 65 million consumers in the Eastern Interconnection. Asthana will also discuss the energy transition, PJM's capacity, energy and ancillary markets, and how the company is planning for the grid of the future.

Enabling Resilience for the DER-rich Power Distribution System

Keynote Session A I

Date: Friday, Dec 17, 2021 **Time: 09:00 AM-09:55 AM**

Speaker: Anurag Srivastava, Chairperson and Professor, Lane Department of Computer Science and Electrical Engineering, West Virginia University, USA

Abstract:

During adverse weather or cyber events, keeping the power on to critical facilities such as hospitals and fire department is essential. A number of resources are available with the integration of distributed energy resources (DER) to improve the sustainability in normal operation and resiliency of the critical loads during adverse events in active distribution system. There is a need for formal metrics to quantify the resiliency of the distribution electric grid, or different configurations of the same network. Additionally, advanced algorithms and tools are needed for the situational awareness and decision support to coordinate the DER management strategies for the distribution grid operators. This talk will cover the basics of DER integration, machine learning for estimating behind the meter DER, defining resiliency, DER based restoration, and a tool to study the resiliency of the DER-rich electric distribution grid.

Renewable Energy Generation and its Integration: Challenges and Solutions

Keynote Session A II

Date: Friday, Dec 17, 2021 **Time: 09:00 AM-09:55 AM**

Speaker: Janaka Ekanayake, Professor, University of Peradeniya, Sri Lanka

Abstract:

Many governments are encouraging an increase in the share of renewable energy (RE) in their national electricity generation mix. It is already evident that RE generators are being connected in all voltage levels. The intermittent and variable nature of the resource, the fluctuation caused by cloud cover and wind turbulences, and the single-phase nature of some REs causes many challenges for network operations and control. In this talk, the challenges faced by the modern grid with high penetration of renewables and possible solutions are discussed in detail while emphasising real-world examples.

Storage, the Ultimate Disruptor. Is There anything Storage cannot Do?

Keynote Session A III

Date: Friday, Dec 17, 2021 **Time: 09:00 AM-09:55 AM**

Speaker: Dr. Mani Vadari, President of Modern Grid Solutions, USA

Abstract:

Electric energy storage (EES) is a set of technologies that stores previously generated electric energy and releases that energy later. Storage uses forms of energy such as chemical, kinetic, thermal, or potential that can be converted to electricity on demand. The figure shows several commodities such as food, water, gasoline, and oil and natural gas, which have an average storage capacity of more than 10% of their daily consumption. In contrast, the electricity market in Massachusetts,for example, has a storage capacity of less than 1% of daily consumption. In addition, without storage, electricity needs to be produced, delivered, and consumed nearly instantaneously for the grid to maintain balance. This requires the entire electric value chain, including generation, transmission, and distribution systems, to be sized at yearly peak consumption, despite consumer electricity demand varying significantly throughout the day and at different seasons of the year.The need to size the entire electric value chain to peak consumption resulted in system inefficiencies, underutilization of assets, and a high cost to ratepayers.

During the Keynote Speech, Dr. Vadari will discuss the disruptive aspects of energy storage and what are the various use-cases for application from a combination of utility, customer, and investors perspective.

Collaborative Online Experiences in Indian Engineering Education

Keynote Session A IV

Date: Friday, Dec 17, 2021 **Time: 09:00 AM-09:55 AM**

Speaker: Dr. Anil K. Jampala, Senior Staff Software Engineer, GE Renewable energy, USA

Abstract:

An unexpected teaching opportunity of a 3rd year elective, electrical engineering undergraduate course at a USA university, soon became a challenge due to COVID-19. Many industry colleagues from the USA and Canada became resource persons for this course in the spring of 2020. This experience led me to try several initiatives in Indian engineering education in the last one year.

This paper shares our experiences in teaching a new advanced undergraduate course in Electric Systems Operations at two rural campuses in India as well as teaching a business course at a National Institute of Technology. As we have become resilient in adapting to COVID-19, we need to leverage this unique opportunity to better the pedagogy and also revisit the policies and framework.

Solar PV Integrations into National Grid: Challenges and Opportunities

Keynote Session B I

Date: Friday, Dec 17, 2021 **Time: 11:30 AM-12:25 PM**

Speaker: Tapan Saha, Professor, School of Electrical Engineering and Information Technology, University of Queensland, Australia

Abstract:

Extensive integration of solar PV generations into their distribution and transmission grids are progressing around the globe to meet their renewable energy targets and also to reduce carbon emissions. Solar PV generation is variable and hence they bring many challenges for network and overall grid management. At the University of Queensland, our research team has been involved in a number of solar PV integration projects, which include both small scale rooftop PV installations in distribution networks and large scale solar farms in transmission networks. This keynote speech will present some key outcomes and solutions from our research projects in PV integrations and grid managements.

Governance Aspects of Indian Power System

Keynote Session B II

Date: Friday, Dec 17, 2021 **Time: 11:30 AM-12:25 PM**

Speaker: S K Soonee, Advisor, POSOCO, India

Abstract:

Power system or any large interconnect needs good governance. Power system is manifestation and analogous to any large society. Both have all kinds of elements, some disciplined and law abiding while there are some non-compliant players acting as a threat to the power system. It is said that while regulation is from outside, Governance is from within. Governance of the power system and government are not exactly the same. While policies are by the government, the governance, regulation, planning and operation are by the statutory institutions. Unlike laws of physics, rules of governance are continuously refined, specific to the power system, depending on its maturity, policy and aspirations.

Who decides, who makes the rules, who implements the rules, who monitors, are the simple questions to be asked. Institutional engineering is one of the very important elements of Governance. Building a sustainable Institution takes time. The Indian power system has evolved in its mode of Governance, keeping intact the federal fabric of the country. Evolution of statutory institutions like CEA , CERC, SERC, SLDC , RLDC, NLDC , RPC, CTU , STU, APTEL as per the

Electricity Act 2003 define the roles and responsibilities as far as Governance of the entire interconnected Grid is concerned.

Socio Political compulsions and style of Governance are intertwined. Culture of Compliance is the bedrock for the overall success of the power system. Need for governance can't be substituted by technical solutions and every Power System, including INDIAN power system needs Good Governance.

Low-Inertia Very Large Grid Digital Twins using HYPERSIM EMT Simulator for Dynamic Transient Performance Evaluation

Keynote Session B III

Date: Friday, Dec 17, 2021 **Time: 11:30 AM-12:25 PM**

Speaker: Jean Belanger, President & CTO Opal-RT Technologies, Canada

Abstract:

Governments and economics encourage to decommission nuclear and coal generation systems and to integrate the maximum quantities of renewable solar and wind energy generation to decrease CO2 emission. Modern electrical grid infrastructure has therefore evolved from systems with high-inertia rotating machines to low-inertia inverter-based systems. The increased use of large quantities of inverter-based generators as well as power-electronic-based HVDC interconnection systems have the effect of decreasing the total system inertia, which make the system more sensitive and responsive to faults or other systems events. Sophisticated and fast control and protection systems must therefore be installed to ensure that the grid will return to normal and stable conditions after the event.

It is therefore evident that the integration of large quantities of inverter-based distributed renewable energy generation over very large territories heavily relying on Ethernet-based communication systems has increased the overall system complexity and has created a new level of fragility. Unless advanced countermeasures are implemented it is also obvious that modern grids will be more vulnerable to natural communication system failures and cyberattack, which could lead to partial or complete system blackouts and equipment failure.

The evaluation of transient performance of these low-inertia systems using approximated phasor-type model is questionable and some experts and utilities now contemplate the use of detailed EMT models of the grid interface with <real-code> confidential black box model of Wind and solar plants.

This presentation will present advancements and challenges to achieve real-time or faster than real-time simulation of very large low-inertia grid in relation with the Australian AEMO grid.

What About Hydrogen?

Keynote Session B IV

Date: Friday, Dec 17, 2021 **Time: 11:30 AM-12:25 PM**

Speaker: Arindam Ghosh, Professor, Curtin University, Australia

Abstract:

Due to the increasing concern for climate change and its implications on the future of humanity and this planet, renewable energy is being increasingly used in electric power generation. So far, Wind Power generation and Solar Photovoltaic based power generation have gained much attention and these technologies, along with different storage options are maturing very fast and the cost of their installation is reducing. Other technologies are under development including Concentrated Solar Power (CSP), Wave Power etc. and the 'Holy Grail' of energy production – Nuclear Fusion. Recently, however, Hydrogen has been mentioned very frequently around various countries in the world – both for automotive usage and for power generation.

Hydrogen has a high energy density by weight but has a low energy density by volume. Even when highly compressed, stored in solids, or liquified, the energy density by volume is only 1/4 that of gasoline, although the energy density by weight is approximately three times that of gasoline or natural gas. However, this is not a primary source of energy. Hydrogen, generated from renewable sources, has the potential to transport renewable energy long distance and store it long term. This talk will focus on the different aspects of hydrogen energy and will look at the plans that are being considered for the generation, storage, transportation, and usage of Hydrogen.

Digital Twins for Digital Transformation

Keynote Session C I

Date: Saturday, Dec 18, 2021 **Time: 09:00 AM-09:55 AM**

Speaker: Dr. Vinay Jammu, VP - Physical-Digital Technologies, GE Digital, India

Abstract:

Over the past few decades, dramatic improvements in communication and computing technologies have driven the growth of consumer internet which has improved efficiencies, increased customer base and created new business models in many industries including retail, banking, hospitality, and transportation. A confluence of these technologies is rapidly changing the landscape of what is possible in industrial internet area as well including power, transportation and healthcare industries by driving new outcomes and efficiencies that were not possible before. For example, 1% fuel saving in airline industry today is worth $30B over the next 15 years in the industry.

This talk will focus on Digital Twin technologies GE is driving for Digital Transformation of industries to improve efficiencies of industrial assets by bringing together sensing, monitoring, control, prognostics and optimization. Digital Twins are living personalized learning models of different assets that assist in improved decision making related to operation and maintenance of these assets. For example, Digital Twins models of turbine system in GE90 engine are used to optimize maintenance saving tens of millions of dollars in unnecessary overhauls. In manufacturing, Digital Thread and Digital Twins are being connected to reduce cycle time and improve manufacturing productivity.

Learnings from Global electricity Markets in Indian Context

Keynote Session C II

Date: Saturday, Dec 18, 2021 **Time: 09:00 AM-09:55 AM**

Speaker: S.S. Barpanda, Director, Market Operation, POSOCO, India

Abstract:

The achievement of a 21st century reliable and secure grid requires new design, new technologies, and new paradigms of operating the power system. Closer co-operation among all market players, be it generators, consumers, power exchanges, power suppliers or technology providers is key to the optimization of the overall system. Changing resource mix would need rigorous resource adequacy at granular level starting from energy security to load forecasting and portfolio balancing in all time horizons. The large synchronous grid of the Indian subcontinent facilitates harnessing diversity of various kinds.

Indian electricity market is one of the most dynamic electricity markets with its unique characteristics and behaviour. The four pillars of electricity market namely scheduling & despatch, imbalance handling, congestion management and ancillary services have been implemented in India. There is evolutionary nature of market development as per local context of resources and requirements. In India, long/medium term contracts with two-part tariff co-exist with energy only short term contracts. Market design has to complement reliability and help in energy transition. A number of far reaching changes like review of deviation settlement mechanism, market based procurement of ancillary services, market based economic despatch, general network access, shorter settlement period, capacity market and financial markets are on the anvil. The keynote address would attempt to share the learnings from developed global markets such as US, Europe and Australia which are relevant in Indian context.

Power Systems on the Cusp of Energy and Digital Transformation

Keynote Session C III

Date: Saturday, Dec 18, 2021 **Time: 09:00 AM-09:55 AM**

Speaker: Akilur Rahman, Chief Technology Officer, ABB Hitachi, India

Abstract:

With increasing renewable energy penetration and vision for carbon-neutral future, power systems are facing new challenges: complexity arising from a greater number of widely distributed and less predictable power generation sources; and the need to significantly upgrade and expand grid capacity to accommodate the rapid growth in demand including electric mobility, energy storage and electricity as a carrier of different forms of energy.

Power systems will be required to be more and more resilient, reliable, efficient, predictable, and secure. To achieve more flexibility in real-time, power electronics which used to be niche application will be widely used across the whole power grid. Automation and software in power systems has been evolving strongly since several decades with protection & control, SCADA, network management & control, wide area monitoring, communication technologies and application of advanced and complex mathematical algorithms. The same will be augmented with digital technologies, could computing, data science, AI-ML, AR-VR, digital twins, time-sensitive networking, block chain, and more to provide better predictability, asset & system performance, user experience and values.

Convergence of energy and digital technology platforms together with process and data science will be the key to take power systems to the next level of operation. This needs multiple

stakeholders like utilities, industries, infrastructures, academia, and policy makers to co-innovate and co-create power system of future with smarter and sustainable energy grid.

How Smart Distribution Systems and Microgrids will Advance Energy Diversity and Equity

Keynote Session C IV

Date: Saturday, Dec 18, 2021 **Time: 09:00 AM-09:55 AM**

Speaker: Noel Schulz, Professor, Washington State University, USA

Abstract:

In February 2021, the U.S. National Academy of Sciences, Engineering and Medicine (NASEM) published a report on "The Future of Electric Power in the United States" that highlighted five major needs for the future U.S. electric power system. The report included recommendations around engineering, business and policy challenges and needed innovations for creating electric power solutions that remain clean, sustainable, reliable, and resilient. This talk will discuss how the energy diversity of the US Pacific Northwest provides an excellent platform for advancing strategies for smart distribution systems and microgrids. Aspects of the integration of electrifying transportation will also be discussed.

The NASEM report also included a need to 'sustain the "social compact" to keep electricity affordable and equitable". Dr. Schulz's presentation will discuss how technical advances in the areas of smart distribution systems and microgrids provide opportunities to advance electricity equity in urban and rural communities. In addition to energy diversity and equity, she will discuss opportunities to increase the participation of underrepresented populations in the energy sector.

Power System Dynamic Phenomena: Correlating Theory with Real-life Measurements

Keynote Session D I

Date: Saturday, Dec 18, 2021 **Time: 11:40 AM-12:35 PM**

Speaker: A M Kulkarni, Professor, IIT Bombay, India

Abstract:

The study of the transient behaviour of a power system is of great practical importance. Mathematical modelling and analysis of a power system predicts fascinating phenomena, both “electro-magnetic” and “electro-mechanical,” like travelling waves, network resonances, unstable power swings, loss of synchronism etc. A few of these phenomena can be replicated using controlled experiments on scaled laboratory models, but in most cases it is difficult to scale down the realistic parameters of high power and high voltage components. Therefore, the phenomena are mostly revealed to a student through computer simulations, which are more flexible, but dependent on modelling accuracy.

A real-life power grid is continually subjected to naturally occurring disturbances, which reveal its underlying dynamic characteristics. Study of the transients following these disturbances can partly compensate for the subdued or missing laboratory experience. The availability of good instrumentation, precise time-synchronization, ample storage and easy exchange of information due to the internet can now facilitate the creation of a repository of real-life transient measurements, which can lead to a better appreciation of the theory.

To bring out this point, this talk presents a selection of interesting measurements obtained through laboratory experiments and real-life disturbance records, and connects them to the known theory.

Role of Electric Mobility in Energy Transition

Keynote Session D II

Date: Saturday, Dec 18, 2021 **Time: 11:40 AM-12:35 PM**

Speaker: Abhishek Ranajan, VP, BSES Rajdhani, India

Abstract:

To hold global average temperature increase to 1.5°C, global CO2 emissions need to reach net-zero by 2050, with rapid decarbonisation in all sectors. Global transport emissions have continued to steadily increase, with transport emissions accounting for about 24% of direct CO2 emissions from fuel combustion. In India, transport sector accounts for about 14% of our energy related CO2 emissions and road transport accounts for about 90% of transport sector’s energy consumption. The energy and carbon intensive sectors include manufacturing, construction and electricity

generation. Electrification of transportation provides us an opportunity to decarbonise transport sector and achieve zero emissions by 2050 in this area. Our rail systems are electrified to a large extent and there is an urgent need to phase out remaining diesel locos. Interestingly, electrification of road transport provides an opportunity to reduce emissions by 50% from BAU scenario by 2050. Light duty vehicles (cars, 3W etc) and 2 W constitute over 60% of vehicles on road and are the major source of emissions (inefficient 2 stroke and 4 stroke ICE). In Delhi scenario is no different. Therefore Delhi EV Policy notified in 2020 provide for incentives including purchase and scrapping incentives, interest subvention schemes , waiver of road taxes and registration fees. The focus is on 2W / 3W / 4W (both freight and passenger) as well as e-Buses. It also provides subsidy for AC chargers (first 30,000 AC charging points). Delhi Discoms have launched first of its kind of the empanelment of partners for providing single window EV charging as a service for its consumers in Delhi. (bundled with subsidized EV tariff as per Regulatory Commission). Times ahead are exciting and the race to zero emissions is getting hotter by day. We must seize this electrification opportunity while aggressively pursuing the strategy to green our power portfolio enabling complete decarbonisation of the sector.

Impact of Renewable Energy penetration on Power System Protection - Grid operator's perspective

Keynote Session D III

Date: Saturday, Dec 18, 2021 **Time: 11:40 AM-12:35 PM**

Speaker: T. Muthukumar, DGM, SRLDC, POSOCO, India

Abstract:

Government of India has set an ambitious target to integrate 175 GW of RE generation by 2022 and further to achieve a target of 450 GW by 2030. The present all India RES installed capacity is 101 GW (as on September 2021) and renewable energy has a share of 26% in the total installed generation capacity in the country. Few states like Karnataka have seen very high RE penetration i.e., nearly 90% instantaneous penetration and almost entire load of the state is met by renewables during high RE season. Increased RE penetration has also led to change in the load pattern of the states and few pockets in the grid experience higher loading during high RE generation period leading to stress in the network. This not only imposes challenges from the integration point of view but also leads to change in the dynamic behaviour of grid. All the more important is the protection aspects of RE as well as the associated system. It is desired that the protection system behaves in a manner for which it is designed. Various protection issues & challenges have been observed with RE (Wind & Solar) connected stations during real time grid operation such as tripping of RE generators due to mis-operation of anti-islanding relays; presence of high zero sequence current at PV inverter stations, high grid voltages in the night time and operation of over flux protection of transformers, protection co-ordination issues, permissible LVRT operation during

successive fault on transmission network, tripping of Inverters during momentary PLL loss of synchronism caused by phase jumps, distortion during grid events. All the protection aspects need to be well co-ordinated in-order to avoid any unwanted tripping which may have a profound and a large-scale impact on the grid. In future there will be large/ vast pockets of renewables in the grid and hence it is required to leverage on new technologies and use adaptive & wide area protection for RE in-order to make the protection system and the grid more resilient. There is need to develop a uniform protection philosophy/ guideline for RE sources and its associated system and carry out regular protection audits.

Future Grid Utilizing Smart Grid Technologies for Sustainable Development

Keynote Session D IV

Date: Saturday, Dec 18, 2021 **Time: 11:40 AM-12:35 PM**

Speaker: Subir Sen, COO, Powergrid, India

Abstract:

Reliable Power supply system, a critical infrastructure, plays a key role that support entire economy and day-to-day life of the citizens in the country. Legacy power supply system is undergoing through significant changes in the way electricity is generated, transmitted, distributed and utilised stimulated by the pressing need to decarbonize electricity supply, replace ageing assets and to make effective use of rapidly developing Information and Communication Technologies (ICTs). The supply system is gradually transitioning towards digital system through data-driven decision process and automation in addition to increasing penetration of renewable capacity, energy storage system etc. There is a paradigm shift from concentrated large conventional generation (thermal, hydro) to distributed renewable generation (wind, solar etc.). In the past one decade, the share of Renewable capacity in the overall capacity portfolio has substantially increased to about 102 GW. Under the changing scenario, the reliance on reliable power supply with self-healing and resilient grid is ever increasing.

