Hanzehogeschool Groningen
University of Applied Sciences

BILFINGER

Flexible Energy Technology

Design Report

Group 5

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Preface

Dear reader,

Thank you for reading this report on designing the electrical installation (key-one line) for harnessing the energy of Syngas at Bilfinger Tebodin Consultants & Engineers. In this report, among other things, the analysis, research, implementation, conclusion, discussion, reflection, and evaluation done in this project are described in detail.

As part of the Flexible Energy Technology minor at Hanze University of Applied Sciences, this project was commissioned by Bilfinger Tebodin Consultants & Engineers. Much was learned about the elements, standards, and practices of designing electrical installations for particular applications during the course of the project.

The project team would like to thank Herman van Deventer, Maarten de Witt, and Daniel Erhan from Bilfinger Tebodin Consultants & Engineers for acting as our coordinators. In particular, we appreciate their taking the time to meet with us on a regular basis for assistance and input on our progress. This has significantly aided in reaching the desired outcome. We also want to express our gratitude to Oscar Grooten, who acts as our supervisor at Hanze University of Applied Sciences, for helping us, pointing us in the correct path, and sharing his insightful professional expertise with us.

John Rodrigues, Thanos Anastasopoulos, Oleh Sotskyi & Thimo Veldema

Groningen, 18 January 2023

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Abbreviations and terms

Abbreviation	*Description*
MWe	Megawatt electrical
STG	Steam Turbine Generator
MVA	Megavolt-ampere
MCC	Motor control centre
kV	Kilovolt
kA	Kiloampere
NEN	Nederlands Normalisatie-instituut
IEC	International Electrotechnical Commission
Block Diagram	Vision Network Analysis schematic
Key-One-Line Diagram	Simplified graphical representation of the power system
TKF	Twentsche Kabelfabriek

1 Introduction

This project, conducted by Bilfinger Tebodin Consultants & Engineers, aims to design an electrical installation that utilises the potential energy from the byproduct Syngas produced by a Carbon Black manufacturing facility. The Syngas is currently being flared, causing air and noise pollution, but with the proposed 29MWe Steam Turbine Generator (STG), it can be redirected as a usable energy source. This report consists of an analysis phase, a research phase, an implementation phase and it ends with the conclusions and discussion.

2 Analysis

2.1 Rationale

Bilfinger Tebodin Consultants & Engineers is an internationally operating consulting and engineering company for the industry. Bilfinger currently employs 36.000 people, of which the Groningen branch employs just under 100.

A customer of Tebodin produces Carbon Black for the industrial market. Carbon Black is used in the manufacturing of various domestic and industrial products. The description of what Carbon Black is exactly, is out of the scope of this project.

A byproduct of the manufacturing process produces a flammable gas called Syngas, which compared to Groningen Natural Gas, has approximately 50% of the calorific energy value. The description of what Syngas is exactly, is out of the scope of this project.

Currently, the client does not have the infrastructure to make use of the potential energy source and thus burns (flares) this gas into the atmosphere. This flaring also causes a considerable amount of air and noise pollution [1].

2.2 Purpose

The purpose of this project is to design an electrical installation to harness the potential energy given off by the syngas and redirect it into usable energy at the Carbon Black facility. This will be achieved by making use of a proposed 29MWe Steam Turbine Generator (STG). The plausibility of this setup will be explored, reasoned, and designed in this report.

2.3 Project Goals

A research goal was used to guide the project and define its goals, and it was followed by a list of sub-questions.

2.3.1 Research Goal

"Design and simulate a system that harnesses the potential energy given off by the byproduct syngas."

2.3.2 Sub Questions

Therefore, to realise the research goal, the following sub questions were used to strategically orient the design report;

a) Is the proposed STG a feasible option?
b) How do you design a fully functional system?
c) How to mathematically simulate the design?
d) How to validate the design?

2.4 Requirements

We were able to agree on a list of formal requirements after analysing the documents provided by the client [1] and conducting client interviews during the early stages of project work. Using this list as a starting point, we came up with a list of functional and technical requirements, which we used as the basis for our first design, which is shown in this paper.

2.4.1 Formal

1. Design the electrical installation (key-one line) for harnessing the energy of Syngas making use of the proposed Steam Turbine Generator.
2. Find methods and equipment to limit or reduce the short circuit currents at medium voltage introduced by adding the generating plant.
3. Find a potential maximum power that can be delivered to the power grid.

2.4.2 Functional

1. The transformers must be selected for stepping down voltage levels from the grid to the generation plant and factory.
2. Appropriate cables must be selected for the medium-voltage applications.
3. The switch gears and breakers must be selected for generator, transformer and cable protection.
4. Appropriate starter devices must be selected for the MCCs.
5. The load and the generator power must be analysed.

2.4.3 Technical

The technical requirements of the project are stated as follows:

1. The dimensions of the main cables should be selected to withstand the maximum restrictions of an overload.
2. The main switch gears and breakers should be designed or selected to be able to withstand the peak load of the entire system.
3. The short circuit current of the transformer should be below the maximum peak fault current of the switchgear and main cables.
4. Calculations on the potential maximum power must be made using the load and the generator power values and taking into account the seasonal cycles.
5. The power delivered back to the grid by the plant shall not exceed 24.99 MVA at any time during operation.

3 Research

3.1 General Design

Given the information from Tebodin, it was understood that their engineers already had a clear concept in mind and had also decided that they wanted to provide the power from syngas through a generator back to the grid by using the same source as the main power plant. The project task was to make sure the concepts were right and safe for implementation by selecting the right components and delivering power of good quality within the specified limits, by first making a realistic simulation of the design.

The initial technical details provided described the grid voltage that could feed the main factory as 10.5kV. The details given on the two loads were 6 MVA for the main factory and 2.5 MVA for the auxiliary power of the steam turbine generator (STG) that was connected to the generator that uses Syngas. The main Carbon Black plant was already running, but as we needed to add the generator part, we needed to draw some additional designs for the main power plant as well by choosing the correct transformers and switchgear as they are the most important parts of this design. Since adding more loads to the design would introduce more power consumption and additional fault currents, we researched methods of protection for the existing Carbon Black plant and also for the new Syngas generator.