Today, uninterrupted power supply with quality at an affordable price in an environmental friendly manner is the major area of concern. Recent developments in the sensing, monitoring, Information and communication technology, IoT applications like intelligent servers and computation, robotic process automation etc. have revolutionized the way complex, geographically distributed resources and power supply systems are monitored and controlled. This transformation is commonly referred to as Smart Grid, an emerging field of power supply system. It is a collection of complex, interdependent systems whose key functions is to ensure reliable and efficient power delivery through improved visualization, monitoring, enhanced situational awareness, integration

of variable and intermittent renewable energy resources through forecasting, real time monitoring & control and energy storage system, efficient asset management etc. In addition, digital power supply system is vulnerable to possible cyber attacks. Thus, continuous cyber-physical security vulnerability assessment and identification of mitigating measures are also an evolving area to maintain reliable and resilient digital power supply system. In order to transform the power supply system to digital system with above features in future, integration of various emerging technologies, policy advocacy, regulatory framework etc. suitable to Indian context along with awareness creation, capacity building and skill sets development are essential.

Invited Paper Sessions

Renewable Integrated Multi-Area Smart optimization Framework for Distribution Network Operators

Invited Paper I A

Date: Friday, Dec 17, 2021 **Time: 01:30 PM-01:50 PM**

Speaker: N P Padhy, Professor, Department of Electrical Engineering, IIT Roorkee, India

Abstract:

Increasing population growth results in expansion of distribution grids by connecting multiple areas under a main distribution substation, owned by a single distribution network operator (DNO). Optimal operation of this multi-area grid is quite challenging as demand profile and load criticality level of a pure residential area is significantly different from that of an area containing both residential and commercial consumers. The solution process becomes further challenging because of penetration of distributed renewable energy resources and battery storages. Comparatively lesser computational burden makes conventional centralized optimization techniques attractive for energy management, however their lengthy solution time and biases towards critical customers are the main impediments to its real world implementation. Aiming to suggest a secure, reliable, unbiased, customer friendly, economic and fast energy management framework to DNO for serving multiple renewable penetrated areas, this article presents a Stackelberg Game based distributed optimization strategy. A detailed case study simulation has been demonstrated on a 132 bus distribution grid, having one substation with four underneath areas, to showcase a comprehensive study between centralized and proposed distributed optimization approaches for providing smart solutions to the DNOs.

AMI Meter Data and Analytics can help to Optimize Grid Operation

Invited Paper I B

Date: Friday, Dec 17, 2021 **Time: 01:30 PM-01:50 PM**

Speaker: Dr. Raghu Pulakurthi, Senior Director, Data and Analytics, Flex Technologies Ltd, Hyderabad, India

Abstract:

The Advanced Metering Infrastructure (AMI) meters provide easy access to not only the consumption data but also to many other quality measurements that will help System operators to optimize the Grid operations. Data analytics then does the rest of the magic to bring the meaningful and actionable insights. This paper presents how Utilities are using data analytics methods to optimize the grid operations to save costs in several areas. These savings offset the costs incurred in implementing AMI meters and associated IT technologies.

Analytics by using measurement and event data collected from AMI meters' IoT capabilities can be divided into three areas. First, the bi-directional energy flow measurements from AMI meters will allow to detect any distributed energy generation assets such as Solar panels. The measurement data when aggregated at transformer level can tell which transformers are overloaded. Event data from the meters can be used to detect outages and power restoration. This data when extrapolated can be used to assess the extent of outage and the restoration times required. Secondly, the energy measurements taken by AMI meters at 15 minutes or hourly intervals can be used to predict the peak load and its contribution by each of the consumers. This when coupled with behavioral economics by giving Peak Time Rebate (PTR) to encourage customers to reduce the consumption during peak hours will reduce the peak load on the system. Third, advanced analytics techniques including machine learning algorithms can be used to forecast the generation of each of the distributed generation assets. This forecasted capacity is used by the Utility to decide how much additional electricity will need to be purchased from outside of the grid and fed into the Grid for forecasted weather conditions a day in advance.

Implementation Experience of Wholesale Electricity Markets in the North American Context

Invited Paper I C

Date: Friday, Dec 17, 2021 **Time: 01:30 PM-01:50 PM**

Speaker: Venkata Sivaram, Sr. Manager, Software Engineering, GE, Hyderabad, India

Abstract:

Subsequent to the National Energy Policy Act 1992, which paved the way for deregulation of electricity, Whole-sale Electricity Market Systems have been around in North America for about a couple of decades. Independent System Operators (ISOs)/Regional Transmission Operators (RTOs) operate these markets, with the prime objective of ensuring reliability of power supply, while administering market rules in a fair manner. It is basically a wedding of laws of Physics and Economics. While it can be said that the markets have performed fairly well in meeting their objectives with a few hiccups, of late, the challenges of ISOs/RTOs have grown enormously. The challenges can be broadly classified to come from the following sources:

- New actors on the energy landscape – renewables, Distributed Energy Resources (DERs), advances in grid technologies, fuel shifts
- Organization driven changes - fuelled internally through changes to footprints, desires to create new member services or other member-driven initiatives

A whole-sale electricity market system is a pretty complex system, consisting of several component systems such as Energy Management System, Market Management System, Settlements & Billing, being the prominent ones. The entry of renewables, DERs, advances in grid technologies necessitates several changes to these systems in terms of modelling and implementation of operational/market rules. The second category of challenges is driven internally by ISOs/RTOs, to meet the aspirations of their market participants to allow for new markets/services. Summarizing, though it may appear that whole-sale markets have fairly matured for the past two decades, the rate of change has not slowed down and the inertia of current implemented systems seems to slow

down that change. To meet these challenges and to make the solutions flexible, easily deployable, secure, resilient, it is time to implement Next Generation Market Systems, taking advantage of current advances in Information Technology and GE has embarked on that path.

Machine and Deep Learning Based Classification Approach for Power Quality Disturbances

Invited Paper I D

Date: Friday, Dec 17, 2021 **Time: 01:30 PM-01:50 PM**

Speaker: Celia Shahnaz, Professor, BUET, Bangladesh

Abstract:

The aim of this talk is to propose a new approach for the pattern recognition of power quality (PQ) disturbances based Deep learning Applications. In literature, it is found that due to the presence of non-linearity and noise on the original signal, it is hard to analyze them by second order statistics. Thus, an effective feature set considering higher order statistics (HOS) like variance, skewness, and kurtosis is found more effective and among all the classifiers, k-NN showed higher classification accuracy and robustness both in training and testing to detect the PQ disturbance events. In the era of Deep learning, different architectures are found outperforming previous state of the art methods in terms of classification accuracy.

Estimation of EV's Daily Load Profile in Bangkok Metropolitan City under Different Policy Scenarios

Invited Paper I E

Date: Friday, Dec 17, 2021 **Time: 01:30 PM-01:50 PM**

Speaker: Jai Govind Singh, Associate Professor, AIT Bangkok, Thailand

Abstract:

The Thailand government plans to support the increase of EVs in 2025, 2030, and 2036, leading to increased energy consumption problems. Several factors are responsible for EV daily load profile, including charging time, charging level, battery size, type of car, number of vehicles, and driving range. Thus, this work will show the daily EVs of the daily load profile in Bangkok metropolitan city, which could be used in the power development plan to handle this extra demand and avoid capacity shortage. Furthermore, this work used Monte Carlo simulation for the forecasting strategy to sample the starting charging time, charging level, battery size, and type of car to estimate the daily load demand of BEVs. The result shows that the maximum peak demand occurs in the latest case.

Investment Decision-Making in Power Systems Employing Data Monitoring Technology

Invited Paper II A

Date: Friday, Dec 17, 2021 **Time: 05:10 PM-05:30 PM**

Speaker: Fushuan Wen, Professor in Energy Systems, Tallinn University of Technology, Estonia

Abstract:

A new round of power industry restructuring in China has invoked changes to the supply and demand relationship in the emerging electricity markets, bringing new challenges to power grid companies and increasing the risks of grid investment. In order to promote the level of lean management and investment of grid companies, an optimal investment decision-making model for power grid investment is presented with data monitoring technology employed in this paper, including the development of an indicator system, the trend prediction of indicators, the early warning and control of the indicators, and data warehouse as the data management tool. Finally, 7150 power grid projects of a provincial grid company in China are taken as an example to demonstrate the feasibility and effectiveness of the method proposed.

Importance of Regional Technical Institutional Mechanism in South Asian Electricity Grid

Invited Paper II B

Date: Friday, Dec 17, 2021 **Time: 05:10 PM-05:30 PM**

Speaker: V K Agrawal, Technical Director (SARI/EI) / IRADe, India

Abstract:

Different countries in South Asia are witnessing a growing imbalance between energy demand and its supply from indigenous sources. Fostering cross-border electricity trade (CBET) is one of the key solutions to meet this challenge. At present most of the CBET is being carried out at a bilateral level. However, going forward, with the creation of newer and enhanced cross-border power trading opportunities, and trade of power on a trilateral/multilateral basis, the complexities towards coordinating the power systems of different countries may increase. Under such conditions, a regional technical institutional mechanism can play a very important role towards harmonization of system operation practices and integrated operation of power systems across the borders, in a secure and economical manner. The South Asia Regional Initiative for Energy Integration (SARI/EI), a long standing program of USAID, has been advocating the need for such cooperation in the system operation and long-term sustainability of CBET in the region. In this paper, a critical review has been made to analyze the different regional institutions and power pools in the different parts of the world, as well as regional multilateral forums in South Asia, such as SAARC, BIMSTEC, and SAFIR. Based on the learning from these, recommendations towards the formation of such an institution in South Asia have been provided. In the conclusion, the action plan towards achieving this goal and the specific gains from such activities have also been deliberated, including the optimization in power system operation and economics.

Success Story of India-Bangladesh Power System Operation

Invited Paper II C

Date: Friday, Dec 17, 2021 **Time: 05:10 PM-05:30 PM**

Speaker: Saif Rehman, Manager, POSOCO, India

Abstract:

This paper follows the evolution of electricity grid interconnections between India and Bangladesh over time. The governance, policy, and regulatory framework facilitating the cross-border exchanges is elaborated. The power system scenario in terms of demand and generation of both countries is also discussed. The major operational aspects, viz. operational coordination, data & voice communication, scheduling & dispatch, reactive power management, protection aspects, system protection schemes, outage coordination, and resilience are examined. Future outlook for expanding the energy coordination between India and Bangladesh and the paper concludes with the benefits accruing due to cross-border interconnections.

Looking beyond 175 GW Renewable Energy Integration in India - Challenges and Remedial Measures

Invited Paper II D

Date: Friday, Dec 17, 2021 **Time: 05:10 PM-05:30 PM**

Speaker: Dr. Nagaraja Ramappa, MD, PRDC, Bangalore, India

Abstract:

In Dec. 2015, India has set itself the ambitious goal of generating 175 GW of renewable energy by 2022. India has achieved 100GW RE penetration by 31st August, 2021.This has enabled India to look beyond 175 GW RE integration into the grid and India has set a target of 450 GW RE additions by 2030. The major initiatives taken to achieve the RE integration include: Deployment of storage facilities like pumped hydro storage as grid connected balancing sources, Enabling of secondary reserves like Automatic Generation Control (AGC) at generation sources, Utilization of Renewable Energy Management System to control the renewable energy as per grid requirements, Improving system operational practices with advanced technologies and tools in control centres, Dynamic reactive power control at grid level. At the planning front, deployment of country wide Integrated Resource Mapping tools like demand forecasting, generation adequacy and optimization can facilitate the DISCOMs to know the mix of generation resources including renewables for future years with present generation at least possible cost. These tools helps to design the required generation mix in the grid for future years and to quantify the correct amount of flexible sources like storage facilities with various use-case benefits applicable to Indian grid regulations. To mitigate the challenges of variability and uncertainty of the renewable generations, it is essential to add appropriately designed storage schemes. The storage system enables renewable generations to bridge the gap between the generation pattern of renewable sources of energy and the demand pattern. Electric transportation system being one of the cleanest among the

alternatives in the transportation system and green, if the electricity required to this mode of transportation is produced through the renewable energy resources, like hydro, wind and solar power, the carbon footprint can further be reduced. The technical talk discusses in detail the various measures taken, way forward and emphasizes how best the future Indian grid can be managed and brings about the nexus between Renewable Energy (RE), Energy Storage (ES) and Electric Vehicle (EV).

Behind the Meter Energy Storage: Role for Supporting Demand Response and Renewable Integration

Invited Paper II E

Date: Friday, Dec 17, 2021 **Time: 05:10 PM-05:30 PM**

Speaker: Dr. Rahul Walawalkar, President, India Energy Storage Alliance (IESA) & President & MD, Customized Energy Solutions, India

Abstract:

Advanced Energy Storage technologies are expected to dominate both stationary and emobility sector for the coming decade. While a lot of attention is provided to grid scale storage deployment, India Energy Storage Alliance anticipates that Behind the Meter (customer sited) energy storage will lead the adoption of stationary storage in India in coming 5 years. Indian consumers are not new to use of energy storage in form of lead acid batteries that have been the back bone of backup power for decades, but the advanced storage technologies such as li-ion batteries and flow batteries can completely transform the way customers get value from these investments. This presentation will provide overview of recent advances and anticipated improvements in techno commercial parameters for leading energy storage technologies in next 3-4 years.

Such adoption of advanced energy storage technologies by consumers will be driven by the desire of customers for adoption of renewable energy which has already reached parity with grid, and in fact for most of the C&I customers in India RE+storage can be cheaper than purchasing power from grid. With the scaling up of giga factories, this trend is expected to continue in the coming decade. In addition with improved cycle life and efficiency of advanced energy storage technologies, customers can also more actively participate in demand response opportunities provided by utilities and IEX. Of course, a lot of regulatory and policy work is required, but we can learn from the developed markets such as the US to understand the opportunities that exist for optimizing system costs as well as reducing price shocks due to supply demand imbalance.

Contributory Paper Sessions

Contributory Paper Session 1

Track 1.1 (PSPR01): Power Systems Protection

Date: Friday, Dec 17, 2021 **Time: 10:15 AM - 11:15 AM**

Paper Id: 178

Relay Coordination Algorithm with Limits on Minimum Operating Time of Customized Time Inverse Relays Characteristics

Author:
Manohar Singh Power Systems Division, Central Power Research Institute Bangalore, India

Abstract:
Operating time of overcurrent relays is minimized in most of the overcurrent relay coordination studies by minimizing the summation of operating time of the all main overcurrent relays. Non- standard time inverse overcurrent relay characteristics are further used for minimization of operating time of overcurrent relays in the distribution system where fault current contribution from the distributed energy resources (DER) is extremely weak. In practical, this fast optimized operating time of relay is very hard to realize in field. If this fast operating time is realized in field, then it may cause unwanted tripping of feeders during the network temporary faults. This article discusses a modified relay coordination algorithm in which, a lower limit is provided on the operating time of overcurrent relays to block their operation during the temporary fault periods. In addition to this contribution, the application of the customized time- inverse relay characteristics are also extended for maintaining the relay coordination in distribution system with integration of distributed energy resources.

Paper Id: 146

Fault Location during Power Swing using Local Measurements

Authors:
Neethu George Hitachi ABB Power Grids Bangalore, India
O.D. Naidu Hitachi ABB Power Grids Bangalore, India
Vedanta Pradhan Hitachi ABB Power Grids Bangalore, India

Abstract:
Power swings can occur due to disturbances in power system, including faults on transmission lines, loss of generation, and switching of transmission lines which are heavily loaded. The phenomenon is characterized by generators accelerating relative to one another. Maloperation of distance relay during power swing is prevented using Power Swing Blocking function in modern relays. Further, accurate operation of distance protection for faults during power swing is ensured by Power Swing Unblock function. Clearance of faults during power swing, to ensure continuous supply of power requires accurate fault location identification. Existing phasor-based fault location methods fail in this scenario, due to the unstable nature of the phasors estimated using traditional phasor estimation algorithms. The paper presents the shortcomings of existing fault location solutions for faults during power swing and presents a new time-domain based single-ended fault location solution for the same. The performance of the algorithm is verified using IEEE 39-bus system modelled in PSCAD.

Paper Id: 182

Fast and Sensitive Time-Domain Protection of Shunt Capacitor Banks

Authors:
Rabindra Mohanty — BITS Pilani, India
Ashok Kumar Pradhan — IIT Kharagpur, India

Abstract:
Protection of shunt capacitor bank is important for identifying an internal fault to improve its service reliability. This paper presents a time-domain protection of shunt capacitor banks with wye connection. The proposed method is sensitive to a single element failure in the capacitor bank and takes decision within a quarter cycle. The superimposed current in time-domain is computed using the subtraction of calculated current from the measured one in each phase of the capacitor bank. The superimposed component of current is zero for normal operation and non-zero for internal fault conditions. Both open and short circuit faults in the capacitor bank can be identified by the proposed method. Using the change in equivalent capacitance in each phase of the shunt capacitor bank, the number of failed capacitor element is obtained. Various cases; symmetrical fault, system voltage unbalance and poor transient response of capacitor voltage transformers are tested to validate the performance of the proposed method and found to be accurate. The issue with division operation in time-domain is also addressed in the paper.

Paper Id: 149

A System Independent Setting Based Power Swing Blocking Technique for Transmission Lines

Authors:
O.D. Naidu — Hitachi ABB Power Grids Bangalore, India
Vedanta Pradhan — Hitachi ABB Power Grids Bangalore, India

Abstract:
In this paper, a system independent setting-based power swing identification and blocking method is presented. The power swing is identified by monitoring the polarity change of superimposed component of voltage signal. The superimposed component is obtained by using a moving window average filter. The proposed method does not require the current signals and it will be suitable to implement for inverter-based resources and weak power systems. The proposed solution is verified with various fault situations. The results confirm that the proposed solution can differentiate between three-phase fault and power swing accurately.

Track 1.2 (MGDS01): Micro-Grid and Distribution System

Date: Friday, Dec 17, 2021 **Time: 10:15 AM - 11:15 AM**

Paper Id: 9

Multiport AC-DC-AC Interfacing Converter for Microgrid Applications

Authors:
Rajarshi Basu — IIT Madras, India
Mahesh Kumar Mishra — IIT Madras, India

Abstract:
Integration of renewable energy resources into the existing power system has been increasing significantly in recent times. This paper presents an AC-DC-AC converter for integrat- ing both AC and DC renewable energy resources into the power system using a single converter with reduced number of switches. The converter is compared against a similar existing topology for analysing the relative performance. A novel performance enhancement technique is proposed to minimize losses in the system. Application of the converter is depicted and verified through detailed simulation studies.

Paper Id: 183

A Low Voltage High Power Bidirectional Multi- Port DC-DC Converter for DC Microgrids

Authors:
Atanu Mondal — IIT Kharagpur, India
Debaprasad Kastha — IIT Kharagpur, India
Prabodh Bajpai — IIT Kharagpur, India

Abstract:
Multi-port DC-DC converters (MPCs) are gaining attention in recent times as it can integrate more than one energy sources and energy storage devices into a single converter block. In this paper, a MPC topology is proposed for battery and supercapacitor-based hybrid energy storage system which is suitable for low voltage high power application in a DC Microgrid. The converter utilizes a three-phase current fed Dual Active Bridge (DAB) structure which provides galvanic isolation between the battery bank and the load. A low voltage high power supercapacitor bank is integrated at the load side by means of two stage conversion to achieve high voltage gain. The wide range zero voltage switching (ZVS) of the three-phase current fed DAB and bidirectional operation between any two ports are the key features of the proposed MPC. In addition, the input current ripple of both the storage devices are greatly reduced due to the interleaved structure. The operation of the proposed MPC and closed loop control strategy are discussed. A 20kW system is designed and simulated in the MATLAB Simulink environment to verify the proposed converter topology.

Paper Id: 177

A Coordinated Strategy for Optimal Operation of Unbalanced EDN via BESS, VVO and DSM

Authors:
Vineeth Vijayan — IIT Kanpur, India
Abheejeet Mohapatra — IIT Kanpur, India
S. N. Singh — IIT Kanpur, India

Abstract:
Battery Energy Storage Systems (BESS) and De- mand Side Management (DSM) increase the efficiency of voltage control-based optimization in an distribution systems. This work proposes an integrated operation strategy in three-phase distri- bution systems for loss minimization, peak reduction, and volt- age/current

unbalance management. For effective implementation of load management, the proposed formulation uses a load-factor improvement scheme. Towards Volt-VAR Optimization (VVO), capacitor banks, voltage regulators, and smart inverters are deployed. Active power from BESS and solar-PV modules are injected into the grid using these inverters and the remaining kVA capacity is utilized towards reactive power support. The optimization problem is applied on the IEEE 123-bus test feeder and solved using Multi-Objective Particle Swarm Optimization. The integrated method provides superior results concerning the objective function, alongside minimizing the switching stress on participating devices.

Paper Id: 53

Application of Z-Source Circuit Breaker in a Solar PV based DC Microgrid with Battery Storage

Authors:

Sharyu Chevale	VNIT, Nagpur, India
Shubham Mahajan	VNIT, Nagpur, India
Jaideep Bedarkar	VNIT, Nagpur, India
Avinash Mathew	VNIT, Nagpur, India
A V D Prasad	VNIT, Nagpur, India
Arghya Mitra	VNIT, Nagpur, India

Abstract:

With the increase in need for power supply, distributed generation and subsequently the microgrids are attracting more attention. Among the different types of microgrids, DC microgrids have attained an upper hand in terms of efficiency, reliability, simplicity of control and integration of renewable energy sources. But simultaneously there are certain downsides of this system which include design and implementation of an appropriate protection system for DC microgrids to limit and clear the rapidly rising fault current in a timely manner. This paper aims to analyze the fault clearing and current limiting characteristics of modified bi-directional Z- source breaker with coupled inductor and modified uni- directional Z-source breaker with coupled inductor when incorporated in a DC microgrid system. Moreover the strategy for an increased reliability during the fault condition, in terms of uninterrupted power supply to the load, is also proposed here. A MATLAB simulation is carried out in order to evaluate the performance of the breaker.

Track 1.3 (PSDS01): Power System Dynamics & Stability

Date: Friday, Dec 17, 2021 **Time: 10:15 AM - 11:15 AM**

Paper Id: 40

Improving Frequency Regulation of Power System Using Primary and Secondary Reserves in Grid Integrated Wind Farms

Authors:
Priyatosh Mahish — IIT Delhi, India
Sukumar Mishra — IIT Delhi, India

Abstract:
Today, with integration of renewables in the grid, many synchronous generators (SGs) are shut down or operated at reduced power levels. This reduces inertia of the system which leads to stability issues. In such a situation, it is desirable to allow power reserve (PR) in renewable generation, along with SGs, which improves frequency regulation (FR) of the power system. For this purpose, in this paper, a reserve allocation (RA) method for grid integrated wind farms (WFs) is proposed. The RA allocates PR among primary and secondary reserves in each WF. These reserves are engaged in FR of the power system by rotor speed controller and pitch angle controller of wind generators in the WFs. The proposed RA is tested in modified New England 39 bus system with WFs. The proposed method is verified with different percentages of the primary and secondary reserves for constant and variable wind speed conditions at the WFs.

Paper Id: 82

Stability Analysis of Power System Connected to Wind Farm Using Eigenvalue Sensitivity Approach

Authors:
Balakrushna Sahu — IIT Ropar, India
Bibhu Prasad Padhy — IIT Ropar, India

Abstract:
This paper presents a comprehensive idea about the eigenvalue sensitivity analysis in a renewable source based power system. This method renders very useful information about power system stability studies. Based on two axis model theory an explicit mathematical model of a four bus test system containing a Doubly Fed Induction Generator (DFIG) based wind farm is developed. The eigenvalue sensitivity analysis corresponds to first-order derivative of the reduced state transition matrix of the power system is performed with respect to various system operating parameters. In this research the system operating parameters taken under considerations are line impedance, real and reactive power loading. Finally, Hopf-Bifurcation margin curve is given for different critical parameters.

Paper Id: 73

Impact of Different Penetration Level of Type-IV Renewable Energy Resources on Power System Dynamics

Authors:
Gayathri K — IIT Palakkad, India
Manas Kumar Jena — IIT Palakkad, India
Akshaya Kumar Moharana — Powertech Labs, Inc. Surrey, BC, Canada

Abstract:
The development of new smart grid technologies and the rising environmental concerns lead to increased penetration of green energy sources into the existing power grid. This increased penetration of renewable energy sources (RES) into the power system will affect system dynamics. This paper discusses the influence

of integrating full converter-based renewable energy sources on different system stability indicators (SSIs) such as rate of change of frequency (ROCOF), frequency nadir, etc. Different test systems such as Kundur's two area model and IEEE-9 bus system are considered to evaluate the impact of different penetration levels of RES on power system stability indicators. The response of the system to common contingencies such as generator outage, load shedding, faults, etc. are studied using Dynamic Security Assessment Tools (DSA Tools) from Powertech Labs. It is observed that the post- disturbance dynamic behavior of a conventional synchronous generator-dominated system is significantly different from that of an inverter-dominated system and it is heavily dependent on penetration level, type of disturbance, type of RES, etc.

Paper Id: 259

A Direct Method for Calculation of Steady-State Operating Conditions of a Doubly Fed Induction Generator

Authors:

D. R. Karthik — BITS Pilani, India

Shashidhara Mecha Kotian — NITK-Surathkal, India

Narayan Suresh Manjarekar — BITS Pilani, India

Abstract:

Sharing reactive power burden between the rotor side converter (RSC) and grid side converter (GSC) under normal conditions reduces the burden on RSC and improves its life- time expectancy. In this paper, a non-iterative or direct method for calculation of steady-state operating points of a doubly fed induction generator (DFIG), considering non-zero reactive power flow through grid side of DFIG, is developed. The approach also considers grid side filter losses. The direct initialization method is applied on both subsynchronous and supersynchronous steady- state models of DFIG. A comparison of initial values obtained at various modes of operation of DFIG is conducted. The approach helps in accurate initialization of DFIG in both subsynchronous and supersynchronous modes. The non-iterative approach also prevents non-convergence issues and significantly reduces the calculation time of DFIG internal variables.

Track 1.4 (LFDM01): Load Forecasting & Demand-side Management

Date: Friday, Dec 17, 2021 **Time: 10:15 AM - 11:15 AM**

Paper Id: 272

Load Forecasting for Rare Events Using LSTM

Authors:

Shivanjali Yadav	MNIT Jaipur, India
Anjali Jain	MNIT Jaipur, India
Kailash Chand Sharma	Dr. B.R. Ambedkar NIT Jalandhar, India
Rohit Bhakar	MNIT Jaipur, India

Abstract:
The increasing complexity in interaction of con- sumption patterns with meteorological, social and economic factors on rare events is making electricity demand forecasting a challenging task. Machine learning algorithms are best suited for demand forecasting. However, data available for rare events is sparse. This underscores the need of updating traditional demand forecasting techniques for the events where consumption of different customer types does not follow a systematic pattern rather are rare in occurrence. In this context, paper proposes a novel demand forecasting technique for rare events that investigates the change in load pattern and classifies customers for better accuracy. The proposed model has been implemented on Ausgrid consumers and Nord Pool regions to forecast America's Day and Christmas demand. Results showed that Long Short- Term Memory model with transfer learning inputs yields better forecasting results as compared to DNN, a benchmark model for forecasting.

Paper Id: 115

Load Forecast using ANN & VAR Techniques for North Eastern Regional (NER) Grid of India

Authors:

Nabarun Roy	NERLDC POSOCO Shillong, India
Praveen Tripathy	IIT Guwahati, India
Samar Chandra De	NERLDC POSOCO Shillong, India
Sheikh Shadruddin	NERLDC POSOCO Shillong, India
Bimal Swargiary	NERLDC POSOCO Shillong, India
Subhash Kumar	NERLDC POSOCO Shillong, India
Sangita Das	NERLDC POSOCO Shillong, India
Namrata Pathak	NERLDC POSOCO Shillong, India
Nishant Kumar Mishra	NERLDC POSOCO Shillong, India

Abstract:
The prediction of electric power or energy demand is required for efficient, economical, and reliable operation of the power system. Considering the importance of power demand forecasting, different models, as well as many new techniques have been proposed in recent times. In this paper, two forecasting methods have been used and compared. The artificial intelligence method, Artificial Neutral Network (ANN) is compared with Vector Auto-regressive (VAR) which is a statistical method. The methods are used to predict the Hourly day ahead short-term load for the NER states of India with two cases i.e. Weekday and Weekend (Saturday & Sunday). The result for the Assam State of India for a period of three days i.e., 23rd -25th January' 2021 has been presented in this paper. The comparison utilizes the Mean Absolute Percentage Error (MAPE). The simulation results have shown lower average values of MAPE for the three days in the ANN model (7.01 % w.r.t. SEM and 7.42% w.r.t. SCADA) than in the VAR model (7.49 % w.r.t. SEM and 7.94% w.r.t. SCADA) indicating better accuracy by the use of the ANN method in predicting the electric power demand forecast of the North-Eastern Region of India. Further, the performance of the ANN model in load prediction is also compared with other machine learning methods such as Random Forest (RF) and Support Vector Machines

(SVM).

Paper Id: 199

An Ensemble Approach for Short-Term Load Forecasting for DISCOMS of Delhi across the COVID-19 Scenario

Authors:

Manish Uppal	ReNew Power Pvt. Ltd. Gurugram, India
Rumita Kumari	ReNew Power Pvt. Ltd. Gurugram, India
Saurabh Shrivastava	ReNew Power Pvt. Ltd. Gurugram, India

Abstract:
The Covid-19 has presented unforeseen challenges to the world that has never been experienced before in history. None of the sectors remained unaffected & witnessed various changes in their day-to-day operations. The impact has also been observed in the power sector, which can easily be illustrated with load fluctuations. The balancing of load & supply in the energy sector is itself one of the critical & complex tasks which becomes more vulnerable to deviation in case of these unforeseen events. Despite using advanced systems like machine learning & artificial intelligence for load forecasting, utilities found the task challenging. This paper covers the impact of lockdown on load patterns of the Discoms of Delhi in the year 2020-21. The effect of weather on load is also analysed to demonstrate the critical correlation between them. The performance of the ensemble technique that has been proven beneficial for better load forecasting & has outperformed other existing models, even in the current pandemic situation, has also been analysed & validated through a comparative analysis against popular benchmark models.

Paper Id: 221

Cost Effective Operational Planning of a Retail Market with Distributed Generations

Authors:

Shaziya Rasheed	IIT Delhi, India
Abhijit R. Abhyankar	IIT Delhi, India

Abstract:
In the retail electricity market, retailers play a very crucial role. They exchange energy through the grid and serve the load demand. Encouragement to deploy more renewable energy sources and storage devices (R&SD) is giving an opportunity to the retailers to install their own distributed generators (DG). In such cases, a market framework must be designed to maintain the rational behavior of an electricity market. In this paper, a retail market simulation model is framed considering R&SD owned by retailers. Profit earned by all retailers is maximized individually, and loss is also minimized from a utility point of view. In this way, this problem can be designed in many ways. Two distinct algorithms based on mixed-integer conic program- ming are proposed here, depending upon the different solution approaches. The first algorithm is solved as a multi-objective optimization problem (OP) using -constraint method. The sec- ond algorithm is solved as mathematical programming with equilibrium constraints (MPEC) model, which is converted into a single objective OP. A non-cooperative game theory approach is employed in this algorithm to satisfy the multiple objectives for different players (retailers). The proposed methodology is implemented on the 16-bus distribution test system to analyze the feasibility and effectiveness of the proposed algorithms. Results of the proposed algorithms are also compared with the existing algorithm comprising no retailers.

Track 1.5 (RIEV01): Renewable Integration & Electric Vehicle

Date: Friday, Dec 17, 2021 **Time: 10:15 AM - 11:15 AM**

Paper Id: 114

Statistical Uncertainty Quantification of Wind Integrated Power System Subjected to Random Injections

Authors:
Suravi Thakur — IIT Delhi, India
Nilanjan Senroy — IIT Delhi, India

Abstract:
Due to the increasing penetration levels of power generation from variable and highly unpredictable sources like solar and wind energy, there is a need to take into account the uncertainty while dealing with the operation and flexibility of the power system. The contention is that classical time series methods are designed to analyze a series at a single and given sampling rate with the consequence that analysts are not often encouraged to think carefully about what an appropriate sampling rate might be. A method is proposed to answer the sampling rate question that incorporates the historical series, sampled at the faster rate. The heart of this method is a technique that is capable of coherently use data sampled at multiple rates. The input to the power system is modeled as stochastic excitations using Stochastic Differential Equations.

Paper Id: 90

DFIG Equivalence of a Wind Farm by Extended Kalman Filter based Parameters Estimation

Authors:
Akhilesh Prakash Gupta — IIT Kanpur, India
A. Mohapatra — IIT Kanpur, India
S. N. Singh — IIT Kanpur, India

Abstract:
The stability and reliability of the power system network are affected by the integration of large scale Wind Farms (WFs). Transient analysis of the power network using complex models of WFs is normally difficult. This paper, thus, proposes a Doubly-Fed Induction Generators (DFIGs) based equivalent model of large WF with its parameters estimated by the Extended Kalman Filter (EKF) approach. The proposed equivalent model of the wind farm is obtained by representing the rotor circuit of the DFIG as a constant current source. Hence, no measurements are required on the rotor side. The small- signal stability analysis proves the adequacy of the proposed model. The results are demonstrated for a practical model of the HornsRev1 WF integrated to the IEEE 39-bus system, and dynamic simulations of the aggregated model are compared to the complete detailed model. The simulation results show the efficiency, accuracy, and fast steady-state and dynamic analyses with the proposed aggregated model.

Paper Id: 180

A Novel Power Converter Configuration for Open-Winding PMSG based High-Power Wind Energy Conversion Systems

Authors:
Sayani Chatterjee — IIT Kharagpur, India
Debaprasad Kastha — IIT Kharagpur, India

Abstract:
This paper presents a novel configuration of an Open-Winding Permanent Magnet Synchronous Generator (OW- PMSG) based high-power Wind Energy Conversion System (WECS), with a unidirectional five-level (5L) converter on one side and a conventional bidirectional two-level (2L) converter on the other side of the

generator. The 5L converter is rated for the full system power while the 2L converter is rated only at a small fraction of the full system power rating. The proposed configuration has several advantages over a conventional star- connected PMSG connected to a unidirectional 5L converter, such as, better utilization of the generator voltage and current ratings, reduced overall machine side converter losses, consequently, higher efficiency, no zero crossing distortion in the machine line currents and hence, better machine current THD and lower harmonic losses and simplified control of the machine side converters. The proposed configuration is analyzed and validated in the MATLAB/Simulink platform and the results are discussed.

Paper Id: 39

Smooth Synchronization Capability of Distributed Generation based AC Microgrid

Authors:

Farheen Chishti — IIT Delhi, India

Bhim Singh — IIT Delhi, India

Abstract:

This paper deals with an effective control strategy that enables the seamless changeover in operating modes of the microgrid that consist of distributed generation and battery storage. An operational criterion is developed for the microgrid to incorporate selective mode transfer in different scenarios. The grid isolation from the microgrid leads to shift in operating control scheme i.e. from current to voltage control for switching the grid connected converter. The isolation/reconnection of the utility to the microgrid takes place with the help of static transfer switches (STS) that operate on the detection/clearance of faults. The high quality power is ensured by utilizing normalized least mean square-sign error (NLMS-SE) algorithm to evaluate the total current active component of loads. All pass filter based frequency locked loop (APF-FLL) effectively estimates the phase angle of grid under phase and frequency oscillations prevailing in the system under synchronization. The proportional resonant (PR) controller regulate the load voltages during voltage control operating mode. The microgrid allows sensitive load operation, uninterrupted residential load supply and improved power quality and these are confirmed from MATLAB simulated results.

Contributory Paper Session 2

Track 2.1 (PSPR02): Power System Protection

Date: Friday, Dec 17, 2021 **Time: 01:50 PM - 02:50 PM**

Paper Id: 25

An Extensive Review on Microgrid Protection Issues, Techniques and Solutions

Authors:
Ekta Gairola — NIT Uttarakhand, India
Mahiraj Singh Rawat — NIT Uttarakhand, India

Abstract:
Past decade has witnessed a constant reduction in conventional energy resources and a surge of environmental concerns globally. Distributed generations now stand as a potential replacement to suffice for the vast spectrum of power requirements. As an efficient amalgamation of distributed resources, microgrids deliver dependable and cost-effective power. In the instances of faults being induced in the main grid, it becomes pertinent that the distribution system operates separated from grid generators, which results in the islanded operation mode. In islanded microgrid, due to inverter based sources, maximum fault current is limited to 2 p.u. These reduced fault currents and alteration in magnitude and direction of fault current, due to the transition between grid connected and islanded mode, renders the conventional protection schemes ineffective. This paper addresses to various protection issues and protection schemes in a microgrid. The advantages and limitations of various protection schemes are also covered.

Paper Id: 12

An Intelligent Differential Protection Scheme for DC Microgrid

Authors:
Nikhil Sharma — IIT Bhubaneswar, India
Abha Saxena — IIT Bhubaneswar, India
Subhransu Samantaray — IIT Bhubaneswar, India

Abstract:
This paper proposes a differential current based intelligent fault detection technique for DC microgrids. The currents of both ends of the faulted line is utilized for the computation of differential current. This differential current is then processed through the machine learning (ML) technique named as support vector machine (SVM) for fault detection in low voltage DC (LVDC) microgrids. The SVM based protection technique is tested on a LVDC microgrid integrated with different types of renewable energy sources (RES) modelled in the SIMULINK platform. The presented protection scheme is examined for pole-ground (PG) and pole-pole (PP) faults with varying fault resistance, fault location and RES penetration in grid-connected and islanding mode. The proposed methodology is verified for its capability to discriminate the transient no-fault condition from fault cases.This paper proposes a differential current based intelligent fault detection technique for DC microgrids. The currents of both ends of the faulted line is utilized for the computation of differential current. This differential current is then processed through the machine learning (ML) technique named as support vector machine (SVM) for fault detection in low voltage DC (LVDC) microgrids. The SVM based protection technique is tested on a LVDC microgrid integrated with different types of renewable energy sources (RES) modelled in the SIMULINK platform. The presented protection scheme is examined for pole-ground (PG) and pole-pole (PP) faults with varying fault resistance, fault location and RES penetration in grid-connected and islanding mode. The proposed methodology is verified for its capability to discriminate the transient no-fault

condition from fault cases.