3.2 Transformers

Transformers are essential AC power system components because they convert electrical energy to different voltage levels with an efficiency of greater than 99 percent.
In order to select transformers to be used in the schematics, the overall consumption of the system has to be taken into consideration: the voltage of the primary to secondary, the configuration of the transformer, as well as the maximum current and fault current draw of the systems following it.
In this case, three transformers fell between the grid and the main carbon black facility, and two separate transformers to power the auxiliary load of the STG (Steam turbine generator) again from the grid.

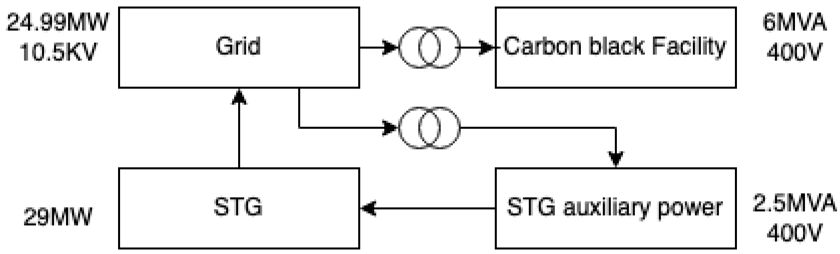


Figure 1: Transformer Locations

When checking the market we found some companies that sell transformers for industrial applications. The ratings of MVA Power are mostly in standard ranges, while some companies also have custom solutions. Another important aspect was which quality standards they were following since our clients use the NPR, NEN, and IEC standards for their projects.
For our project, we needed to use the 10.5 kV voltage from the grid to supply the 6 MVA main factory load (consumers of 400 line voltage) and for the other load 2.5 MVA (generator load/auxiliary power of the generator) by using the same 10.5 kV incoming voltage and supply the auxiliary power of the generator with 400 line voltage.
The transformer ratings that we mostly found were about 1 MVA up to 3.1 MVA power ratings with the voltages that we required (see figure above for setup). Another requirement was to keep a power space of about 20-25% in case the client wanted to add some future loads on the main factory for example more machines etc. Moreover, the transformers should be quickly available for purchase and preferably from European sources for quicker delivery.

3.3 Protection devices

The requirement to provide customers with appropriate levels of dependability, quality, and safety at reasonable prices becomes more crucial as our society becomes more dependent on the electrical supply. To reduce the number of faults that occur, every power system must be carefully built and properly maintained [8].
Due to the potential harm that short-circuit currents can bring to the cables, lines, busbars, and transformers, protection devices are built to help clear faults such as short circuits. For the power system, dependable protection is essential. The corresponding protective relay must function in response to a fault or other abnormal system situation in order to isolate the afflicted area and keep the rest of the power system operational [7].
When a fault occurs, the protection must be sensitive enough to activate, but it also needs to be stable enough to remain inactive when the system is using its maximum rated current [7].

Circuit breakers

Circuit breakers of the following types are commonly used in power systems:

1. Minimum-oil circuit breakers – the interrupting medium is oil and these are generally produced for the voltage range 24-72.5 kV.
2. Air circuit breakers – these operate with air and are still a preferable choice to use up to 15kV [6].
3. Magnetic air-blast breakers – the magnetic field produced by the fault current blows the arc into a segmented compartment. These are mainly used for medium voltage applications up to 50 kV [7].
4. Vacuum circuit breakers – the interruption procedure is handled by a vacuum arc. These are produced for voltages up to 72.5 kV. The short-circuit current rating goes up to 31.5 kA [7].
5. SF6 circuit breakers – based on sulphur hexafluoride gas and are used for the interruption of the highest short-circuit powers, up to 550 kV and 64 kA per interrupter [7].

Differential

Differential protection detects differences in the current going in and the current going out. If it detects a significant difference it will trip the circuit breakers because there is probably a fault inside the device it is trying to protect.

Overload

Overload protection is a sort of overcurrent protection that is slow. It makes sure that the device it protects doesn't overload. It does this by not directly opening the circuit breaker when the current is too high but only opening after a while, the time depends on how much higher the current is. If the current is a bit higher it will take a while and if it’s much higher it opens quickly.

Short circuit

Short circuit protection monitors the currents and opens the circuit breakers very quickly when the current is too high. It shouldn’t trip when the current is only a bit higher because that is the task for the overload protection.

Reverse power protection

Reverse power protection makes sure that the power only goes in the preferred way. For generators this means that the generator will only be supplying power and not taking it. If it is detected that the power is going in the wrong direction the circuit breaker will trip.

3.4 Switchgear

There are several factors that can influence the dimensions of switchgears, including the following:

1. Different types of switchgear, such as air-insulated or gas-insulated, may have different uses or constraints due to their design and construction.
2. Higher voltage levels typically require larger switchgears to accommodate the increased electrical forces and insulation requirements.
3. The current rating of the switchgear, which is the maximum amount of current it can safely carry, can also affect its dimensions. Higher current ratings may require larger switchgears to accommodate the increased current flow and heat generation.
4. The available space in the electrical room or installation location can also influence the dimensions of the switchgear. The switchgear may need to be designed to fit within the available space constraints.
5. The type and number of protective and control devices, such as circuit breakers and relays, can also affect the dimensions of the switchgear.
6. The cooling requirements of the switchgear, such as air or water cooling, can also influence its dimensions.

Overall, the dimensions of switchgears are typically determined based on a combination of these factors to ensure that the switchgear is suitable for the intended application and meets all necessary safety and performance requirements.

There are three different types of switchgear: low/medium and high voltage with the low being up to 1 kV, medium from 1kV to 75 kV, and more than that is High voltage[1]. There are a number of companies in Europe that it is possible to make a fast order with ABB, Siemens, etc. Initially, we were not aware of how many switchgear units we would need until we made the Key-One-Line diagram. While running the vision program with the block diagram we realised that with a single load for all the transformers the fault currents were too high so we needed to make first the Key-One-Line diagram so we can distribute the load more evenly and pass this high current through more busbars than one which would result in finding switchgear with lower ratings, so it would be easier, in the end, to find what we needed.

3.5 Motor Control Center (MCC)

The dimensions of a Motor Control Center (MCC) in electrical engineering are typically determined based on a combination of factors, including the following:

1. The number and size of the motors that will be controlled by the MCC can influence its dimensions. Larger motors may require a larger MCC to accommodate the increased electrical load and heat generation.
2. The voltage level of the motors and the MCC can also affect its dimensions. Higher voltage levels typically require larger MCCs to accommodate the increased electrical forces and insulation requirements.
3. The type and number of control devices, such as motor starters, contactors, and relays, can also affect the dimensions of the MCC.
4. The available space in the electrical room or installation location can also influence the dimensions of the MCC. The MCC may need to be designed to fit within the available space constraints.
5. The cooling requirements of the MCC, such as air or water cooling, can also influence its dimensions.