Paper Id: 8

Adaptive Voltage Restrained Overcurrent Relaying for Protection of Distribution System with PV Plant

Authors:

Priyanka Mishra	IIT Kharagpur, India
Ashok Pradhan	IIT Kharagpur, India
Prabodh Bajpai	IIT Kharagpur, India

Abstract:

With the integration of inverter based solar photovoltaic (PV) plant in the distribution system, the fault current behavior changes significantly which limits the application of overcurrent relay (OCR) for line protection. As a solution, voltage restrained overcurrent relay (VR-OCR) can be used for line protection. The loading condition of distribution system further limits the application of VR-OCR. This work highlights the issue with the existing VR-OCR scheme and proposes a protection scheme that changes the pickup settings of VR-OCR adaptively to suit the prevailing power system conditions. At a sampling rate of 1200 samples/sec for 60 Hz system, the method updates its setting at each cycle and uses it for protection decisions. Using MATLAB/Simulink, the performance of the proposed scheme is tested for various loading conditions and fault resistances in a PV connected distribution system. Hardware-in-loop testing using real-time simulator OPAL-RT and IEC 61850 communication protocol validates the proposed method in real-time application.

Paper Id: 110

Line Protection Challenges and Its Mitigation in a New Grid Scenario

Authors:

Jaisaikiran reddy Kurre	IIT Kharagpur, India
Subhadeep Paladhi	IIT Kharagpur, India
Ashok Pradhan	IIT Kharagpur, India

Abstract:

A noticeable transformation in the power network fault characteristics is being observed with the large-scale integration of renewable sources. Control operations associated with renewable plant interfacing converters challenge the available line protection schemes, especially for lines integrating such sources to the grid. Such an issue with available distance protection for lines interconnecting renewable sources is addressed here with a solution, especially for zone-1 operation. Two indices are formulated in the proposed method using local end current and voltage data to ensure correct zone-1 decision. Proposed method is assessed for its performance for different fault situations in a 39-bus New England system with renewable integration and the results are accurate. Comparative analysis with conventional distance protection schemes indicates the strength of the proposed method.

Track 2.2 (MGDS02): Micro-Grid and Distribution System

Date: Friday, Dec 17, 2021 **Time: 01:50 PM - 02:50 PM**

Paper Id: 238

Unscheduled Intentional Islanding in Microgrid using Trust Region based Sequential Linear Programming

Authors:
Abhisek Mishra — IIT Roorkee, India
Premlata Jana — IIT Roorkee, India

Abstract:
In this paper, a novel Trust Region based Sequential Linear Programming (TRSLP) method is proposed for unscheduled intentional islanding in microgrid. In unscheduled islanding, the solution must be obtained with minimum time and minimum load curtailment by maintaining all the system parameter constraints intact. First, the unscheduled intentional islanding is formulated as a nonlinear constrained optimization problem. Then, the TRSLP based optimization method is employed to obtain the final switching sequence of the network so that intentional islanding can be done in optimal manner. The objective function of the optimization problem is to minimize the amount of load curtailment. To validate the proposed technique, a 7-bus microgrid test system is simulated in Real-Time Digital Simulator (RTDS) and corresponding system parameters are further used in the TRSLP optimization technique to get the optimal islanding area.

Paper Id: 84

Synchrosqueezing Wavelet Transform based Identification of Transient Events in AC Microgrid

Authors:
Ayushi Gupta — IET Lucknow, India
Seethalekshmi K. — IET Lucknow, India

Abstract:
This paper deals with the identification of transient events in AC microgrid using continuous wavelet transform-based synchrnosqueezing transform. The traditional time-frequency (TF) transforms always generate low-resolution Time-Frequency Responses (TFR). However, Synchrosqueezing transform is a reassignment method that provides a high-resolution time-frequency spectrum while being invertible. In this paper, the focus is put on the wavelet-based synchrosqueezed transform (SWT) that represents the joint application of time-frequency transformation and T-F enhancement. The transient events considered in this study, include single line-ground (L-G) fault, three-phase fault (dead short circuit), load switching, grid disconnection, and distributed generation (DG) switching. SWT is also compared with other time-frequency transforms, namely, continuous wavelet transform (CWT) and S-transform. SWT gives a more concentrated and sharp TFR which improves the readability of the spectrum. Secondly, the effectiveness of the synchrosqueezing wavelet transform (SWT) over other time-frequency transforms including continuous wavelet transform (CWT), S-transform is verified by computing Renyi entropy as a performance indicator.

Paper Id: 243

Stealth Attacks in Microgrids: Modeling Principles and Detection

Authors:

Devakumar Annavaram — IIT Delhi, India
Subham Sahoo — Aalborg University, Denmark
Sukumar Mishra — IIT Delhi, India

Abstract:

This paper proposes a attack index to detect stealth attacks on current sensor information in a distributed controlled DC microgrids. Stealth attacks are considered the intelligent false data injection attack where it satisfies consensus algorithm objectives in the secondary control. This particular study is carried out on a secondary controller, which is highly prone to cyber-attacks due to involved communication. An attack index (AI) is calculated to detect the stealth attack on the current sensor information, which effectively identifies the stealth attack with existing low bandwidth communication. A stealth attack on current sensor information to the DC microgrid's secondary controller is simulated using Matlab/Simulink environment, and attack detection results are presented and verified with the experimental result.

Paper Id: 148

Active Islanding Detection with Parallel Inverters in Microgrid

Authors:

Sahil Gaurav — IIT Bhilai, India
Prashant Agnihtri — IIT Bhilai, India

Abstract:

Distributed energy resources (DERs) connected to the main grid may experience unintentional islanding. The most widely used technique for islanding detection is the passive islanding detection method. However, conventional passive methods have wider non-detection zone (NDZ) area. Failure to detect unintentional islanding events impose various issues like voltage & frequency instability, power quality degradation, protective devices malfunctioning, equipment damage, and threats to line workers. This paper presents active islanding detection for parallel inverters in AC microgrid in which the effects of d-axis and q-axis disturbance current injection are analysed and compared. Further, the outcomes of current injection at different parameters through multiple inverters have been shown and discussed. The simulation results of the active islanding detection are obtained using MATLAB/Simulink.

Track 2.3 (PSSR01): Power System Security & Reliability

Date: Friday, Dec 17, 2021 **Time: 01:50 PM - 02:50 PM**

Paper Id: 189

Adequacy and Limitations of the Information Technology Act in Addressing Cyber-Security Issues of Indian Power Systems

Authors:
Sarasij Das — IISc Bangalore, India

Abstract:
Conventional power grids are being transformed into Indian Power Systems with the help of modern computer technologies. India is not an exception. Though the increasing use of computer and computer systems has improved the performance of the Indian power grid, it has brought new challenges. Digital protection, monitoring and metering devices have significant connectivity with the cyber world. As a result, Indian Power Grid has become potential target of cyber criminals. Possibility of cyber attack on Indian Power Grid is a reality and an imminent threat. From the energy policy point of view, it is important to ensure that the Indian laws adequately address such possible attacks on Indian power grid. In India, Information Technology Act 2000/2008 (IT Act) is the current law that is specifically meant to address the issue of Cyber Space and Crimes. As a result, any cyber attack or cyber crime in Indian power grid will be tested against the provisions of IT Act 2000/2008. This paper examines the adequacy and limitations of the provisions of the IT Act 2000/2008 in addressing cyber security issues of Indian power grid. It is found that appropriate amendments are required to address the limitations of the IT Act 2000/2008 in tackling cyber threats in Indian power grid.

Paper Id: 205

Major Blackouts of the Decade: Underlying Causes, Recommendations and Arising Challenges

Authors:
Nirupma Sharma — MNIT Jaipur, India
Aparna Acharya — MNIT Jaipur, India
Irene Jacob — MNIT Jaipur, India
Sumanth Yamujala — MNIT Jaipur, India
Vikas Gupta — MNIT Jaipur, India
Rohit Bhakar — MNIT Jaipur, India

Abstract:
Large disturbances in electric grids lead to severe load-generation imbalances, thus resulting in power outages or blackouts. Blackout is a phenomenon that occurs not because of a single cause, but due to multiple cascading disturbances. A critical review of such events can help in drawing preventive strategies and ensures readiness to mitigate the risk of blackouts. In this context, the work reviews the causes and severity of blackouts of various geographical locations in the past decade. An attempt has been made to summarize major blackouts and their effects. Some recommendations are also presented to provide strategies for grid protection and to mitigate the severity of blackouts. Further, an index to identify potential category of events that may cause a blackout in a geographical location is formulated. Finally, the work highlights few challenges arising due to transition in power systems. This work helps system operators and planners to develop grid technologies, electricity market models, and grid codes for improving system resilience.

Paper Id: 132

Analysis of Single and Multiple Line Contingency in a 62 Bus Indian Practical Power System using Track Structure Algorithm Approach

Authors:
Swasti Bachan Panda — NIT Rourkela, India
Sanjeeb Mohanty — NIT Rourkela, India

Abstract:
This paper presents an analysis of multiple line contingencies in a power system. Two evolving contingency screening methods are described for faster screening of important double-line contingencies that occur in a system. These methods analyze the complete double line contingencies without considering all possible double line outages, instead of taking only a few outages for the complete analysis, which in turn reduces computational effort and time as well, by using predefined power system sensitivity factors. The method described in this paper is used in an Indian 62 Bus power system, and promising results are obtained.

Paper Id: 282

Optimal Location and Sizing of Multiple DGs to Improve Resiliency of Power System after an HILF event

Authors:
Harsh Pachouri — MNNIT Allahabad, India
Ankit Uniyal — NIT Uttarakhand, India
Saumendra Sarangi — NIT Srinagar, India

Abstract:
Several disastrous extreme weather disasters have demonstrated that improving power grid resilience is becoming increasingly important. The use of optimal siting and sizing of distributed generation (DG) in radial power distribution networks to minimize real power losses and voltage deviation is discussed in this research as a combined resilience evaluation and analytic operational enhancement strategy. To achieve overall minimal power losses and better voltage control, the Marine Predator (MPA) meta-heuristic optimization technique is adopted in this research. MPA will be utilized to discover the best DG location and size at the same time. The proposed method is applicable to both single and multiple DG unit sizing and location. Furthermore, to calculate the best size of DG unit, the suggested method just requires the results of the base case load flow (s). On IEEE 33-bus radial distribution test systems, the proposed approach is evaluated.

Track 2.4 (LFDM02): Load Forecasting & Demand-side Management

Date: Friday, Dec 17, 2021 **Time: 01:50 PM - 02:50 PM**

Paper Id: 49

A Hybrid Wind Speed Forecasting Model using Complete Ensemble Empirical Decomposition with Adaptive Noise and Convolutional Support Vector Machine

Authors:

Vishal Teja	NIT Andhra Pradesh, India
Kiran Teeparthi	NIT Andhra Pradesh, India
Santosh M.	Kakatiya Institute of Technology and Science, Warangal, India

Abstract:
Wind energy is a clean, green energy source that is used effectively in power system grids. Wind forecasting is the key requirement for enhanced integration. Wind speed forecasting is more challenging due to the unpredictable and intermittent nature of the wind. As a result, a robust and novel framework is proposed by hybridizing complete ensemble empirical decomposition with adaptive noise (CEEMDAN), convolutional neural network (CNN), and support vector machine (SVM). The CEEMDAN algorithm is used to remove noise from the raw data. Then, to extract the dominating characteristics from the noiseless wind speed data, CNN is used. Finally, SVM forecasts the wind speed. The hybridization of CNN and SVM enhanced the computational efficiency as well as the performance. For comparative analysis, six different state-of-the-art forecasting approaches are employed. An experimental study is carried out utilising real-time 5-minute interval data obtained from Manhattan's Garden City. The proposed framework performance is assessed through various statistical metrics. With relatively low error metrics and higher R2 score, the proposed framework outperformed all other comparative models, according to the experimental results.

Paper Id: 278

Short-term Wind Speed Forecasting using Multi-Source Multivariate RNN-LSTMs

Authors:

Arun Nayak	MNIT Jaipur, India
Kailash Sharma	Dr. B.R. Ambedkar NIT Jalandhar, India
Rohit Bhakar	MNIT Jaipur, India
Harpal Tiwari	MNIT Jaipur, India

Abstract:
With the increasing percentage penetration of wind energy, wind power forecasting has become a crucial tool for power trading and electricity grid operations. The physical and statistical methods used for WPF models, mostly rely on meteorological information, site specific data and historical data from wind farms. In the existing literature, the WPF models are mostly using single input data sources and a prediction variable. A gap in using multiple data sources and multiple prediction variables as input has been identified to substantiate and enhance forecast accuracy of these models. In this study, a multi-source and multivariate surveillance approach has been conducted using time series methods and machine learning algorithms. Firstly, the proposed model uses multiple sources to understand the deciding prediction variables. Secondly, an analogy among time series Autoregressive Integrated Moving Average (ARIMA), Recurrent Neural Networks (RNNs) with Long Short-term Memory units (LSTMs) is used. Although, the prediction models using single data source are economical for forecast providers and wind power producers but considering multiple sources can certainly improve the forecasting accuracy thus reducing wind curtailments and imbalance penalties. A comparative approach has been made using data sources obtained for Gulf of Khambhat, a south to north penetration of the Arabian Sea on the western shelf of India.

Paper Id: 281

Wind Power Forecasting using Generalized Autoregressive Score Model

Authors:
Yash Pal — MNIT Jaipur, India
Kailash Sharma — Dr. B.R. Ambedkar NIT Jalandhar, India
Archee Gupta — ReNew Power, Gurugram, India
Archita Vijayvargia — IIT Delhi, India
Rohit Bhakar — MNIT Jaipur, India

Abstract:
Accurate Wind Power Forecasting (WPF) is essential for the economic operation and planning of electric power systems and electricity markets. Wind power forecasts up to few hours ahead (very short-term) are utilized for optimal operation of power systems. Several time-series models are proposed in the existing literature for Very Short-Term Forecasting (VSTF) of wind power. These include Autoregressive Integrated Moving Average (ARIMA), Generalized Autoregressive Conditional Heteroskedasticity (GARCH), Hybrid ARIMA-GARCH, etc. Although these models are mathematically well off and effective for short-term WPF but not accurate because of their fixed or time-independent parameters. Therefore, this paper presents a novel Generalized Autoregressive Score (GAS) model for WPF considering time-varying parameters. GAS model parameters are updated online for each forecasting lead time by a feedback system. The proposed model is implemented on three Australia-based wind farms and obtained results are compared to benchmark ARIMA and ARIMA-GARCH Hybrid models. The simulated results show that the GAS model has the highest accuracy and offers minimum error followed by ARIMAGARCH Hybrid, and then ARIMA.

Paper Id: 270
Virtual Energy Storage Systems: Challenges and Opportunities

Authors:
Chandra Prakash Barala — MNIT Jaipur, India
Parul Mathuria — MNIT Jaipur, India
Rohit Bhakar — MNIT Jaipur, India

Abstract:
Maintaining synchronism between generation and demand is becoming a tedious task with increasing penetration of renewables in the evolving power systems. Ancillary services are needed to settle these load-generation imbalances. The ancillary services requirement increasingly utilizing Energy Storage Systems (ESS) considering its quick response and high ramping capability. However, existing ESS technology faces challenges, such as high cost, unsteady charging/discharging cycles, life cycle issues, and optimal sizing. Thus, advanced mechanisms are required to cater the demand for ancillary services. Virtual Energy Storage Systems (VESS) is an innovative and economic way to replace/reduce higher ESS requirements. VESS utilizes existing network assets and Thermostatically Controlled Loads (TCLs). In recent years, the research in this area expands in multi-domains. Hence, there is a need to summarize the potential application of VESS in power systems. In this context, this paper is an attempt to summarise and develop an overarching view about the potential of VESS worldwide, the VESS technologies, the switching model of TCLs, and existing projects. Moreover, this review highlights the key factors and applications of VESS in power systems.

Track 2.5 (RIEV02): Renewable Integration & Electric Vehicle

Date: Friday, Dec 17, 2021 **Time: 01:50 PM - 02:50 PM**

Paper Id: 128

Change in Power based P&O Algorithm for Maximum Power Extraction in Solar Energy Conversion System

Authors:

Madhu G M	NIT Goa, India
C Vyjayanthi	NIT Goa, India
Modi Chirag Navinchandra	NIT Goa, india

Abstract:

Perturb and observe (P&O) is one of the commonly used maximum power extraction algorithm in solar energy conversion systems. Wherein, it suffers from its inherent limitations such as more tracking time, large power oscillations and deviations from the operating point during irradiance variations. This paper presents the concept of change in power to track the operating point at a faster rate and minimize power oscillations in steady-state conditions for efficient maximum power point tracking (MPPT) operation. The proposed algorithm applies the conventional P&O technique and tracks the maximum power point (MPP) using large step size. Once it reaches near the MPP, the concept of change in power is used to detect the oscillations and step-size of the duty-cycle is dynamically altered to operate at MPP with negligible power oscillations. In the event of a varying irradiance, the step-size of the duty-cycle is intelligently altered to a maximum value for fast tracking of MPP. The performance of the proposed algorithm is verified using MATLAB simulations and compared with the existing P&O algorithms to validate its efficacy.

Paper Id: 141

A Novel High Gain Switched Capacitor Topology for Fuel Cell Vehicles with Wide Voltage Gain

Authors:

Ishita Biswas	IIT Kharagpur, India
Debaprasad Kastha	IIT Kharagpur, India
Prabodh Bajpai	IIT Kharagpur, India

Abstract:

In this paper, a non isolated high gain DC-DC converter topology is proposed for the Fuel Cell (FC) vehicle application. The proposed switch capacitor based step up topology with common ground structure provides high voltage gain for a wide range of input voltage with lower voltage stress on the capacitors and power devices. The two phase interleaved structure at the input terminal reduces the input current ripple of the fuel cell. The input inductor currents are self balanced and operates at half of the total input current. In addition, the proposed converter has the ability to operate over a wide duty ratio range without compromising the system performance. The proposed converter can integrate low voltage FC stack (35-65 V) to 400V DC-link, suited for fuel cell vehicle application.

Paper Id: 20

Electric Vehicle Charging Station for Solar PV Based Grid Interactive System

Authors:

Pavitra Shukl — IIT Delhi, India
Bhim Singh — IIT Delhi, India

Abstract:

A transition from fossil fuel-based vehicles to electric vehicles (EVs) is increasing manifold with an increase in green energy implementation. In view of it, an EV charging system (EVCS) based on solar photovoltaic generation is presented here, with EV charging/discharging capabilities during base/peak load periods, respectively. For an EV charging system based on solar array, a fractional Lagrange filter is utilized here, thereby, improving the power quality of the distribution network. Furthermore, in order to guarantee an improved power quality (PQ), the grid currents are analyzed in covenant with the IEEE-519 standard. The EV charging mechanism is also obtained during grid absence through the usage of a voltage controller. The validation of the system performance is obtained via hardware in loop implementation through OPAL-RT platform, during various weak grid conditions.

Paper Id: 109

An Improved Crow Search Algorithm to Control MPPT Under Partial Shading Conditions

Authors:

Swetha K.T — NIT Goa, India
Abin Robinson — NIT Goa, India

Abstract:

This paper proposes an improved crow search (ICS) nature-inspired algorithm for maximum power point tracking (MPPT). The main objective of the proposed method is to mitigate the drawbacks of the conventional algorithms such as steady-state oscillations, delayed convergence, and the inability to track maximum power peak during shading conditions. Crow search (CS) is mainly based on the intelligence factor of hidden food places. In this paper, an experience factor is introduced, which speeds up the searching process of crows and accurately detects the shade occurrence. Furthermore, this algorithm is simple and easy to implement. Matlab simulations and experimental results are carried out to evaluate the performance under various shading patterns. The proposed algorithm is compared with conventional methods to validate the competence. The results show that this algorithm has comprehensive superiority in tracking global maximum power point in less convergence time.

Contributory Paper Session 3

Track 3.1 (PSPR03): Power System Protection

Date: Friday, Dec 17, 2021 **Time: 05:30 PM - 06:45 PM**

Paper Id: 98

Wide Area Synchronous Disturbance Recording System

Authors:

Sancho Simmy Louis	IIT Bombay, India
Faizan Feroz	IIT Bombay, India
Gopal Gajjar	IIT Bombay, India
A. M. Kulkarni	IIT Bombay, India

Abstract:
Synchrophasor based Wide Area Monitoring Systems are deployed at many places in the world. This paper discusses an extension to the existing WAMS infrastructure that measures phasor data to also obtain instantaneous values in a time synchronous manner over a wide area. Extensions are made by utilizing user definable fields in the command and data frames of the synchrophasor standard C37.118 2011 Part 2. A practical implementation of the proposed extension in a free and open source PMU simulator, PDC, integrated COMTRADE reader and historian is demonstrated. A possible application of such a system is presented.

Paper Id: 223

Wide-Area Measurement Assisted Algorithm for Secure Backup Protection during Stressed Conditions

Authors:

Shivaji Raskar	College of Engineering, Pune, India
Prashant Gawande	College of Engineering, Pune, India
Sanjay Dambhare	College of Engineering, Pune, India

Abstract:
This paper proposes an algorithm for secure backup protection of the distance relays by voltage magnitude comparison method (VMC) with fault detection factor. Voltages and currents for each bus are computed from the optimally placed phasor measurement units (PMU). The voltage magnitude comparison method gives a significant deviation in the computed voltage magnitudes of the bus connected to the faulty line compared with the measurements from healthy lines. This can be used as a differentiating factor for symmetrical faults from the stressed system conditions such as power swing, load encroachment, and voltage stress for secure backup protection. The algorithm is developed in MATLAB, and EMTP-ATP software is used to simulate the IEEE-14 bus test system.

Paper Id: 276

Testing of WAMS-based Supervised Zone-3 Distance Relay Protection Scheme using a Real-Time Digital Simulator

Authors:

K. K. Gajjar	IIT Bombay, India
A. M. Kulkarni	IIT Bombay, India
Gopal Gajjar	IIT Bombay, India
S. A. Soman	IIT Bombay, India
Rajeev Gajbhiye	IIT Bombay, India

Abstract:
Power swings, load encroachment, and low voltage conditions can cause false tripping due to the Zone-3 backup protection feature of a distance relay. To avoid this, a distance relay can be supervised using the measurements from Phasor Measurement Units (PMUs) of aWide Area Measurement System (WAMS). The algorithm and software for this purpose was developed. Through the monitoring of differential currents of the backed-up lines, the software generates Block and Trip signals which are communicated to the relay. This paper presents the results of testing of this scheme using a real-time digital simulator. Different fault scenarios in a four-machine ten bus system were simulated. The results indicate that the scheme is effective in preventing the false tripping of distance relays.

Paper Id: 129

Application of Synchrophasor Angular Difference as a Grid Monitoring Tool and for Assessment of Real Time Voltage Stability-Case Study

Authors:
Alok Pratap Singh — POSOCO, India
Saibal Ghosh — POSOCO, India
Saurav Kumar Sahay — POSOCO, India
Chandan Kumar — POSOCO, India
Akash Modi — POSOCO, India
Saugato Mondal — POSOCO, India

Abstract:
This paper investigates about the application of Synchrophasor angular difference for detecting the various grid events which allows operators ease and advancement for grid monitoring. This paper explains the real time grid events and cases observed in eastern regional grid, where Phase angle difference has been used as a grid monitoring index for monitoring and sensitizing the grid stress. Synchrophasor angular difference used for predicting voltage collapse in collaboration with PV curve obtained from PMU, in real time which is very much effective and specially effective for weak nodes with low fault level and nodes with skewed/variable generation pattern. Monitoring Angular difference is of very much importance as system stress can be identified easily, under all set of different scenarios and contingencies. To enhance the situational awareness of grid operators, path flow monitoring along with the angular difference of the path is used for defining operating state of a particular corridor/area of the power system, whether operating in normal, Alert, or emergency state so that with corrective action system can be brought back to normal state. Path angular difference gives an upper hand and can predict about voltage collapse events beforehand and also margins to the knee point can be accessed in terms of angular difference of the path. In real time with the help of synchrophasor data, real time reserve monitoring for the identified path/area can be done so that sufficient margin can be maintained for contingency situations.

Paper Id: 229

Communication Latency Calculation in Complex IEC 61850 based Substation

Authors:
Praveen.A.N — IIT Madras, India
K. Shanti Swarup — IIT Madras, India
Sachin Srivastava — India Development Centre Hitachi ABB Power Grids Bangalore, India

Abstract:
IEC 61850 has become the de-facto standard to follow for communication in a substation. The use of IEC 61850 based Client–Server communication service and Publish– Subscribe communication-service, which include Generic Object Oriented Substation Events (GOOSE) and Sampled Values (SV) have aided in the deployment of a more communication-intensive architecture in substation when compared to a non-IEC

61850 based substation. Performance of Protection and Control Systems (PACS) is now additionally influenced by the communication system in a substation. The fault-clearance time in an IEC 61850 based substation now includes the operating time of the protection Intelligent Electronic Device (IED) relay and the communication delay between protection IED and a Switchgear Control Unit (SCU).

This paper proposes a method to calculate communication latency in a complex IEC 61850 based substation. It is vital to determine communication latency for understanding the overall performance of PACS. Latency calculation is also essential to optimize PACS design to achieve the requirements of various applications. The communication latency calculation method proposed in this paper uses the Substation Configuration Description (SCD) file to accurately determine the communication path and data flow between a publisher and subscriber. The method also calculates the coincident messages or traffic in the communication path between publisher and subscriber, which aids in determining the latency accurately.

Track 3.2 (MGDS03): Micro-Grid and Distribution System

Date: Friday, Dec 17, 2021 **Time: 05:30 PM - 06:45 PM**

Paper Id: 161

Application of Piecewise-Smooth System Theory in Droop Control

Authors:

Sharwari Udaykumar Shah	VNIT, Nagpur, India
Dande Chandra Sekhar Charan	VNIT, Nagpur, India
Bhooshan Rajpathak	VNIT, Nagpur, India

Abstract:
In this paper we have investigated various droop control strategies for DC Microgrid. We have compared piecewise-smooth droop control with linear and nonlinear droop control methods. Further, simulational results using MATLAB Simulink© for all above types are presented. Finally, it is shown that the piecewise-smooth droop control method has better voltage deviation control and enhanced current sharing profile as comapred to other two methods.

Paper Id: 175

Model Predictive Control Based Economic Operation of Grid-Connected DC Microgrid System

Authors:

Arghya Mallick	IIT Kharagpur, India
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Prabodh Bajpai	IIT Kharagpur, India

Abstract:
Microgrids are becoming a quintessential option due to rapid growth of renewable energy technologies. However, the stochastic nature of renewable energy sources and variable power demand have introduced challenges such as voltage and frequency instabilities, complex power management and interaction with the utility grid. In this paper, a Model Predictive Control (MPC) based energy management approach is proposed to facilitate stable and economic operation of grid-connected DC microgrids. Case studies are designed to evaluate the stability and economic operation of a DC microgrid under the proposed optimization based control strategy.

Paper Id: 69

Mitigation of Power Oscillations in DC Microgrid using Model Predictive Control

Authors:

Chandrima Sahu	NIT Kurukshetra, India
Rahul Sharma	NIT Kurukshetra, India

Abstract:
An MPC (Model Predictive Control) approach to control the dc-dc boost converter used in battery of a dc microgrid system has been proposed in this paper. MPC is an intelligent control technique which uses system model and present values to predict the future output with the help of some constraints. The dc microgrid model used here consists of a battery energy storage system (BESS) and a PV system used as distributed generation (DGs). A dc-dc boost converter has been used for each DGs. A reduced output voltage and current fluctuations (almost smoothened curve) were achieved using MPC controller for BESS, keeping dc

bus voltage constant. Also, a comparative analysis was carried out between MPC and PID type controllers used in the above-mentioned model separately. Also, a disturbance was created in the load as practical microgrids have changing loads. This disturbance was introduced by adding switch in one load and at a specific time it was on and the load was added to the existing grid model. The effect of switching characteristics were then studied and conclusions were drawn that out of MPC and PID, MPC is better in providing stability and reliability.

Paper Id: 118

Comparative Fault Analysis in an Active Distribution Network

Authors:

Diasa Bhattacharjee	Techno International, New Town, India
Arkaprabha Roy	Techno International, New Town, India
Bhaskar Saha	Techno International, New Town, India
Avik Kumar Mukherjee	Techno International, New Town, India
Syamasree Biswas Raha	Techno International, New Town, India

Abstract:

The presented research paper proposes fault analysis of an active distribution network (ADN). In the proposed work, a distributed generation (DG) oriented distribution network with few loads and generator buses are considered. Now, these ADNs are caused to have severe faults due to presence of DG system and it's uncertain penetration of power to the main grid. These generate major faults in the network however it's analysis are extremely limited. Hence, in this work different case studies on two types of major faults like line to ground (LG) fault and double line to ground (LLG) fault are demonstrated by formulating an ADN using Power World Simulator. Here, faults are injected at certain locations in the simulation network. After fault injection, the fault parameters in terms of phase voltages, phase angles and line currents are observed and comparatively analyzed. Here, it has been noticed that the fault parameters in the load bus have been found most severe compared to the fault parameters in the DG connected bus and the generator bus.

Paper Id: 211

Modified VSG Scheme for Secondary Frequency Regulation in Islanded Microgrid

Authors:

Muhammad Khalid Raza Khan	IIT Mandi, India
Pratim Kundu	IIT Mandi, India

Abstract:

The traditional control strategy of a microgrid in islanded mode mainly consisted of Droop control. To improve it Virtual Synchronous Generator (VSG) concept was developed. The objective of the method was to improve the frequency response of a system following a sudden disturbance. Though these traditional control strategies are successful in providing primary frequency response (PFR) and inertial response (IR), the frequency restoration process is overlooked. The proposed method introduces two PI controllers in the active power frequency loop of VSG by which the system frequency returns attains the nominal value in a quick time after the disturbance. The process is called secondary frequency regulation (SFR) and the proposed controller is called modified VSG as it uses the same set of control models as used in VSG. This work focuses on the comparison of traditional and proposed controllers in providing the three responses namely IR, PFR, and SFR. The controller performance is validated using MATLAB Simulation.

Track 3.3 (PSOP01): Power System Operation & Planning

Date: Friday, Dec 17, 2021 **Time: 05:30 PM - 06:45 PM**

Paper Id: 41

A New Convex Relaxation based OPF for Mutually Coupled Unbalanced Active Distribution Network

Authors:

Sanat Kumar Paul	IIT Kanpur, India
Abheejeet Mohapatra	IIT Kanpur, India
P. Naga Yasasvi	IIT Kanpur, India

Abstract:

Increasing penetration of Distributed Generations (DGs) in Distribution Networks (DNs) for improved network reliability and efficiency has been a subject of great interest. A typical DG can be dispatchable or non-dispatchable and is generally associated with uncertain generation output. Hence, a proper setting of dispatchable DG's real power generation and voltage magnitude is necessary for Optimal Power Flow (OPF) and maintaining various network constraints. Further, DNs are complex networks due to their inherent radial and unbalanced nature with a high R/X ratio. Thus, in this paper, a first OPF problem is demonstrated for a mutually coupled unbalanced active DN. The associated optimization problem is modeled using KCL and KVL equations via a new convex relaxation for optimal settings of the DGs. The effectiveness of the proposed model is investigated for two unbalanced radial distribution feeders - IEEE 34 bus and IEEE 123 bus systems. Further, the robustness of the obtained solution is verified for load fluctuations using Monte Carlo Simulations (MCS).

Paper Id: 260

Optimal Planning of a Distribution Network with P, PQV Buses by Jaya Algorithm

Authors:

Sumanth Pemmada	VNIT Nagpur, India
Nita R. Patne	VNIT Nagpur, India
Ashwini D. Manchalwar	VNIT Nagpur, India
Ajay Kumar T	VNIT Nagpur, India

Abstract:

This article performs reconfiguration of the distribution network (DN), including distributed generations (DGs) with a new set of buses P, PQV. P-bus is a reactive power support bus that maintains specific voltage at a minimum voltage bus, i.e., PQV-bus. Optimal locations of multiple DGs are determined using sensitivity factors based on reducing power loss and improvement in voltages. The capacity of reactive power support, ratings of DGs, and switching configuration are optimized by employing the recently developed Jaya algorithm. DGs accommodation is followed in sequential and non-sequential approaches. Topology constraints of reconfiguration are validated utilizing a spanning tree concept from smart graph theory. The following constraints are applied to study the problem: voltage limits at buses, current carrying limits of lines, radial configuration, and no isolated node in the network. The proposed method's applicability is demonstrated on IEEE 33 and 69 bus radial DNs. Numerical results illustrate the validity and efficacy of the suggested method in comparison with the other existing algorithms.

Paper Id: 152

Cost of Voltage Violation

Authors:

Suresh Varwandkar	VJ Technological Institute Mumbai, India
Jeremy Lin	New Grid Solution, Austin, Texas, USA

Abstract:
Line flows and voltages in power systems are allowed to vary within limits without affecting the local price of electricity. Beyond the specified limits, however, these must be brought within the specified band by appropriate means. Operators achieve this by rescheduling generators or by calling up ancillary services. The amount of violation of flow/voltages must be first determined for this purpose. The proposed work obtains flow and voltage profiles as a function of the network parameters and injections for which a new approach is used. Its similarity with fractals is explained. Generators that have a dominant effect on a particular line flow or load-voltage are uniquely identified in the analysis. The corrective mechanism is then implemented for mitigating violations. Fractals are products of scalar multipliers for injected powers. The scalar multipliers are functions of network parameters and structure and need to be evaluated only once. The method is in sharp contrast with those employing sensitivities. The computation of cost of mitigation is direct and does not need an optimization with Lagrange multipliers. The method is expected to be useful to system operators in market-based power systems and for, designing at the planning stage, and calling up ancillaries during operation. Charges for congestion or voltage violation can be analytically obtained to the satisfaction of stakeholders.

Paper Id: 233
Envisioning Low-carbon Indian Power Grid Using Demand-Side Flexibility

Authors:
Ashok M. Jadhav — IIT Delhi, India
Shri Ram Vaishya — IIT Delhi, India
Abhijit R. Abhyankar — IIT Delhi, India

Abstract:
The liberalization of the electricity market worldwide has allowed new entities and innovative contemporary business models to emerge. It also enabled economically sustainable investment in flexible energy assets. A synergy between energy markets and grid management systems must introduce new services to support a high renewable energy penetration. In this regard, the local flexibility assets have a vast potential to help the distribution system operator efficiently manage active distribution networks and regional load despatch centre deploy system-wide reserves. Thus, there is a need to re-design the existing electricity market framework and introduce new products. This paper intends to propose a higher-level model of reliable grid operation utilizing the local flexibility resources for the Indian power system. The distribution system operator and regional load despatch centre are considered as the potential buyers for demand-side flexibility. The sequential local flexibility market clearing and settlement mechanism have been discussed in the Indian context.

Track 3.4 (PSDS02): Power System Dynamics & Stability

Date: Friday, Dec 17, 2021 **Time: 05:30 PM - 06:45 PM**

Paper Id: 239

Critical Assessment and Comparative Study of PID and ADRC Approaches Applied to AGC in Multi-Source Single Area Power System

Authors;

Nagendra Muppoori	Bapatla Engineering College, Andhra Pradesh, India
Nagalakshmi Dasari	Bapatla Engineering College, Andhra Pradesh, India
Yatendra G	Bapatla Engineering College, Andhra Pradesh, India

Abstract:
The power system is continuously subjected to load changes. The load changes are dealt with the emergency control measures, such as generator shedding and also with automatic generation control (AGC). The AGC's primary purpose is to adjust the generator output power to minimize the power imbalance in the system, thus maintaining the system power at a nominal value. Conventionally, the AGC is designed with the help of an aggregated model of the system. The designed AGC is applied to the control area as a whole. However, in practice, all of the generators may not be able to comply with the AGC output to deliver the desired output. Moreover, all of the generators in the system not necessarily behave well for a given control signal under some operating conditions. In such cases, the practicality of different AGC control techniques has to be evaluated, which is the primary objective of this paper. In this paper, AGC is designed with the help of an aggregated model and implemented at each of the turbine models. Two control techniques are considered, namely, the PID and active disturbance rejection control (ADRC) to evaluate the implementation difficulties in a single area multisource (coal, hydro and nuclear) power system.

Paper Id: 21

Load Frequency Control of Two Area Microgrid using Reinforcement Learning Controller

Authors:

Subal Beura	IIT Ropar, India
Deepak Kumar Soni	IIT Ropar, India
Bibhu Prasad Padhy	IIT Ropar, India

Abstract:
In this paper, automatic generation control problem is inspected and different modelling parameters are decided. Initially Genetic algorithm (GA) based parameters of proportional integral- derivative (PID) controller is applied to the model. Then Q learning (Reinforcement learning) applied to control the frequency and tie line power deviation by controlling the power mismatch between generators and loads. Area control error (ACE) are used as objective function for PID and RL controller respectively. Q-learning based reinforcement agent is introduced which takes the action according to averaged ACE values. Parameters like step size, discount rate, and exploration rate decides the effectiveness of the RL scheme.

Paper Id: 147

PSS Tuning of Radially Connected Hydro Power Plant of Eastern India using SMIB Model and Phase Compensation Technique

Authors:
Saibal Ghosh POSOCO, India

Abstract:
Power systems are very often exposed to large disturbances such as loss of load, loss of transmission lines, and loss of large generating units. Now the main challenge in operating large power system is that running all the generators synchronously even after these disturbances. Generally following a large disturbance different generators respond differently to the disturbance and low frequency oscillation among the generators comes into the picture. Hydro power plants are generally located to very remote hilly area and connected to the electrical grid via long radial transmission lines. Small signal stability issue is sometimes get triggered following some disturbance or during system wide inter-area oscillation. In this paper a radially connected hydro generating station "A" of Sikkim having 3X170 MW installed capacity is studied. Generating station is connected to the grid at a pooling station via two 400 kV twin moose lines. Machine is currently equipped with static excitation and one simple Power system stabilizer model at the site. However excitation system has the provision of activating complex stabilizer model also. Analyzing various past disturbances and low frequency events in the Indian power grid it is found that the performance of the above mentioned generators in damping the local and inter-area oscillation is poor and ranges between 0 to 7 % damping for all the modes. This paper aims at improving the damping of oscillation to 15-25%.