In total, the dimensions of an MCC are typically determined based on a combination of these factors to ensure that the MCC is suitable for the intended application and meets all necessary safety and performance requirements.

3.6 Main Cables

The dimensions of main cables in electrical engineering are typically determined based on a combination of factors, including the following:

1. The voltage level of the main cables is a key factor that influences their dimensions. Higher voltage levels typically require larger cables to accommodate the increased electrical forces and insulation requirements.
2. The current rating of the main cables, which is the maximum amount of current they can safely carry, can also affect their dimensions. Higher current ratings may require larger cables to accommodate the increased current flow and heat generation.
3. The length of the cable run, or the distance the main cables need to cover, can also influence their dimensions. Longer cable runs may require larger cables to reduce voltage drop and maintain a sufficient level of power quality.
4. The environment in which the main cables will be installed can also affect their dimensions. Cables that will be installed underground or in wet or corrosive environments may need to be larger to accommodate the increased insulation and protective requirements.
5. National and local electrical codes may also specify minimum dimensions for main cables based on the intended application and installation location.

Overall, the dimensions of main cables are typically determined based on a combination of these factors to ensure that the cables are suitable for the intended application and meet all necessary safety and performance requirements.

3.7 Limiting Short Circuit Current

Part of the requirements from the client is to find what methods or equipment can be introduced to limit or reduce Short circuit currents at medium voltage? In order to do this some research was done

1. Surge protectors are devices that can protect electrical equipment from voltage spikes, which can occur during a fault. Surge protectors work by limiting the amount of voltage that can reach the equipment, which can help to prevent damage to the equipment and extend its lifespan.
2. Protective relays are electrical devices that can detect when a fault has occurred and trigger other protective devices, such as circuit breakers, to interrupt the flow of current and prevent damage to the electrical system. Protective relays can be programmed to respond to different types of faults and can be used to protect both low-voltage and high-voltage electrical systems.
3. Transformers are electrical devices that can step up or step down voltage. An important parameter of the transformer is its impedance, which is given in percentages and is a current limiting characteristic of the transformer, since it sets a restriction on the maximum short circuit current that may be obtained from its output. The higher the impedance the lower fault current will flow and the other way around.
4. Is-limiter from ABB, This device can stop a short circuit before it reaches its peak current. It has 2 parallel running conductors, one is the main conductor and the second one is a fuse. When a short circuit is detected it will switch off the main conductor and after 1 ms the fuse will be blown. It is able to switch this fast because it doesn’t use mechanical switches but rather uses electronically triggered charge as a switching mechanism. A downside of this kind of protection is that it only has a single use but it can be refurbished because only the main conductor and the fuse have to be replaced.

3.8 Selectivity

Selectivity is an important addition to an electrical design because of its property to keep the main system alive while only shutting down the non healthy part of the circuit.

In the electrical installation that was designed several distinctly different cases were identified to show how the circuit breakers in the system will trip in a selective way in case of the short-circuit current. These cases were analysed as can be seen in Figures 2-4.

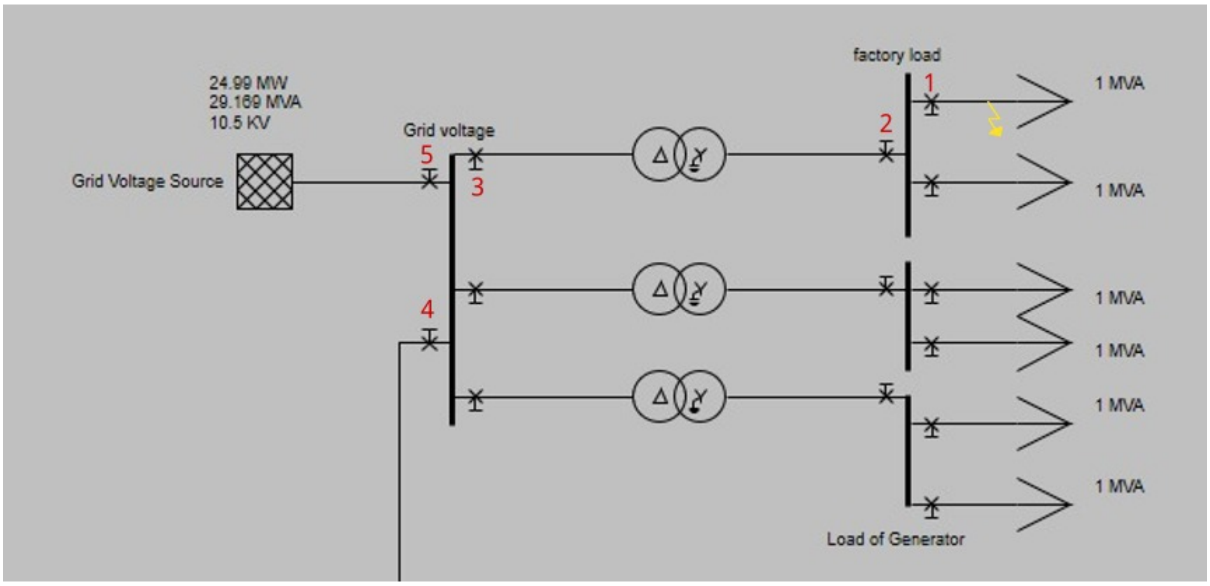


Figure 2: Selectivity case 1.

First case is depicted in Figure 2 above. As can be seen, the short-circuit is on one of the factory loads (yellow lightning bolt). Each one of the factory loads is connected to one of three busbars, that are connected to one of the three transformers, that are connected to a common busbar which is supplied from the grid and the generator, which means that in case of a short-circuit on any of the factory loads the circuit breakers should trip from right to left (sequence is shown in Figure 2 with red coloured numbers).