Paper Id: 59

Detailed Investigation of Mode Information based System Inertia Estimation using Synchrophasor Measurements

Authors:
Adithya Surya Tarun Papa IIT Palakkad, India
Gayathri K IIT Palakkad, India
Manas Kumar Jena IIT Palakkad, India

Abstract:
This paper has carried out a detailed investigation on oscillatory mode information-based system inertia estimation techniques. In the first step, the critical modes of oscillation are extracted from the post-disturbance frequency deviation signal which is obtained from the phasor measurement units (PMUs). In this process, two popular methods for parameter estimation such as Estimation of Signal Parameter via Rotational Invariance Techniques (ESPRIT) and Matrix Pencil technique are deployed to extract the mode information. The investigation reveals the superiority of the Matrix Pencil method over the ESPRIT method for inertia estimation application. Once the mode information is available, an equivalent swing equation is used to estimate the inertia at any desired bus of the power system. The analysis is carried out on both Kundur's two-area system and the IEEE-39 bus system. The results obtained demonstrate the superiority of Matrix Pencil based method over ESPRIT method for inertia estimation application.

Paper Id: 173

Back Stepping Optimal Scheme with Fractional Order Control for Power System Model

Authors:
Vivek Kumar — IIT (BHU), Varanasi, India
Soumya R. Mohanty — IIT (BHU), Varanasi, India

Abstract:
In power system networks, system perturbations may cause severe instability in synchronous generator (SG) states. The SG dynamics rely on unknown and uncertain parameters like, transient time constants that are varying under power system operation. Therefore, to achieve the reference trajectory in the fixed final time, an adequate control strategy is essential for the SG state stabilization in the power system under uncertainties. In this paper, a fractional order optimal control is proposed along with backstepping for fixed final time state stabilization of SG states by estimating unknown parameters through an adaptive law. First power system dynamics are partially linearized, then for each state error backstepping method is employed to achieve robust performance. In the final step of backstepping algorithm, a fractional order optimal control scheme is applied by designing the respective cost functions. The fractional-order term is integrated with the optimal control to achieve a fast transient response. The efficacy of the proposed control technique is validated using single machine infinite bus power system model as well as two area four machine power system model.

Track 3.5 (RIEV03): Renewable Integration & Electric Vehicle

Date: Friday, Dec 17, 2021 **Time: 05:30 PM - 06:45 PM**

Paper Id: 256

Market Based Congestion Management in the Distribution System Under Electric Vehicle Integration

Authors:
Jitendra Kumar — MNIT Jaipur, India
Prerna Jain — MNIT Jaipur, India

Abstract:
With the goal of reducing distribution network congestion caused by electric vehicle (EV) charging planned for a day-ahead basis, an economically efficient distributed optimization based dynamic tariff (DDT) is presented. All aggregators engage in the congestion control technique that adopts a decomposition-based optimization method. As a result, as compared to the traditional approach of day-ahead dynamic tariff, this method gives more predictability and clarity. In DDT approach aggregators provide their complete accumulated demand response (DR) and must be consider it during the operation. The DSO estimates congestion in days ahead and releases the DDT before to the settlement of the day-ahead market, using iterative interactions between the DSO and aggregators congestion control framework. As a result, the aggregators optimize their energy purchase portfolio considering expected price and publicly available DDT. The Roy Billinton Test System (RBTS four-feeder)'s network is being employed to perform case studies to illustrate the efficiency of the established approach towards preventing distribution network congestion caused by EV charging. The case study results show that the DDT technique, when compared to alternative decomposition-based approaches such as the multiagent system method, may minimize total energy usage and power losses costs.

Paper Id: 236

Study of Optimally Located Electric Vehicle Charging Stations for Frequency Control Service in Distribution Network

Authors:
Syed Nafiz Hasan — IIT Gandhinagar, India
Satish Kumar Singh — IIT Gandhinagar, India
Naran M. Pindoriya — IIT Gandhinagar, India

Abstract:
The enhanced growth of electric vehicle market has created a necessity of electric vehicle charging stations that can transfer charge at a very fast rate. The EV charging stations, which operate with the purpose of supplying energy to electric vehicles have the capability to be utilized for providing frequency control service to the distribution network along with regular operation of EV charging. The Battery Energy Storage System (BESS) has been deployed at the EV charging station to avoid the instability to the grid at the time of providing fast charging and the utilization of this BESS has created a new opportunity of providing frequency control service to the grid. Proper coordination is needed to be maintained between the fast charging of EV and frequency control service for frequency regulation. Also the integration of solar PV at distribution network can support the EV charging stations for improving the power quality of the distribution network. Optimally located distributed generation sources are capable of providing sufficient contribution to improve the power quality of a distribution network and its effectiveness has been shown at this research work by utilizing BESS and solar PV. The developed algorithm ensures the proper functioning of the two type of EV charging stations with the objectives of providing charge to EV and also providing frequency control service to the distribution network while maintaining the constraints of the battery so the SOC level stays within a required limit to ensure the smooth operation of both of these objectives.

Paper Id: 29

Lyapunov Stability Analysis of Load Frequency Control Systems with Communication Network Induced Time-Delays and EV Aggregator

Authors:

B. S. Sharini Rithigaa	Pondicherry Engineering College, India
Kalavagunta Vamshi	Pondicherry Engineering College, India
K. Ramakrishnan	Pondicherry Engineering College, India

Abstract:
In this paper, an improved stability analysis is presented to compute the stable delay margin of a class of networked load frequency control systems involving communication channels and electric vehicle aggregator. In networked control systems with a centralized control framework, the use of communication links for information exchange among various sub-systems introduces inevitable time-delays in the feedback loop. These communication delays invariably exert a negative influence on the dynamic performance and stability of the system. If the network-induced time-delay escalates beyond a critical delay margin, called stable delay margin, the stability of the closed-loop system is lost. In recent times, for improved frequency compensation, a fleet of plug-in-electric vehicle units called aggregators are integrated as a distributed generation source in the load frequency control system. In such systems, in addition to improved frequency compensation, the integration of electric vehicles also paves way to enhancement in stability margin of the time-delayed system. In this paper, using Lyapunov-Krasovskii functional approach coupled with Wirtinger inequality, a new stability analysis is presented for determining delay-dependent stability of networked load frequency control systems integrated with electric vehicle aggregator. Furthermore, to impart a realistic operating condition, time-delays in the networked centralized control loop and electric vehicle aggregator loops are considered to be non-identical, and appropriate participation factors for effective load sharing are incorporated in the system framework. In the sequel, the analytical delay bounds are corroborated through extensive simulation studies.

Paper Id: 279

Electric Vehicle Charging Policies in Indian states: Key Learnings from International Experiences

Authors:

Renu Banjarey	MNIT Jaipur, India
Irene Jacob	MNIT Jaipur, India
Shivanjali Yadav	MNIT Jaipur, India
Sumanth Yamujala	MNIT Jaipur, India
Ashok Kumar Agrawal	MNIT Jaipur, India
Rohit Bhakar	MNIT Jaipur, India

Abstract:
Transportation sector is experiencing a rapid transition towards Electric Vehicles (EVs) to decarbonize the sector and reduce petroleum dependence. Many nations have set ambitious targets to increase a significant share of EVs in near future. However, evidence from various countries shows that EV adoption is slow without proper policies and incentives. Despite the government's efforts to introduce regulations and programs for encouraging the use of EVs, the same problem is observed in India. An in-depth study on EV adoption policies of various countries can help in analyzing the pitfalls of existing strategies and initiatives to build an EV environment in India. In this context, the work aims to review EV adoption policies of various countries and Indian states. A comparison between Indian and international practices in terms of charging infrastructure standards, policies, and incentives to promote EV adoption is presented. Further, the work highlights the impact of EV adoption on socio-economic growth and possible challenges for Distribution Companies (DISCOMs). Finally, the work draws some policy recommendations for a smoother transition.

Paper Id: 105

Charging-Cost Minimization of Electric Vehicles and its Impact on the Distribution Network

Authors:

Arjun Visakh — NIT Tiruchirappalli, India

Selvan M P — NIT Tiruchirappalli, India

Abstract:

Widespread deployment of electric vehicles (EVs) could have adverse effects on the operation of power systems, especially at the distribution level. To prevent network overloads caused by the simultaneous recharge of several vehicle batteries, there is a need for coordinated charging schemes that can optimally schedule the EV charging loads. The scheduling algorithm determines the optimal time and power at which individual EVs should be recharged to achieve certain technical or financial objectives. Technical objectives, such as peak shaving, loss minimization, or voltage enhancement seek to improve the operational aspects of the distribution system. Financial objectives, such as minimization of generation cost or charging cost aim to improve the economics of power distribution. In this paper, the impact of financially-motivated charge scheduling on the operation of a distribution network is examined. The scheduling algorithm seeks to minimize the total charging cost incurred by vehicle owners using convex optimization. The impact of optimized EV charging on the system demand and voltage profile of the test system is analyzed here. The simulated algorithm is able to reduce charging cost and peak load by 30% and 41% while improving the load factor and minimum voltage by 76% and 18%, respectively.

Contributory Paper Session 4

Track 4.1 (PSPR04): Power System Protection

Date: Saturday, Dec 18, 2021 **Time: 10:15 AM - 11:30 AM**

Paper ID : 28

A Time Varying Filter-EMD based Intelligent Technique for Protecting UPFC Installed Transmission Line

Authors:

Sauvik Biswas — NIT Patna, India
Paresh Kumar Nayek — NIT Patna, India
Gayadhar Pradhan — NIT Patna, India

Abstract:

The conventional distance relays exhibit limited performance while used for the protection of unified power flow controller (UPFC) compensated transmission lines (TLs) due to rapid changes of voltage and current signals during various operational modes of UPFC. This paper investigates the impact of the different operating modes of UPFC and proposes an improved protection algorithm for the relay. The sign information of one-cycle differences of α-aerial currents at line ends are used to detect an internal fault. Then, the features extracted from time-varying filtering-empirical mode decomposition (TVF-EMD) are used in the decision tree (DT) classifier for fault type identification. The proposed protection algorithm is verified by creating various fault/non-fault cases in a 220 kV two-bus system modelled in MATLAB/Simulink. The fast response and high accuracy clearly provide adequate ground for the performance of the proposed protection technique for UPFC installed TL.

Paper ID : 253

An Efficient Travelling Wave based Fault Localization for MTDC Transmission System

Authors:

Mahitosh Banafer — IIT (BHU) Varanasi, India
Soumya R. Mohanty — IIT (BHU) Varanasi, India

Abstract:

This article proposes a low sampling frequency travelling wave-based fault location technique for the MTDC grid. It is based on the matrix pencil method applied on the DC terminal voltage samples in the sliding window moving along the time axis. The sliding matrix pencil method decomposes the voltage signal samples in the sliding window into time-indexed damping factors. In the absence of a travelling wave, the damping factor is zero. But in the presence of a travelling wave, depending on the position of the travelling wave in the sliding window, the damping factor is either positive, negative, or zero. After that linear regression is used to find the zero-crossing point of the time-indexed damping factor, which will help further to calculate the travelling wave arrival time. Finally, first travelling arrival time information from both DC terminal end will help to calculate the estimated DC fault location at the low sampling frequency.

Paper ID : 104

Positive Sequence Components based Fault Location Algorithm For Three Terminal Transmission Network with Non-Homogeneous Tapping

Authors:

Purushotham Reddy Chegireddy — IIT Hyderabad, India
Ravikumar Bhimasingu — IIT Hyderabad, India

Abstract:

The research work presents a new positive sequence components based fault location estimation algorithm for three terminal non-homogeneous transmission network. The algorithm utilises the data corresponding to pre-fault and during fault for calculating line parameters and determines the faulted line section and fault location. The simulations are carried in PSCADr and the algorithm is evaluated through MATLAB for a 161kV network. The algorithm has been evaluated for all fault types with different values of fault resistances at various fault locations. Out of 144 test cases 142 cases have resulted % error less than 1.5% i.e. the % error is less than 1.5% for 98.6% cases.

Paper ID : 139

Adaptive Distance Relay based on Estimation and Update of Two-Port Equivalent across Transmission Lines

Authors:

Vedanta Pradhan — Hitachi ABB Power Grids, India
O. D. Naidu — Hitachi ABB Power Grids, India
Neethu George — Hitachi ABB Power Grids, India

Abstract:

Apparent impedance measured by a distance relay during fault matches the impedance of the faulted line segment for bolted faults. However, it is not so for resistive faults wherein the effect of infeed from the remote end also influences the measured impedance. It depends on the prevalent pre-fault two-port equivalent across the protected line. In this paper, we propose adapting zone-1 characteristics of the distance relay by estimating and updating the two-port equivalent. The paper presents methods for estimating and updating the equivalent model which predominantly utilize measurements available locally at the relay station. It is also envisaged that based on these estimations, the power swing blinder position/timer settings can also be adapted. The proposed method is illustrated based on the IEEE 39 bus test system.

Paper ID : 15

Transmission Network Protection using Line Current Phase Information

Authors:
Pratim Kundu IIT Mandi, India

Abstract:

A method based on current signals obtained from local and remote ends is proposed for protection of transmission lines. Two indices are developed for detecting and distinguishing internal and external faults in different power networks including series compensated lines and three terminal lines. The first index is defined using an error function calculated from the sampled data of current signals at the local end. The second index is synchronized data based phase angle difference calculated using prefault and fault phasor data of local and remote end. The proposed method is not affected by high resistance faults due to line charging current, unlike conventional differential protection schemes. Also, identification of the faulted segment of three terminal lines can be achieved using this method; an advantage over differential, overcurrent or directional relaying schemes. Results have been simulated in a modified series compensated WSCC 9-bus system and a three terminal line system using PSCAD to highlight the advantages of the proposed method. Index Terms—Least Square technique, Discrete Fourier Transform (DFT), Series Compensation, Three-terminal network, Transmission line faults.

Track 4.2 (MGDS04): Micro-Grid and Distribution System

Date: Saturday, Dec 18, 2021 **Time: 10:15 AM - 11:30 AM**

Paper ID : 188

Optimal Planning of DG and Shunt Capacitor in a Harmonic Distorted Distribution Network

Authors:

Ram Prakash — IIT Patna, India

S. Sivasubramani — IIT Patna, India

Abstract:

Rapidly growing electricity demand and increasing use of advance power electronic devices introduce power quality issues in distribution networks. If these issues go beyond considerable limits, they can affect the efficiency and the reliability of the power system. In this work, the optimal allocation of distributed generation (DG) and shunt capacitor is studied in a distorted network to address various power quality issues. These issues are incorporated by formulating a multi-objective function, considering total harmonic distortion (THD), active power loss and voltage stability index. An Improved Particle Swarm Optimization (IPSO) method with chaotic variation of inertia weight and crossover is applied to the proposed optimization problem. Two cases are formed to show the impact of DG and capacitor integration on a modified IEEE 33 bus-distributed system with non-linear loads. Superiority of the proposed method is observed by comparing the optimal solution obtained with the standard Particle Swarm Optimization and Genetic Algorithm techniques.

Paper ID : 158

A Graph Theoretic approach based Capacitor Placement in Unbalanced Distribution System

Authors:

Sourav Mondal — IIT Patna, India

Mala De — IIT Patna, India

Abstract:

This paper presents a graph theoretic centrality index based methodology to solve capacitor placement problem for unbalanced distribution system (UDS). The aim of this paper is to present a new approach for optimal placement of capacitor bank (CB), to minimize system loss and maximize the net saving for UDS. Particle Swarm Optimization is used to determine the optimal size of CB. The objective function for optimal sizing of CB consists of three terms - cost associated with CB purchase and installation, and cost of energy loss. The proposed method was tested on benchmark networks (IEEE 13-bus, and 25 bus systems) and compared with power loss index (PLI) based method. The results obtained from both methods are comparatively analysed and discussed. The comparison of power loss reduction, status of voltage profile, and net saving are presented for both approaches for the test systems.

Paper ID : 64

Local Distribution Network Management through Optimal Flexibility Scheduling: the Austrian Pilot of the Horizon 2020 MERLON Project

Authors:

Da Huo — Newcastle University, England

Neal Wade — Newcastle University, England

David Greenwood — Newcastle University, England

Philipp Novakovits European — Center for Renewable Energy Güssing Ltd. (EEE), Austria

Joachim Hacker — Center for Renewable Energy Güssing Ltd. (EEE), Austria
Dimitrios Papadaskalopoulos — Imperial College London, UK
Nikolaos Chrysanthopoulos — Imperial College London, UK
Goran Strbac — Imperial College London, UK
Markus Resch — Wirtschaftsagentur Burgenland Forschungs- und Innovations GmbH
Uma Rajarathnam — Enzen Global Solutions, India
Katerina Valalaki — Hypertech Energy Labs, Greece
Vasiliki Katsiki — Hypertech Energy Labs, Greece

Abstract:
The EU electricity system is going through a transition driven by increasing penetration of distributed energy resources (DERs) and new energy marker actors, such as prosumers and aggregators. Decentralization of electricity generation can facilitate the integration of more renewable energy sources, increase security of supply and decarbonize the energy future. To benefit from these opportunities while keeping pace with the transformation of the power sector and evolving needs of energy market players, the EU Horizon 2020 project "Integrated Modular Energy Systems and Local Flexibility Trading for Neural Energy Islands (MERLON)" has developed an integrated local energy management system (ILESEM) to support local distribution grid operation in a high-renewable energy scenario. ILESEM performs a multi-level optimization using decentralized intelligence for efficient coordination of DERs within a local distribution grid. This way, ILESEM is used to form a self-coordinated and self-balanced energy island while offering services to the wider electrical system. An algorithmic framework has been designed that optimally schedules battery energy storage, local generation, and demand side management offering a cost-efficient pathway (in comparison to high-CAPEX grid upgrade investments) for active local distribution grid management in the presence of high volumes of variable renewable energy. The effectiveness of DER scheduling in an Austrian pilot site has been demonstrated and replication of the solution in the Indian context has been explored.

Paper ID : 164

Frequency Stability Analysis of Microgrid interconnected Thermal Power Generating System with GWO Tuned PID controller

Authors:
K. Jagatheesan — Paavai Engineering College, India
Sourav Samanta — University Institute of Technology, India
D. Boopathi — Paavai Engineering College, India
B. Anand — Hindusthan College of Engg and Tech, India

Abstract:
In this proposed research delivers about the frequency stabilization of hybrid power system (thermal unit with Distribution Generation System (DGS)) is analyzed by considering Proportional Integral Derivative (PID) regulator as an auxiliary controller. Gain values of the introduced regulator is tuned by Grey Wolf Optimization (GWO) technique with the Integral - Time - Absolute – Error (ITAE) objective function. The behavior of the projected optimization technique tuned controller is examined in this research work by comparing the response with Genetic Algorithm (GA), Particle Swarm Optimization (PSO) and Ant Colony Optimization (ACO) tuned controller behavior to show its efficacy. In the proposed work, all the analysis is carried out by applying one percent step - load - perturbation (1% SLP). And, also time domain specification parameters are measured to demonstrate the effectiveness of GWO dependent on the PID controller. Simulation results proves that

GWO designed PID controller provides more supremacy (lesser Peak overshoot and undershoot with minimal relaxing time) result during emergency loading condition over GA, PSO and ACO technique designed secondary PID controller.

Paper ID : 242

The Effect of Multiple PV and Battery Penetration on Stability of DC Microgrid with Single Bus Topology

Authors:

Jithin K.	Paavai Engineering College, India
Mayadevi N.	Paavai Engineering College, India
Hari Kumar R.	Paavai Engineering College, India
Mini V P.	Paavai Engineering College, India

Abstract:

Solar Photo-voltaic (PV) power generation has played a significant role in the development of microgrid technologies. Nowadays, there is large penetration of PV units into the grid and the stability of the overall system may get affected when a new Distributed Energy Resource (DER) is added to the system. In this paper, stability analysis of a DC microgrid with single as well as multiple PV units and battery is carried out using the transfer function model. A DC microgrid having a single bus topology and multiple DERs, controlled using multi-loop control is considered for the analysis. The effect of penetration of DERs on the stability of the system is investigated using the eigenvalue approach. A system with communication delay is also considered for the analysis. From the analysis it can be seen that, addition of a new DER unit into the system affects the stability and hence the controller gains needs to be re-tuned to bring the system back to the stable state.

Track 4.3 (PSOP02): Power System Operation & Planning

Date: Saturday, Dec 18, 2021 **Time: 10:15 AM - 11:30 AM**

Paper ID : 227

Solar Photovoltaic on Water Bodies in Rajasthan

Authors:

Vijay Kumar	MNIT Jaipur, India
Kusum Lata	MNIT Jaipur, India
Rohit Bhakar	MNIT Jaipur, India
Parul Mathuria	MNIT Jaipur, India

Abstract:

Solar power plants on water bodies are gaining popularity nowadays and are being acknowledged by several states of India. Floating Solar Photovoltaic (FSPV) and Canal Top Solar Photovoltaic (CSPV) plants are deployed on lakes, canals, and other water bodies. Their deployment mitigates the issues of land scarcity, dust deposition on panels, and high module temperature, faced by traditional solar power plants. However, limited studies are available that review various techno-economic aspects and promote the full-scale deployment of such technologies. In this context, the paper contributes to review the feasibility and potential assessment of solar plants on water bodies in India's highest solar potential state, Rajasthan. The technology used in FSPV and CSPV plants is discussed here along with their components. Further, the paper presented a cost analysis of various FSPV/CSPV plants across the country. This work highlights the potential benefits and challenges of these plants. This work provides a pathway that would help system planners to install such plants in Rajasthan.

Paper ID : 36

Proactive Operation Strategy to Enhance Resiliency of Indian Power System during Super Cyclone Amphan

Authors:

Aman Gautam	POSOCO, India
G.Sudhakar	POSOCO, India
M.K.Gupta	POSOCO, India
Rahul Shukla	POSOCO, India
R.K. Porwal	POSOCO, India
Debasis De	POSOCO, India
S.R.Narasimhan	POSOCO, India

Abstract:

Power systems are designed to be operated under expected weather conditions. Unexpected weather conditions sometimes create widespread damage to the power system. The failure rate of equipment in power system along with redundancy and accuracy of forecasting decide the scope of damage. Eastern coast of Indian sub-continent experiences cyclones of varying intensity every year. These cyclones have severe impact on the infrastructure including the power infrastructure. The proactive operation strategy to counter each stage of uncertainty helps not only in managing the power system but also in early restoration. Amid the NCOVID-19 pandemic, Indian power system witnessed super cyclone named 'AMPHAN' which originated in the Bay of Bengal. The cyclone, after landfall passed through densely populated regions affecting the load centers. Cyclone of matching severity was last witnessed by India in the year 1999. The landfall of cyclone started during afternoon hours of 20th May 2020. The proactive action strategy based on

past experience resulted in minimization of loss to electrical system and power supply outage. This paper presents the proactive measures taken by POSOCO and power utilities across all key sectors, viz., generation, transmission, distribution, during different phases of cyclone trajectory and the impact of cyclone on Indian power system.

Paper ID : 225

Evolution and Institutional Building of Load Despatch Centres in India

Authors:

Akhil Singhal	POSOCO, India
K.V.N. Pawan Kumar	POSOCO, India
Vivek Pandey	POSOCO, India
S.C. Saxena	POSOCO, India
Debasis De	POSOCO, India
S.R.Narasimhan	POSOCO, India
S.S. Barpanda	POSOCO, India
S.K. Soonee	POSOCO, India
K.V.S. Baba	POSOCO, India

Abstract:

This paper attempts to document the evolution of Load Despatch as an institution in India. It describes initiatives taken in India for institutional restructuring of Load Despatch Centres. The paper traces the history of the establishment of an Independent System Operator for the integrated operation of the Indian national grid. The technical, financial, organizational and human resource related challenges have been discussed. The various strategies adopted for managing the transition in different phases have been outlined. The paper also highlights the key learnings which may be relevant for the organizational restructuring initiatives in other public infrastructure institutions as a part of the reforms process.

Paper ID : 224

Applicability of VSAT Communication for Indian Power System

Authors:

Nabarun Roy	POSOCO, India
M.K. Ramesh	POSOCO, India
Akhil Singhal	POSOCO, India
Tapobrata Paul	POSOCO, India
Ashutosh Kumar	POSOCO, India
Sakal Deep	POSOCO, India
Paominlal Doungel	POSOCO, India
Royal Sutnga	POSOCO, India

Abstract:

Indian power system is one of the largest synchronously operated Power System Networks in the world with an installed capacity of about 370 GW. The Indian Power Grid is being monitored by a multi-level integrated Supervisory Control & Data Acquisition (SCADA)/ Energy Management System (EMS) installed at many

control centres (or Load Despatch Centres) dispersed all over India. The Load Despatch Centres acquire real-time data from the substations as well from the other control centres and this critical power system operational data is transferred through a dedicated and secure communication system backbone network spread across the country. Keeping in view the importance of the communication system in a vast meshed network at the National, Regional and State level in India, the regulatory body of power sector i.e. Central Electricity Regulatory Commission (CERC) has also specified the regulations regarding Communication System for inter-State transmission of electricity.

Paper ID : 16

Wireless Communication Technologies for Indian Smart Grid: Fitness Evaluation and Optimal Decision-Making

Authors:

Jignesh Bhatt — Dharmsinh Desai University, India
Omkar Jani — Kanoda Energy Systems Pvt.Ltd, India
V.S.K.V. Harish — Netaji Subhas University of Technology, India

Abstract:

Decision for the best efficient communication technology is a major design challenge that necessitates serious attention. Considering the impact of communication technologies on the overall smart grid resilience, a meticulous methodology is essential. A methodology presented in this work attempts to optimize the selection by balancing the communication needs of smart grid applications against capabilities of wireless technology alternatives. Fitness evaluation of communication technology of a pilot of smart grid in India conducted for validation of proposed methodology and suggested better-fit alternatives. Due to its minimal computing needs, simplicity and flexibility, the presented methodology demonstrates practical viability.

Track 4.4 (LFDM03): Load Forecasting & Demand-side Management

Date: Saturday, Dec 18, 2021 **Time: 10:15 AM - 11:30 AM**

Paper ID : 51

Coexistence of Day Ahead Market and Real Time Market in Indian power sector

Authors:

Naresh Kumar Mhalas	WRLDC, POSOCO, India
Aditya Prasad Das	WRLDC, POSOCO, India
S. Usha	WRLDC, POSOCO, India

Abstract:

In India, Short term open access (STOA) in transmission and distribution provides a range of opportunities to the market players. Sellers and buyers can transact power bilaterally through over the counter contracts or bid collectively through the power exchanges in Day Ahead Market (DAM). Real Time Market (RTM) was introduced in India from 01.06.2020. This has created a new opportunity for the electricity market players for trading in real time with a lead time of 1.5 hours. RTM provides 48 bidding windows over a day. This provides additional flexibility for last mile portfolio optimization. This paper attempts to analyze the impact of coexistence of DAM and RTM to derive further inferences. It provides an insight to the relationship of the Market Clearing Price (MCP) of DAM and RTM. Trend of MCP of DAM and RTM is analyzed with respect to variation in demand.

Paper ID : 216

Bhutan-India Interconnected Grid Operation and Electricity Market Transactions

Authors:

Pinki Debnath	POSOCO, India
K V N Pawan Kumar	POSOCO, India
Subhendu Mukherjee	POSOCO, India
S C Saxena	POSOCO, India
G Chakraborty	POSOCO, India
Debasis De	POSOCO, India
S S Barpanda	POSOCO, India
KVS Baba	POSOCO, India

Abstract:

The electrical interconnection between India and Bhutan is one of the oldest amongst the global transnational interconnections. The export of power from the Hydro Electric Projects in Bhutan are a unique example of complementary collaboration in cross border trade which provides a clean and reliable source of electricity to India along with economic value for Bhutan. The authors illustrate here in this paper the governance architecture at the regulatory and policy level for facilitating transnational transactions between Bhutan and India. The authors outline the key aspects for ensuring the reliability and security of the interconnection and other challenges. The research community would be benefited from key aspects regarding the operative knowledge of synchronous operation of India-Bhutan interconnector in this paper. The Cross Border Transactions in Electricity (CBTE) policy of the Government of India has boosted up our nearby countries to further strengthen the interconnection with India leading to greater regional interconnections development.

Paper ID : 57

Day-Ahead Energy Market Framework Utilizing Transmission-Distribution Coordination

Authors:

Megha Gupta — IIT Delhi, India

A. R. Abhyankar — IIT Delhi, India

Abstract:

The penetration of Distributed Energy Resource (DERs) in the distribution system (DS) is expanding with time. This has raised the need of having a distribution system operator (DSO) that encourages the participation of DERs in the energy market. However, there could be a disagreement in the primary objectives of each DSO with the transmission system operator's (TSO's) objective. Thus, there will be a shortfall of cooperation across the system. Moreover, if TSO has direct control of DERs, then a huge computational burden will get introduced at the transmission level. Hence, the coordination between TSO and DSOs is required to take advantage of the resources available in DS at the transmission level. In this paper, a coordinated energy market framework is presented that involves the exchange of limited information at the common bus of connection. This will allow the efficient and economical utilization of cheaper and greener resources available in DS for the entire transmission & distribution (T&D) network without adding much communication burden and complexity. The proposed framework is implemented on an integrated T&D test system to validate its efficacy.

Paper ID : 248

Peer-To-Peer Decentralised Local Energy Trading Markets Using Blockchain

Authors:

Jayati Shrivastava — IIT Roorkee, India

Srasti Sethi — IIT Roorkee, India

Tanisha Sahu — IIT Roorkee, India

Urjita Sharma — IIT Roorkee, India

Gnana Lakshmi T C — Emerging Technologies, Wiley, Bengaluru, India

Deep Kiran — IIT Roorkee, India

Abstract:

Rising growth and development are accompanied by increasing demand for energy. The result is the increased load on power grids, higher energy costs for consumers, and increased greenhouse gas emissions. Peer-to-Peer (P2P) local energy trading is a method that can give some relaxation on all such issues. Motivated by the existing literature on integrating blockchain technology in the smart grid, this paper proposes an efficient blockchain-based P2P energy trading market for local users such as communities, residential complexes, business centres, or neighbours. Consumers have installed Renewable Energy Sources (RESs) in this arrangement, i.e., PV panels, to generate energy locally, acting as prosumers. The surplus energy, remaining after self-utilisation, is traded with energy-deficit neighbours in the market at a lesser price than the grid price. This setup empowers small-scale prosumers by giving them a platform to earn profits by selling their surplus energy. This technology will increase sustainability and promotes security, transparency and decentralisation of the utility grid.

Paper ID : 190

Blockchain-based Decentralized Hybrid P2P Energy Trading

Authors:

Bhawana Solanki	MNIT Jaipur, India
Ayushi Agarwal	MNIT Jaipur, India
Raveena Meena	MNIT Jaipur, India
Nitika Mahiya	MNIT Jaipur, India
Divya Sharma	MNIT Jaipur, India
Priyanka Kushwaha	MNIT Jaipur, India
Parul Mathuria	MNIT Jaipur, India
Rohit Bhakar	MNIT Jaipur, India

Abstract:

With increasing local energy generation consumers are converting into prosumers by selling their excess generation with their peers. This transaction of locally generated energy is called Peer-to-Peer (P2P) energy trading. For P2P energy trading, a community system is widely endorsed but causes an increase in overall system cost as both prosumer and consumer need to pay charges to the community manager. In this context, a hybrid P2P energy trading market is implemented through a decentralized blockchain-based mechanism. It permits market participants to trade energy directly without involving an additional entity. Contracts play a crucial role in blockchain-based energy trading mechanisms. Thus, smart contracts are designed for the efficient implementation of this trading mechanism. These contracts are designed using the Solidity platform on REMIX IDE. Prosumer and consumer interact among themselves through the main smart contract to execute P2P energy trading till market-clearing time. Afterwards, they interact with the grid through Peer-to-Grid (P2G) smart contracts for additional sell/purchase of energy. Results show that the proposed approach leads to a smart, secure and economical mechanism of energy trading.

Track 4.5 (RIEV04): Renewable Integration & Electric Vehicle

Date: Saturday, Dec 18, 2021 **Time: 10:15 AM - 11:30 AM**

Paper ID : 179

Open-Source Active Distribution Grid Model with a Large Share of RES- Features, and Studies

Authors:

Aeishwarya Baviskar	Technical University of Denmark, Denmark
Anca D. Hanseni	Technical University of Denmark, Denmark
Kaushik Das	Technical University of Denmark, Denmark

Abstract:

Future distribution grids are likely to shift awayfrom a passive grid consuming power to an active grid with a high share of weather-dependent renewable generation. Distribution grid operations are greatly interlinked between different voltage levels and depend upon the fluctuating load demand. Thus it is imperative to study and analyze multivoltage level distribution grids to understand the challenges and opportunities in a distribution grid with a high share of weatherdependent generation. In this research, an open-source multivoltage level distribution grid model, named the DTU 7k-Bus Active Distribution Grid Model, is presented. The distribution grid model spans across three voltage levels and is modeled on geographical data for network topologies. The generation and load time-series provided with the model are simulated from weather data and derived from measurement data respectively. This work addresses key features of the model and highlights challenges due to the high share of renewables.

Paper ID : 284

Evolution of Integrated Multi-Energy Vector System and Innovation Opportunities

Authors:

Arpit Mantri	MNIT Jaipur, India
Aaquib Firdous	MNIT Jaipur, India
Chandra Prakash Barala	MNIT Jaipur, India
Rohit Bhakar	MNIT Jaipur, India
Parul Mathuria	MNIT Jaipur, India

Abstract:

Increasing energy demands and visibly changing climatic conditions have led to various deliberations to look at and mitigate the effects causing this adversity. The Paris agreement received greater attention from major countries aiming to decarbonize energy systems and adopt more Renewable Energy Sources (RES). In this regard, India is already ahead of its ambitious targets in increasing its RES installation capacity. However, given the nature of these RES, it has increased the challenges in power systems and questioned the prime component of energy trilemma which is the security of supply. These challenges need to be addressed to avoid failures; one way is to exploit the various synergies between different energy systems. This can reduce carbon emission and increase the renewable penetration in the energy system and meet the requirements of the changing energy sector. This can be facilitated using Multi Energy Systems (MES). These systems optimally interact with each other at different levels and can increase the overall technical, economic, and environmental performance relative to existing energy systems which are planned and operated independently or separately. This paper discusses the overview of MES concepts, key components,

opportunities in the Indian perspective, challenges, Energy markets and enumerates a few future works in this direction.

Paper ID : 226

Aerodynamic Energy Harvesting for Electric Vehicles

Authors:

Ashishsingh Solanki IIT Kharagpur, India

Abstract:

This study aims to achieve a method for harvesting energy from an automotive vehicle to improve its performance. A novel idea is discussed where the aerodynamic drag is used to harvest the energy from a car. This paper encloses virtual experiments and trials to use the vehicle's frontal area to channel the airflow at high speeds into a duct and generate power using a turbine generator system inside the duct. Numerous trials and simulations are done to optimize the experiment, and this paper gives a great insight into the possibility of harvesting energy utilizing the drag force experienced while driving a car at a considerable speed. The paper discusses the methods taken to design the duct inside the frontal area of the vehicle more efficient and robust in geometry, and also considers the shape of the frontal area so that it does not hamper the airflow reaching the duct, which in turn rotates the turbine forth the duct to generate power. All aspects of this paper are minutely taken care of, and the calculations are based on various assumptions mentioned in the paper itself. This paper focuses on a better way to harvest energy and is expected to be helpful in future studies and help the upcoming industry of electric cars.

Paper ID : 165

Solar Powered EV Fast Charging Station to Support Distribution Grid

Authors:

Harshita Arya IIT Mandi, India

Moumita Das IIT Mandi, India

Abstract:

The demand for charging stations is increasing with the advancement of electric vehicles. The required power in the charging station is very high. The power demand is even higher in a fast-charging station. The sudden high-power demand causes voltage instability, power loss, harmonic distortion and transformer overloading on the distribution grid. Hence, the work proposed in this paper focuses on, firstly to investigate the fast-charging impact on the grid. Secondly, to provide a solution by integrating renewable energy sources (such as solar PV) along with a battery in dc bus to reduce this effect. The proposed system also facilitates bi-directional power flow from grid to vehicle and vehicle to grid. The control method of various modes of a fast-charging station with and without the presence of a solar PV are presented. The analysis, simulation and preliminary hardware results of the proposed system are included in the paper.

Paper ID : 112

Modified Energy Management Strategy for HESS in Electric Vehicle

Authors:

Alok Ranjan — Shri Ramdeobaba College of Engineering and Management, India

Sanjay B. Bodkhe — Shri Ramdeobaba College of Engineering and Management, India

Abstract:

Range of electric vehicle depends on onboard energy storage system and strategies used to handle this power. Range anxiety, current drain during peak power demand and less battery life are the discouraging factors associated with battery alone electric vehicle. Suitable factor for battery as stress reduction is ultracapacitor and its utility along with the battery is in development stage. Limited research work is reported on control algorithm for battery and ultracapacitor as hybrid energy storage systems in electric vehicle. In this paper, different energy management strategy is studied and presented. Conventional rule-based strategy is studied and simulated on Simulink platform. A modified rule-based strategy is proposed and simulated on the same platform. A comparative analysis suggests that modified rule-based strategy is having fast response, capable to provide constant dc link voltage and having better performance.

Contributory Paper Session 5

Track 5.1 (AIML01): Artificial Intelligence & Machine Learning

Date: Saturday, Dec 18, 2021 **Time: 03:15 PM - 04:15 PM**

Paper ID: 195

The Adaptive Forecast Combiner

Authors:

Yash Raizada	Climate Connect, India
Rahul Kumar	Climate Connect, India
Sanand Sule	Climate Connect, India

Abstract:

An accurate solar power prediction is vital for the smooth and stable operation of the power grid. A combined forecast is often preferred over an individual model's predictions as it significantly increases the overall forecast accuracy. In this paper, we propose a novel forecast aggregation algorithm called the Adaptive Forecast Combiner. It combines multiple input forecasts with dynamic weight allocation after a multi-horizon performance review. Three machine learning models are trained on the dataset of a 48 MW solar power plant in India, and the corresponding intra-day and day-ahead forecasts are obtained. A comprehensive performance evaluation illustrates that the proposed combiner consistently outperforms all the individual machine learning models irrespective of the season or forecasting methodology.

Paper ID: 134

Impact of Renewable Energy Penetration on PMU based Grid Event Detection using Machine Learning Framework

Authors:

Rajib Majumdar	IIEST Shibpur, India
Abhishek Rai	IIEST Shibpur, India
Paramita Chattopadhyay	IIEST Shibpur, India

Abstract:

This paper is a systematic investigation and comprehensive study on ML based grid event classification in presence of renewable energy resources. In this data-driven approach, PMU data with reporting rate of 24 samples/cycle have directly been processed by various ML algorithms. Finally, it has clearly demonstrated the success of 1-D CNN for multichannel signal processing by wiping out the challenges of inter class similarities due to RE integration. The efficacy of the algorithm has been established with IEEE -9 bus system. Preliminary results obtained so far are very encouraging, projecting the promising future 1-D CNN in this area due to its excellent feature extraction using convolution process.