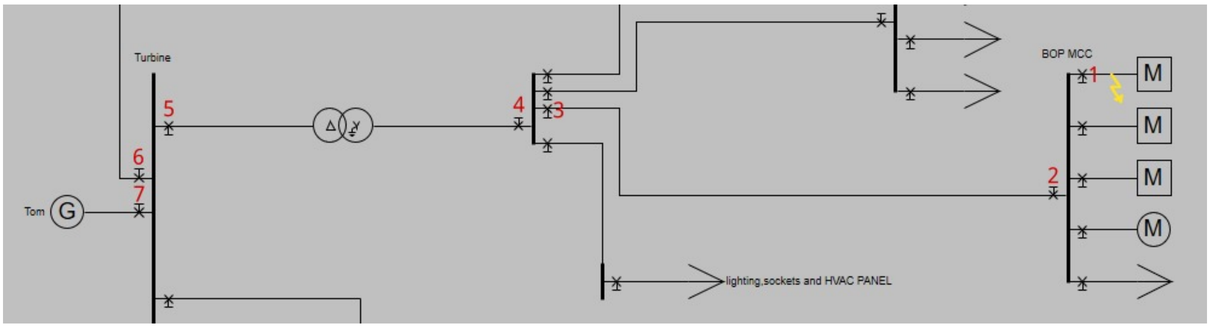


Figure 3: Selectivity case 2.

Second case is depicted in Figure 3 above. As can be seen, the short-circuit is on one of the motor loads (in this specific scenario BOP MCC). Each one of the motors is connected to one of the busbars, which is connected to another busbar, that is connected to one of the two transformers, that are connected to a common busbar that is supplied from the generator and the grid. This case is very similar to the previous one, except for one additional busbar in between the loads and the transformers. The sequence of circuit breakers tripping is shown in the Figure 3 as well.Finally it is worth to mention that as indicated through the numbers ,the circuit breakers 4,5 and 3,2 with switch at the same time because every group is placed in between the same nodes.

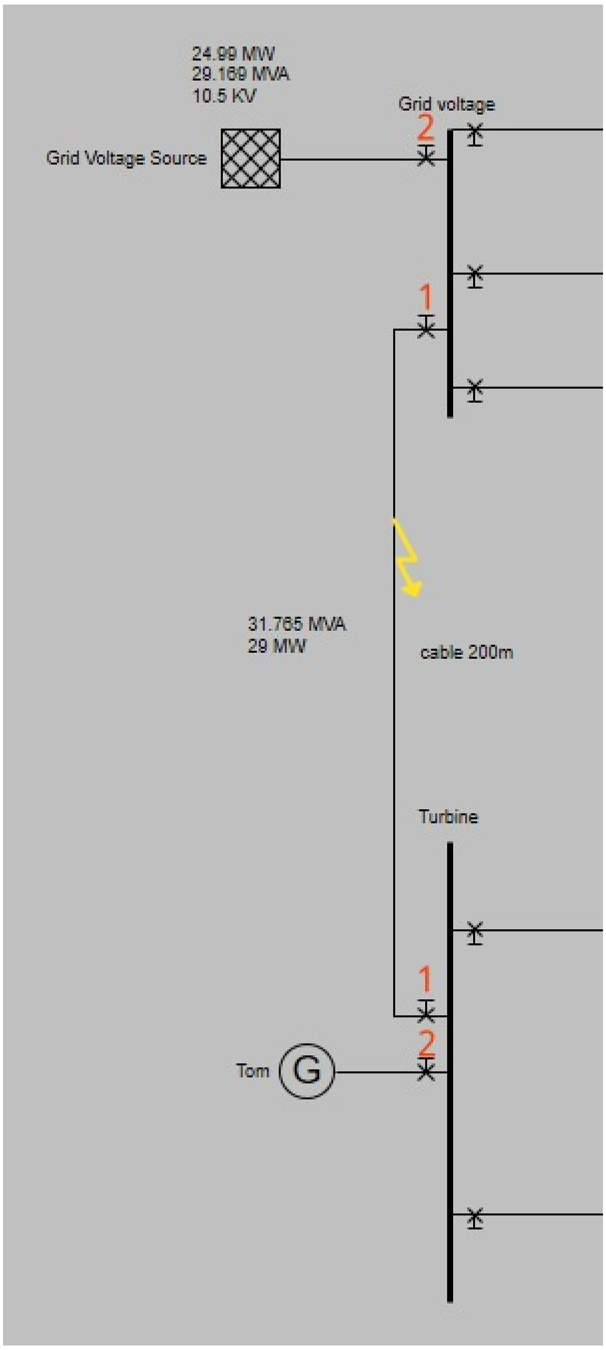


Figure 4: Selectivity case 3.

Third case is depicted in Figure 4 above. As can be seen the short-circuit is on the cable connecting the busbars supplied from the grid and the generator. In this case, there is a high chance of blackout, since if one of the circuit breakers on the cable fails, then the respective power supplier should be disconnected, which leaves a big part of the system with no power.

One of the cases was analysed/implemented in more detail in Vision to show that selectivity is indeed achievable for the system designed. The results are shown in Appendix E.

4 Implementation

Our design process was separated into three main stages. In the first one, the Block Diagram was designed to give a general overview of the power system, its components, connections between them, and some of its most important specifications. In the second one, the Key-One-Line Diagram was developed to give a more detailed look at the same power system, specifically the details on the switchgear and transformers. In the next and final part of our project, the Key-One-Line diagram was to be designed.

4.1 Final Selection of components

4.1.1 Transformers

Since it is necessary to power up larger loads while also having an additional 25% of power for the possibility of adding additional loads in the main factory and in consideration of future costs, the group decided to put **three** 2.5 MVA transformers [4] (totaling 7.5 MVA) in parallel from the start of the grid to power up the 6 MVA load, leaving 1.5 MVA of power space for the clients to add additional loads in the future if they wish.

For the 2.5 MVA in total loads of the STG auxiliary power, it was decided to use **two** 1.6 MVA transformers [3] that leave a power space of 0.7 MVA since that load is not going to change in the future and can be used to quickly hold bigger power surges if required. Lastly, the transformers meet the standards set by the NEN and IEC, and they can be bought quickly on the market. All our transformers are from the company Schneider.

4.1.2 Switchgear

We decided to use 2 kinds of switchgear, both from ABB: one for medium-voltage, which is the ABB UniGear ZS1 parts[6], and the other for low-voltage MNS ABB parts[5], mostly because of their power ratings matching the ratings of the design and their flexibility in terms of adding extra accessories, possibilities for different kinds of sizes, and their quick availability. We used two units for medium voltage and 5 units for low voltage. For more information about the ratings of the switchgear see the datasheet and also the Key-One-Line diagram below.

4.1.3 Protection Devices

The placement of the protection devices that we used can be seen in the Key-one-line and Block diagrams presented in sections 4.3 and 4.4 of the report. Each of these components was placed in specific spots of the power system with the purpose of protecting transformers, cables and the generator from anomalies in the system. Table … shows which protection devices were chosen for each of the power system components.

Power System Component	*Protection Type*
Transformer	Differential Short circuit Overload
Generator	Differential Short circuit Overload Reverse Power
Cables	Overload Short circuit
Motors	Overload Short circuit

Figure 5: Protective Devices

Protective relay

For this purpose Relion 615 series of relays were chosen, due to it being versatile enough to cover all of the mentioned applications, a wide range of control and protection features, whether using sensors or traditional instrument transformers, numerous earth-fault prevention options with a special multifrequency admittance-based protection for greater sensitivity and selectivity, as well as advanced and quick fault location for earth faults and short circuits.

Circuit Breakers

We also used circuit breakers (EMAX 2 for the low voltage side and VD4G for the medium voltage side). They are good enough for almost all use cases. We selected all our circuit breakers by adding 20% to our nominal current and then we selected the next highest value circuit breaker. We also took into account break currents so that our circuit breakers wouldn’t be destroyed, for a couple of circuit breakers we picked values higher than we needed because the break current would be too low.

4.2 Dimensions of Components

4.2.1 Transformers

2.5 MVA Transformer Data sheet[05-D]

Rated frequency	50 Hz	Rated primary voltage	10 kV	Secondary voltage (at no-load)	No load: 400 V
Height	2330 mm	Width	1230 mm	Length	1840 mm

Figure 6: 2.5 MVA Transformer Trihal Tier2 dry type [05-D]

1.6 MVA Transformer Data sheet[05-E]

Rated frequency	50 Hz	Rated primary voltage	10 kV	Secondary voltage (at no-load)	No load: 419 V
Height	1940 mm	Width	950 mm	Length	1750 mm

Figure 7: 1.6 MVA Transformer Trihal IEC dry type [05-E]

4.2.2 Switchgear

Details of the sizing of columns and number of units can be found in sizes.xlsx [9]

MCC	Number of units	Number of Columns	Dimensions LxWxH
Syngas MCC	6	1	2200x800x600 +2125x400x1000
Boiler MCC	28	2	2200x5400x600 +2125x400x1000
Fluegas MCC	48	4	2200x5200x600 +2125x400x1000
Turbine MCC	15	2	2200x1600x600 +125x400x1000
ACC MCC	15	1	2200x4800x600 +2125x400x1000
BOP MCC	36	2	2200x2600x600 +2125x400x1000
	Location	Amount	Dimensions LxWxH
High Voltage 2500A	Generator	4	2200x4000x1340
High Voltage 2000A	Factory	5	2200x4000x1340
	Location	Amount	Dimensions LxWxH
Low Voltage 2500A	Left	4	2400x1000x2125
Low Voltage 2500A	Right	5	3000x1000x2125

Figure 8: Switchgear dimensions

4.2.3 Main Cable

Nominale spanning Umax	17,5 kV	Geleider AC weerstand @max. cont.geleidertemp.	0,036 Ohm/km	Toelaatbarestroom in lucht platvlak	1.415 A
Length	200m/ 200000mm	Nom. conductor diameter	31.1 mm	Diameter over insulation (at sector: sector height)	41.3 mm

Figure 9: TKF Cable [05-A]

Based on the cables datasheet the total impedance is defined as <<Homopolaire impedance Zo (trefoil) 0,594 Ohm/km>>. That means for 200 metres the impedance for 3 cables in trefoil configuration is

0.2 x 0.594=0.1188 Ohms.

Since we have 9 wires in total, that means 3 trefoil cable pairs in parallel (all in trefoil configuration) the total impedance will be

1/((1/(0.1188))*3)=0.0396 ohms.

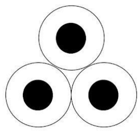


Figure 10: Trefoil configuration

4.2.4 Cable Dimensions

There cables were selected for each of the groups of motors/feeders. This was done with the TKF cable calculation tool[10]. All the results are in the cables.xlsx [11] file. The lengths were provided by the client but simplified.

MCC	Length(m)	Current (A)	+20% current (A)	Amount	voltage	mm^2
ACC	25	1015	1218	4	400	185
Turbine	25	684	820.8	3	400	185
Boiler	25	940	1128	4	400	185
BOP	25	43	51.6	1	400	10
Flue Gas	25	176	211.2	1	400	95
Syngas	25	758	909.6	4	400	185

Figure 11: Cable dimensions

It was assumed that all the motors/feeders that fall under an MCC all had the same length and the client only requested to do it for each group and not all of the motors.
The most important fields to fill out in the TKF cable calculations tool was the Nominal current, installation method, installation method of the rack and the amount of racks. Our installation method was method E which means the cable is in the air and is close to the wall. The nominal current depends on the motor/feeder attached. For the cable rack we used an Unperforated One and the client informed us that we should use 2 of these racks.
The cable dimensions from the MCC to the motors are included in Appendix C.