Paper ID: 160

Alternative Regression Approach for Data-Driven Power Flow Linearization Methods

Authors:

Gopal Jain	IIT Roorkee, India
Suraj Sidar	IIT Roorkee, India
Deep Kiran	IIT Roorkee, India

Abstract:

The knowledge of essential parameters for a power network is necessary for many applications. Evaluating them using traditional methods is computationally intensive and may fail to consider all external factors affecting the system. Therefore, a machine learning-based approach is proposed that predicts these parameters in this paper. The datasets are prepared for IEEE standard test systems and extended for their training and testing. This method can prove helpful to find all the unknown parameters for a power system, especially voltage magnitude and voltage angle, with significantly less error.

Paper ID: 125

Estimation of Time Drift in Interface Energy Meters

Authors:

Mastanvali Shaik	WRLDC, POSOCO, India
Vivek Pandey	NLDC, POSOCO, India
Sushrut Meshram	WRLDC, POSOCO, India
Sunil Kumar Aharwal	WRLDC, POSOCO, India
Sachala Mishra	WRLDC, POSOCO, India
Velury Balaji	WRLDC, POSOCO, India

Abstract:

Time drift in the internal clock of the Special Energy Meters (15-minute interval meter) installed for measuring inter-utility energy exchanges in India is a major concern in energy accounting and deviation settlement. Since the meter clock is accessible only locally, the time drift can only be determined locally by visually comparing the time in the internal clock of the meter with the Indian standard time. Collection of information related to meter time drift every week from the locations where these meters are installed, is a cumbersome process and it is also prone to errors due to manual intervention in data collection. This paper shares the various techniques being applied presently for determination of time drift and proposes a novel application of cross correlation with linear interpolation (used in signal processing) for estimation of meter time drift at the data collection centre. The efficacy of the proposed method has been demonstrated with the help of simulations. The novel application has been successfully used in Western Regional Load Despatch Centre in India and is found to be accurate to +/- 1 minute with a reasonable confidence level. The whole process of time drift estimation has been automated to significantly improve the energy meter asset administration.

Track 5.2 (MGDS05): Micro-Grid and Distribution System

Date: Saturday, Dec 18, 2021 **Time: 03:15 PM - 04:15 PM**

Paper ID: 156

Energy Storage Unit for Dynamic Voltage Support in Distribution Networks

Authors:

Bonu Ramesh Naidu — IIT Kharagpur, India
Prabodh Bajpai — IIT Kharagpur, India
Chandan Chakraborty — IIT Kharagpur, India

Abstract:

The increasing participation of distributed energy resources in the low voltage distribution network prompt mandated grid-supporting activities from these entities during short term disturbances. The primary idea of the work presented in this paper is to leverage the dynamic voltage support capability of the grid-connected energy storage units during voltage fault ride through conditions on the distribution network. Firstly, a detailed analysis about the role of energy storage units in providing dynamic voltage support for both low and high voltage disturbances is presented and the conditions for maximizing the voltage support are derived. Further, the dynamic voltage support oriented control strategy for the converters of the energy storage unit is presented in detail along with the state-of-charge management of the storage device. Finally, a simulation study considering a supercapacitor energy storage unit connected to the CIGRE European LV residential distribution test feeder is carried out using Matlab/Simulink to validate the proposed control strategy. The results assert the fact that the grid-connected energy storage units aid the network voltage during disturbances with the proposed control strategy within their design limits.

Paper ID: 171

Comparative Study of Various Communication Technologies for Secondary Controllers in DC Microgrid

Authors:

A B Shyam — IIT Kanpur, India
Soumya Ranjan Sahoo — IIT Kanpur, India
Sandeep Anand — IIT Kanpur, India
Josep M. Guerrero — Aalborg University, Denmark

Abstract:

With the increased emphasis on power generation from renewable sources, microgrids are considered as the best solution for distributed generation. Control of distributed sources in dc microgrid have been a topic of interest for both academia and industry. Reliable operation of secondary controller of a dc microgrid depends on a good communication network. However, the literature on dc microgrid does not give the methodology to select a particular communication technology from a wide variety of wired and wireless technologies. The selection of proper technology is based on many factors like the size of the microgrid, bandwidth, number of power electronic converters supported, latency, range, etc. A comparison of wired and wireless communication technologies based on these factors, and their suitability to use in dc microgrid is performed in this paper. Expressions are derived to calculate the maximum permissible number of devices

supported and the network latency for each communication technology. The observations made in this paper are validated with case studies on low and medium power dc microgrids.

Paper ID: 11

Fractional-Order Adaptive Sliding Mode Approach for Frequency Regulation in Power System

Authors:

Vivek Patel — MNNIT Allahabad, India
Dipayan Guha — MNNIT Allahabad, India
Shubhi Purwar — MNNIT Allahabad, India

Abstract:

The increased penetration of renewable sources in power system makes it more vulnerable to instability due to their intermittent outputs. Most importantly increased deviation in frequency and voltages during transient disturbances effect stability of power system. To ensure stable and reliable power supply, area frequency deviation needs to be maintained at its theoretical value (±0.5Hz). So as to decrease the frequency deviation, a fractional-order adaptive sliding mode control (FO-ASMC) is applied in a hybrid power system. To improve the system response and reduce the impact of chattering, a fractional calculus and adaptive law is incorporated into the design of traditional SMC. The performance of FO-ASMC has been examined under various load perturbations and wind power fluctuations. The findings of FO-ASMC are compared to those of traditional SMC.

Paper ID: 62

A Novel Hybrid Algorithm for Event Detection, Localisation and Classification

Authors:

Arup Anshuman — IIT Delhi, India
Bijaya Ketan Panigrahi — IIT Delhi, India
Manas Kumar Jena — IIT Palakkad, India

Abstract:

Effective management of multiple real-time transient events and unstable low-frequency oscillations in the modern power system has been a matter of concern to the Transmission system operators. This manuscript unifies the idea of transient event detection and localization with the analysis of the oscillation mode that accompanies these impulsive events. The paper employs Discrete wavelet transform (DWT) to segregate transient events from oscillatory behavior that follows these events. The paper also proposes a novel indicator for the classification of transient events based on the most affected signals in due course of the event. Empirical Mode decomposition (EMD) and Hilbert spectral analysis (HSA) are utilized on the PMU signals severely affected by the event and further examine the oscillatory modes succeeding the real-time events. Oscillatory modes deduced from the above adaptive transformations are further categorized into three frequency bands based on power system control applications, thus helping operators provide efficient control actions. The novel methodology discussed in the paper has been applied to the IEEE 39 bus system with a dataset generated using the RTDS power system simulator and GTNETx2 based PMUs.

Track 5.3 (CMSC01): Condition Monitoring & System Characterization

Date: Saturday, Dec 18, 2021 **Time: 03:15 PM - 04:15 PM**

Paper ID: 150

Impact of Defect Functionalization and Thickness Variation on EMI Shielding Efficiency of Epoxy-MWCNT Nanocomposites

Authors:

Abhishek Sharma	IIT Madras, India
Myneni Sukesh Babu	IIT Madras, India
Asapu Vinaya Kumar	IIT Madras, India
R. Sarathi	IIT Madras, India
V. Subramanian	IIT Madras, India

Abstract:

Epoxy resin is loaded with Multi-Walled Carbon Nanotubes (MWCNT) to understand its impact on the Electromagnetic Interference (EMI) Shielding Efficiency (SE) in the X-band frequency range (8-12 GHz). The study is performed by varying weight percentages of Multi Walled Carbon Nanotubes (MWCNT) before and after defect functionalization process and also by varying the thickness of the composite. The EMI SE of epoxy-MWCNT nanocomposites, increases with increment in the wt% of pristine MWCNT nanofillers. No significant improvement in EMI SE of epoxy nanocomposites loaded with defect functionalized MWCNTs is noticed. Also, a substantial increment in EMI SE of epoxy- MWCNT nanocomposites, is noticed with increment in thickness up to 3mm.

Paper ID: 122

Classification of Polluted Silicone Rubber Micro Nanocomposites based on ESDD Using ANN

Authors:

Pabbati Vinod	IIT Madras, India
Myneni Sukesh Babu	IIT Madras, India
Ramanujam Sarathi	IIT Madras, India
Stefan Kornhuber	University of Applied Sciences Zittau/Görlitz, Zittau, Germany

Abstract:

Silicone rubber micro nanocomposites are coated with various types of pollutant with variation in concentration and the laser-induced breakdown spectroscopy (LIBS) technique is used to understand the pollution performance of test specimens. The chemical composition of the contamination present on the sample was effectively established via elemental analysis of LIBS spectra. The equivalent salt deposition density (ESDD) and the normalized intensity ratio of LIBS spectral data have a direct relationship. In order to correlate the normalized LIBS spectral data intensity ratio and ESDD, the regression coefficient (R2) is employed to determine its performance. The LIBS spectral data is used to implement an artificial neural network (ANN) approach to the categorization of contaminated silicone rubber micro nanocomposite samples based on ESDD and pollutant type. In this work, the total hidden layer neurons are selected based

on classification accuracy and number of epochs needed for convergence. The developed ANN model is successful in classifying contamination level and type of contamination on silicone rubber specimens with a classification accuracy of 100%.

Paper ID: 184

Comparative Assessment of Spectral Analysis Methods for Characterizing Forced Oscillation

Authors:

Priya Singh	IIT Patna, India
Abhineet Prakash	IIT Patna, India
Kundan Kumar	IIT Patna, India
S. K. Parida	IIT Patna, India

Abstract:

The oscillations in a power system can be categorized into free oscillations and forced oscillations. Forced oscillations (FOs) are caused due to periodic forced disturbance. It has been reported that estimating natural and forced oscillatory modes is problematic when the frequency of the forced oscillation is close to that of the system's natural oscillations. Hence, FOs are now becoming a highly concerned phenomenon in the power system. In this paper, a systematic comparative assessment is presented based on power spectrum estimation analysis between the Welch periodogram and the Multitaper method (MTM). Besides, if not properly taken into account, the calculation of the mode and mode estimation of low frequency oscillation may be adversely affected by forced oscillation. Forced oscillations must quickly be identified and mitigated, otherwise the persistence of FO may lead to severe damages to the system equipment and protective devices consequently leading to blackout.

Paper ID: 56

Estimation of Inertia in Power Systems using Law of Conservation of Energy

Authors:

Lavanya L	IIT Madras, India
K Shanti Swarup	IIT Madras, India

Abstract:

One of the fundamental challenges for powering the grid with a significant share of renewable sources is to operate the grid securely with low levels of inertia. Hence, it has become imperative for the grid operator to monitor the inertia of the power grid to optimize the share between conventional and renewable sources and plan for frequency reserves. This paper details the formulation of a novel method to monitor the inertia of the grid and its areas using measurements from PMUs (Phasor Measurement Units). The method uses the Law of Conservation of Energy and Kinetic Energy to devise the problem. Upon detection of frequency events, i.e., power imbalance events, a system of linear equations is formed using PMU measurements, which is then solved by the least-squares algorithm to obtain inertia. The method is tested in Kundur two-area system and modified IEEE 39 bus system.

Track 5.4 (LFDM04): Load Forecasting & Demand-side Management

Date: Saturday, Dec 18, 2021 **Time: 03:15 PM - 04:15 PM**

Paper ID: 274

P2P Energy Trading in Local Energy Market considering Network Fees and Losses

Authors:

Divya Sharma	MNIT Jaipur, India
Rohit Vijay	MNIT Jaipur, India
Parul Mathuria	MNIT Jaipur, India
Rohit Bhakar	MNIT Jaipur, India

Abstract:

Integration of distributed energy resources (DERs) into distribution networks offer various benefits, including lower greenhouse gas (GHG) emissions, loss reduction, and grid reliance reduction. However, as the number of distributed energy resources grow, existing distribution networks face a variety of operational and market concerns, including voltage limit breaches, line congestion, visibility issues with DERs, and intermittent energy balances. It is difficult to construct a centralized market that serves several areas to handle such local concerns due to a variety of barriers. So, this work proposes a Peer-to-Peer (P2P) energy trading platform for participants with the capability of active participation in the market, where they can manage their demand and generation and participate as a buyer or seller considering network losses and network fees. For energy transfer, physical network or grid is considered, hence power losses cannot be ignored and grid related costs are always present in the Peer-to-Peer trading. Grid-related cost consists of the network utilization fees, that is calculated using an electrical distance approach.

Paper ID: 251

Multi-Objective Optimization based Automated Demand Response Model in Smart Distribution Grid

Authors:

Priyanka Sharma	IIT Gandhinagar, India
Abhishek Tiwari	IIT Gandhinagar, India
Naran M. Pindoriya	IIT Gandhinagar, India

Abstract:

Automated Demand Response (ADR) plays a vital role in the smart grid. This paper uses a two-layer hierarchical day ahead model where the utility and consumer are the key stakeholders. The Utility being at the top layer initiate an ADR event during peak load conditions. It sends a signal for managing the load to the consumers, equipped with smart meter and load control device technologies at their end. The main objective of the utility is to minimize electricity generation costs and give a particular part of the saving to the consumer for reducing their electricity consumption in the form of incentive. The customer wishes to maximize its benefit, while taking into consideration the dissatisfaction factor. A multi-objective problem is formulated to achieve a fair solution, and a pareto optimal set is achieved using the epsilon constraint method in GAMS. Also, the time-frame of activities involved between utility and consumer to carry out an ADR event is discussed in this paper. Simulation results over different consumer categories, i.e., industrial/ commercial, shows the feasibility of the model.

Paper ID: 197

Automated Demand Response for Residential Prosumer with Electric Vehicle and Battery Energy Storage System

Authors:

Abhishek Tiwari — IIT Gandhinagar, India

Naran M. Pindoriya — IIT Gandhinagar, India

Abstract:

In today's smart active distribution network, end-consumer can participate in the system stability enhancement and system operating quality improvement through the Automated Demand Response (ADR). This paper presents the optimized scheduling of the flexible energy resources under Real-Time Pricing (RTP). The objective of the optimization is to reduce the energy cost of the residential end-consumer, which includes an electric vehicle (EV) with a vehicle-to-grid facility enabled and three extra appliances, with minimal possibility of compromise in comfort and levelized cost. The RTP price variation depends on the system condition, and the consumption of the end consumer under optimized scheduling depends upon the RTP. So indirectly, consumers participate in system stability and quality improvement by curtailing the load at a higher price and shifting it to a lower price. The scheduling problem is formulated as a non-linear optimization problem. The two cases viz optimization problem with and without the discomfort index and levelized cost of energy are presented through simulation results in this paper.

Track 5.5 (RIEV05): Renewable Integration & Electric Vehicle

Date: Saturday, Dec 18, 2021 **Time: 03:15 PM - 04:15 PM**

Paper ID: 208

Implementation of Active and Reactive Power Control in a Novel Solar Power Plant Controller Solution

Authors:

Ashutosh Kumar Tiwari — L&T Construction Chennai, India
Anamika Dubey — L&T Construction Chennai, India
Prabakaran Selvaraj — L&T Construction Chennai, India
Soumya Kanta Panda — L&T Construction Chennai, India

Abstract:

The increasing penetration of variable renewable energy resources connected to the distribution grid creates a number of challenges for system operators and utilities, in particular in the areas of voltage and frequency management. In order to mitigate some of these challenges, regulators have introduced grid codes that impose some level of controllability on the power output of renewable energy plants. In this paper, the authors present a power plant controller solution designed to meet the active and reactive power control grid code requirements for PV plants in India. The control solution coordinates the real-time active and reactive power output of the plant inverters to meet aggregate target values measured at the plant's point of interconnection with the grid. After presenting the overall solution architecture, the authors detail the different control modes that were implemented (direct active/reactive power control, droop-based control based on frequency or voltage) and how operational constraints such as inverter availability, inverter thermal limits, permissible grid frequency and power plant voltage were accounted for. The performance of the control algorithm is presented and discussed based on offline simulation results. The performance of the overall solution where the algorithms are embedded in a real-time runtime environment is also evaluated. To assess the solution performance, real-time hardware-in-the-loop (HIL) tests are performed and presented. The overall results are discussed, and future enhancements are proposed.

Paper ID: 130

Phase Shifting Strategy for Mitigation of Local Voltage Rise in Highly PV Penetrated Distribution Network

Authors:

Dhaval Y. Raval — Gujarat Technological University, India
Saurabh N. Pandya — Lukhdhirji Engineering college, Morbi, India

Abstract:

The polluting nature of conventional sources is leading the world toward non-polluting renewable energy sources. Solar Photovoltaic (PV) technology is considered to be the future of energy. Small-scale rooftop plants are favorable for the fulfillment of consumer demand and generating revenue from surplus energy. Traditional distribution systems face power quality issues as a result of rooftop solar plant integration. For distribution networks with high PV penetration, Local Voltage Rises and reverse power flow (RPF) are major concerns. In this work, the author has proposed a Phase Shifting Strategy (PSS) for mitigation of Local Voltage Rises and Reverse Power Flow. Under high PV penetration, the IEEE 906 Bus European LV Test feeder was investigated. Cosimulation using OPENDSS and MATLAB has been performed to validate PSS in solving

Local Voltage Rise and minimizing Reverse Power Flow issues. The results show that the voltage profile of all the consumers is significantly improved with the PSS.

Paper ID: 7

Design and Optimization of Mini-Grid PV System for Developing Country

Authors:

Ashwini V. Chaware	College of Engineering, Pune, India
S.S. Dambhare	College of Engineering, Pune, India
Vasim Pathan	Rolls Royce Power System, Pune, India
Gaurav Mistry	Rolls Royce Power System, Pune, India

Abstract:

In this paper, mini-grid has been designed for developing countries using PV as a source of energy to get electricity at zero CO2 emission. The mini-grid design has been proposed to provide power to off-grid locations of Sub-Saharan Africa at a lower cost, higher efficiency. The location of the minigrid design is considered in developing countries. The design includes a containerized mobile mini-grid solution for Sub-Saharan Africa using photovoltaic as a source of generation and the battery as energy storage to provide a complete off-grid solution. The sizing of PV, the battery is done using a complex approach instead of the traditional approach which unnecessarily increases the size of the PV, battery. After sizing, the different arrangement has been tried on a container to get maximum output and using simulation, an optimum arrangement has been found out. The results have been verified by Helioscope.

Paper ID: 194

Simulation and Analysis of Solar Based Water Pump System using Separately Excited DC Motor with Different Converter Topologies

Authors:

Kalyan Singh Malviya	MANIT Bhopal, India
Savita Nema	MANIT Bhopal, India
Suresh Kumar Gawre	MANIT Bhopal, India

Abstract:

This paper presents Simulation and Analysis of Solar Based Water Pump System Using Separately Excited DC Motor for a good selection of DC-DC converter and smooth starting of motor. This work also compares the three DC-DC converters i.e. Boost, Cuk, and SEPIC converters one after the other, and their appearance is analyzed for pumping system application and simple starting of the separately excited DC motor is achieved by gating the switch of the converter through the direct duty ratio controller system and their result demonstrates that the SEPIC converter is a companionable arrangement for a solar photovoltaic cell (SPVC) based water pump system and the findings of various parameters obtained at the output of the three converters, as well as the motor and centrifugal pump output parameters.

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