4.3 Block Diagram

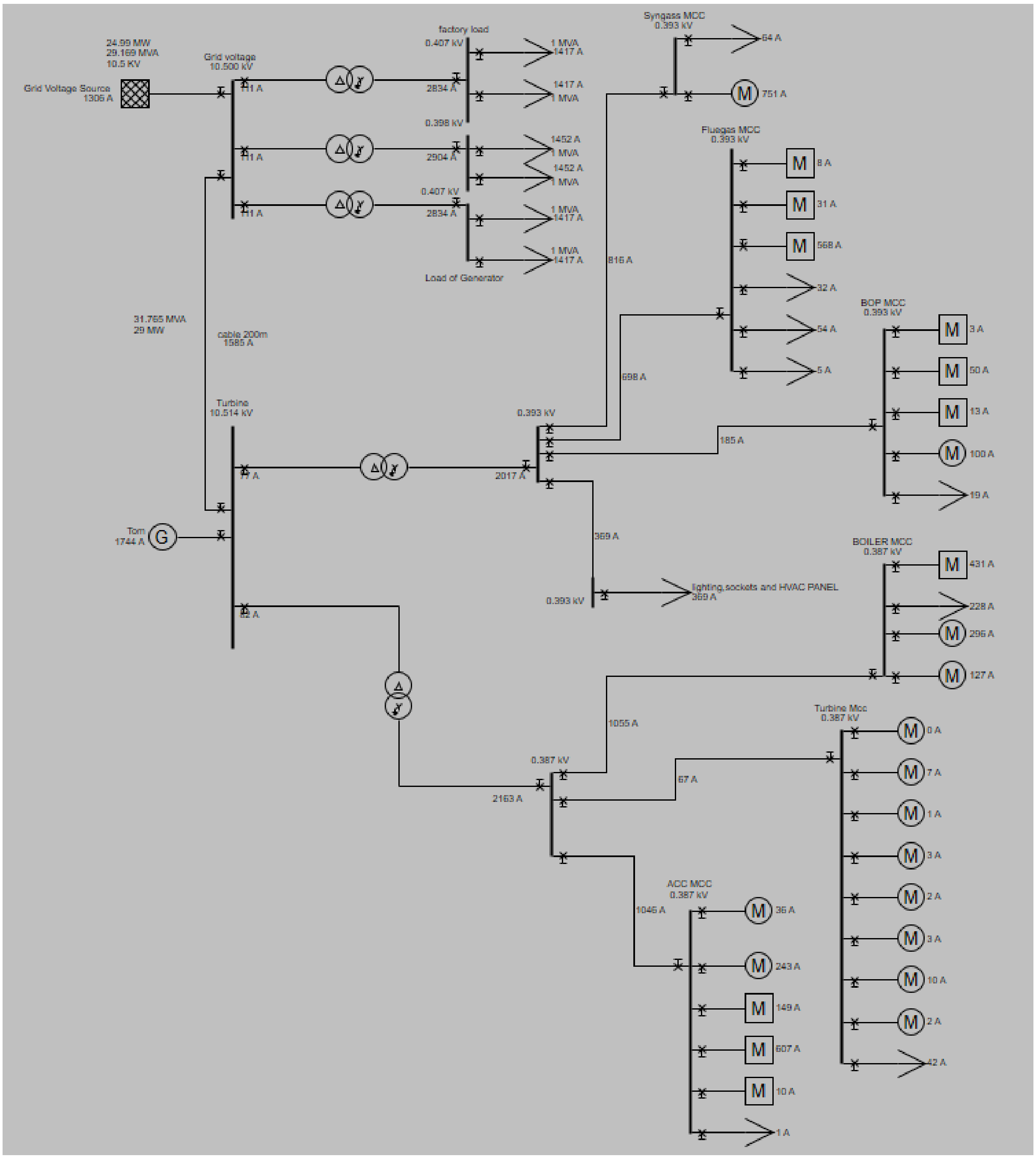


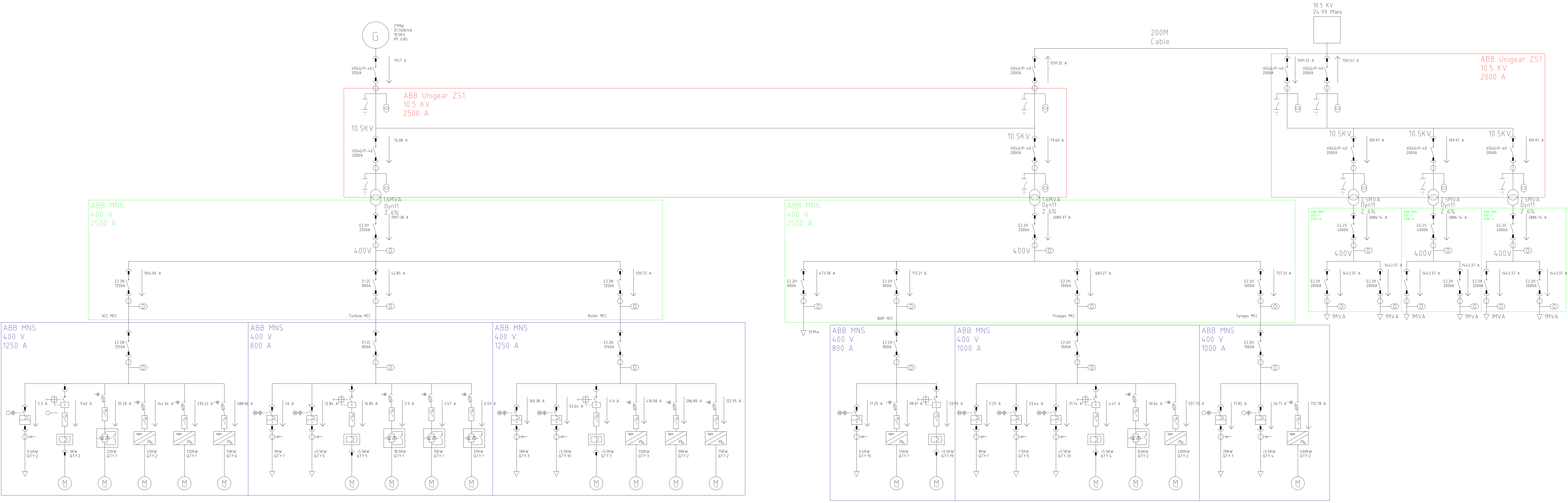
Figure 12: Block Diagram Overall Structure

Above is a block diagram of the entire system that will have to be modelled.
It consists of a grid voltage supply at 10.5kV that feeds into the 3 transformers arranged in parallel which steps down the voltage to 400V which supplies the 6 MVA load in a total of the carbon black factory. The grid voltage is also used to power the auxiliary power of the Steam Turbine Generator (STG) at 400V using the two 1.6 MVA transformers. The STG is directly connected back to the grid. The secondary part of the transformers are supplying different kinds of loads (different MVA's) and motors where single motors are indicated with a circle or group of motors which are indicated by a square.

4.4 Key-One-Line Diagram

The Key-One-Line diagram below represents the overall design, including in more detail what the switchgear consists of and how it is rated. In the figure below it can be observed that the switchgear has some main fuse, input, and output of wires but also some monitoring system which is a voltage and a current transformer across it. It also includes earthing which can be observed with an earthing symbol, when the voltage is medium but not necessarily when the voltage is low. Furthermore, we needed a total of 7 switchgear units where the two of them are represented as red boxes for the medium voltage (and the boxes represent the area that they are protecting) and 5 green boxes for the low voltage. Last but not least, the medium voltage compartments of the circuit are on the top side, and the lower on the bottom.

The Key-One-Line is attached in the package along with the vision simulation and data sheets.


10.5 KV
24.99 MWe
200M
Cable
ABB Unigear ZS1
10.5 KV
2000 A
ABB Unigear ZS1
10.5 KV
2500 A
10.5KV
400V
ABB MNS
400 V
2500 A
ABB MNS
400 V
1250 A
ABB MNS
400 V
800 A
ABB MNS
400 V
1000 A
1.6MVA
Dyn11
2.5MVA
Dyn11
1MVA

4.5 Calculations

Power Calculation STG Off

When the turbine is off the factory and plant are consuming 7.5 MVA**.**

Power Calculation Summer

During summer, the turbine only generates 18 MWe or 19.7 MVA. The factory and power plant consume 7.5 MVA, leaving a total output of 12.2 MVA. The current delivered to the grid is the difference between the generated current and the current consumed by the factory and power plant, which is 679 A (1164A - 485A).

Power Calculation Winter

During winter, the turbine generates 27 MWe or 31.8 MVA. The factory and power plant consume 7.5 MVA, leaving a total output of 24.3 MVA. The current delivered to the grid is the difference between the generated current and the current consumed by the factory and power plant, which is 1262 A (1747A - 485A).

Short circuit calculations

Short-circuit calculation is an important part of any power system design. On the result of these calculations a number of components choice is based, including protections, cables, etc. Vision Network Analysis software was used to perform short-circuit analysis in the power system designed. It uses the methods presented in IEC60909 and short-circuit currents in all points on the schematic.

For this analysis, all the components' were put in the schematic from the data-sheet information. Then, the grid short-circuit capabilities were checked with Tebodin and put in the simulation as well. The short-circuit current values were then calculated and the results can be seen in the excel file:
Short Circuit Calculation - IEC 60909 - 20230117_110507.xlsx Appendix D

5 Conclusion

In conclusion, with reference to the following research question “How to design and simulate a system to harness the potential energy given off by the byproduct Syngas?”, this report accomplished the outline goal by the implementation and answering of the subquestions:

a) Is the proposed STG a feasible option?
b) How do you design a fully functional system?
c) How to mathematically simulate the design?
d) How to validate the design?

The proposed STG proved to be a feasible option and was able to be designed into a fully functional system through assisted research on components by the Tebodin clients. Moreover, the design was mathematically simulated using the Vision Network Simulation, and will be further validated by utilising Tebodin’s simulation as a benchmark of comparison. To compare the project group's Vision Network Analysis simulation to the Tebodin clients simulation using the software ESKAYEM.

6 Discussion

Upon completion of the design report for the Tebodin clients, this chapter aims to reflect on the successes, limitations, and key areas of development based on the project's timeline. As the group was primarily from the Electrical Engineering & Sensor Technology major, a majority of the knowledge regarding power electronics was learned throughout the project within the Flexible Energy Technology Minor, and from the clients Tebodin. It was a steep learning curve for the group members involved and proved to be a complex, yet entertaining, challenge.

The clients from Tebodin were of great help, as they took the time to explain and coach the members of the group. They were actively involved in the project and provided feedback and working sessions whenever requested through the use of open communication on teams. The weekly Monday meetings allowed progress to continue throughout the semester and kept the momentum within the group. It is highly recommended to continue this for future projects, if possible.

The group's coaching sessions were helpful and guided the project members through the use of SCRUM, as well as, delivering key insights into tackling a project within the industry of power electronics.

Suggestions for future projects would be to have a secondary meeting between members on fixed days throughout the week, for example, having a client meeting on Monday where everyone is present, and a second meeting for group members on Thursday, to make certain progress is being made and tasks are being followed. This also gives opportunity to spread knowledge, so all members are aware of what is to be done and how to achieve it. This also ensures that there are constant updates between members on certain tasks which have already been accomplished and tasks which require more attention and time, making the process more efficient.

7 Evaluation

Finally to evaluate the project we will reflect on the requirements for the project starting with the formal requirements, in which the group accomplished:

1. The group was able to design and create a Key-One-Line diagram representing the system in its entirety. In section 4.4 Key-One-Line Diagram

2. Calculations were done to find the maximum potential power that could be delivered to the grid taking into account seasonal changes. These are located in section 4.5 Calculations

Alongside these are requirements from Tebodin to define the dimensions of the:

- Main Cable
- Main switch boards and breakers
- Transformers
- Starter devices

These can be found in section 4.2 Dimensions of Components.

This met the functional requirements:

1. Transformers were selected for the intended use to step down voltage levels from the grid to the generation plant and factory in 4.1.1

2. Cables were selected for the medium-voltage level in section 4.2.4 Cable Dimensions

3. Switchgear installations were selected for the generator, transformers and cable protections. In section 4.1.2

4. Starter devices were researched and selected for all MCCs to fulfil the necessary parameters and functions.

5. The power of the loads and generators were analysed and calculated taking into account seasonal changes.

Which brings the report to the technical requirements:

1. The dimensions of the main cables were selected to tolerate the maximum restrictions of an overload and were simulated in the vision software. 4.2.3 Main Cable

2. The switchgears and breakers are able to cope with the peak load of the entire system and protect the components. 4.2 Dimensions of Components.

3. The transformers were selected such that the short circuit current was below the maximum peak fault current of the switchgear and main cables. 4.1.1 Transformers.

4. Calculations on the potential maximum power were made as well taking into account the seasonal changes. These are located in section 4.5 Calculations

5. The power delivered back to the grid does not exceed 24.99 MVA during operation. 4.5 Calculations

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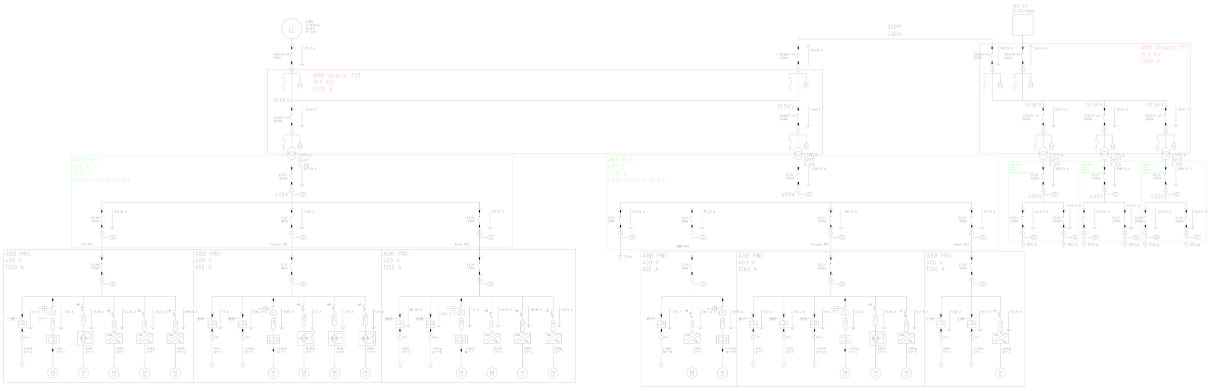
Appendix A

Data Sheet references

No.	Item	Description	Hyper-Link
05-A	Cable	200m Cable	Link
05-B	Switchgear	Switchgear high voltage	Link
05-C	Switchgear	Switchgear low voltage	Link
05-D	Transformer	Trihal Transformer 2.5MVA	Link
05-E	Transformer	Trihal Transformers 1.6MVA	link
05-F	Circuit Breaker	High Voltage Circuit Breaker	Link
05-G	Circuit Breaker	Low Voltage Circuit Breaker	link
05-H	Current limiter	Current limiter for High voltage	Link
05-I	MCC	MCC for motors	Link
05-J	Generator	27/29 MW Generator from Tebodin	link

Appendix B

Key-One-Line Diagram (the file is uploaded to the zip file that was delivered as well)



Appendix C

Cables from MCC to motors/loads wires.xlsx

ACC MCC	current	20%	length	voltage	mm^2	Iz (A)	amount
Cable 1	2.3	2.76	95	400	1.5	23	1
Cable 2	9.62	11.544	95	400	2.5	32	1
Cable 3	35.28	42.336	95	400	10	75	1
Cable 4	144.34	173.208	95	400	50	192	1
Cable 5	235.22	282.264	95	400	95	298	1
Cable 6	588	705.6	95	400	150	399	2
Turbine MCC							
Cable 1	1.6	1.92	85	400	1.5	23	1
Cable 2	12.84	15.408	85	400	2.5	32	1
Cable 3	16.85	20.22	85	400	4	42	1
Cable 4	3.3	3.96	85	400	1.5	23	1
Cable 5	2.67	3.204	85	400	1.5	23	1
Cable 6	6.59	7.908	85	400	2.5	32	1
Boiler MCC							
Cable 1	160.38	192.456	85	400	70	246	1
Cable 2	53.64	64.368	85	400	16	100	1
Cable 3	4.9	5.88	85	400	1.5	23	1
Cable 4	416.98	500.376	85	400	185	456	1
Cable 5	286.89	344.268	85	400	95	298	1
Cable 6	122.95	147.54	85	400	50	192	1
BOP MCC							
Cable 1	17.25	20.7	65	400	2.5	32	1
Cable 2	98.01	117.612	65	400	35	158	1
Cable 3	59.95	71.94	65	400	10	75	1
Fluegas MCC							
Cable 1	5.29	6.348	135	400	1.5	23	1
Cable 2	53.44	64.128	135	400	10	75	1
Cable 3	31.74	38.088	135	400	6	54	1
Cable 4	4.41	5.292	135	400	1.5	23	1
Cable 5	30.64	36.768	135	400	6	54	1
Cable 6	557.75	669.3	135	400	150	399	2
Syngas MCC							
Cable 1	17.82	21.384	175	400	10	75	1
Cable 2	26.71	32.052	175	400	16	100	1
Cable 3	712.78	855.336	175	400	185	456	2

Appendix D

Short Circuit Calculation - IEC 60909 - 20230117_110507

Short Circuit Calculation - IEC 60909 - 20230117_110507.xlsx

Name	**Unom**	**Ik"a**	**Ik"b**	**Ik"c**	**Ik"e**	**Ip**	**R/X**	**Sk"**	**Ri**	**Xi**	**tmax**	**Ib (20 ms)**	**Ib (50 ms)**	**Ib (100 ms)**	**Ib (250 ms)**	**Ik**
	kV	*kA*	*kA*	*kA*	*kA*	*kA*		*MVA*	*mOhm*	*mOhm*	*s*	*kA*	*kA*	*kA*	*kA*	*kA*
Grid voltage	10.5	30.03	30.03	30.03	0	74.63	0.097	546.1	21	221	0	29.05	28.13	27.5	26.83	23.33
Turbine	10.5	29.73	29.73	29.73	0	73.68	0.099	540.7	22	223	0	28.73	27.79	27.14	26.46	22.93
	0.4	68.2	68.2	68.2	0	164.42	0.132	47.2	0	4	0	66.32	64.71	63.56	62.42	60.18
	0.4	49.28	49.28	49.28	0	110.33	0.201	34.1	1	5	0	46.57	44.68	43.38	42.25	39.7
	0.4	60.09	60.09	60.09	0	148.83	0.098	41.6	0	4	0	60.07	60.06	60.04	60.03	59.99
	0.4	60.33	60.33	60.33	0	149.41	0.098	41.8	0	4	0	60.31	60.3	60.28	60.27	60.23
	0.4	60.09	60.09	60.09	0	148.83	0.098	41.6	0	4	0	60.07	60.06	60.04	60.03	59.99
Syngass MCC	0.4	66.39	66.39	66.39	0	155.88	0.154	46	1	4	0	64.56	62.99	61.86	60.75	58.58
Fluegas MCC	0.4	66.31	66.31	66.31	0	155.62	0.155	45.9	1	4	0	64.54	62.99	61.87	60.77	58.58
BOP MCC	0.4	66.15	66.15	66.15	0	155.13	0.156	45.8	1	4	0	64.4	62.91	61.83	60.77	58.58
BOILER MCC	0.4	48.34	48.34	48.34	0	106.57	0.216	33.5	1	5	0	45.71	43.86	42.59	41.48	38.97
Turbine Mcc	0.4	48.13	48.13	48.13	0	105.96	0.218	33.3	1	5	0	45.57	43.79	42.57	41.5	38.97
ACC MCC	0.4	48.39	48.39	48.39	0	106.71	0.215	33.5	1	5	0	45.72	43.86	42.58	41.47	38.97
	0.4	66.09	66.09	66.09	0	154.95	0.156	45.8	1	4	0	64.38	62.9	61.83	60.77	58.58

Appendix E

Selectivity Analysis

To be added