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Simulation & Control of HVDC Grid with Power Converters

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Abstract: Due to the need for electric connections between offshore, wind farms and oil platforms as well as for long-distance power transmission lines like THE TALCHER-KOLAR high voltage direct current (HVDC) link, also known as the East-South HVDC interconnector-2 and one of the longest power transmission lines in the world, as well as the electrification of transports, the High Voltage Direct Current (HVDC) is a growing technology. In this study, a design technique for the multi-terminal HVDC networks connecting offshore wind farms to the primary onshore electrical grid is presented. This thesis presents a full explanation of the process along with necessary information regarding converters and HVDC. First, two simple models are examined to provide an overview of the control system under study. The first model is a voltage source converter (VSC) in power control mode, and the second is a VSC grid converter in DC voltage control mode. Additionally, a multi-terminal HVDC grid made up of four terminals is used as an example where the control design methodology is put to use. The major goal is to evaluate the ideal range of values for the DC primary voltage regulator while taking into account the restrictions on each electrical magnitude during both the transient response and the steady state. A number of scenarios have been examined applying simulation models and the Matlab-Simulink software to conduct the present study.

Introduction

History: There are two various kinds of HVDC: the standard technology, which converts HVDC is a known technology with 60 years of industry experience. It was a specialized technology for the first 30 years, with few installations annually. Future global transmission networks will frequently use HVDC because to the changes in demand driven on through changing environmental needs. Using thyristors, and the VSC (voltage source converters) technology, called HVDC Light, which converts using transistors (IGBTs). A traditional HVDC transmission usually has a power rating of several hundred megawatts (MW), and many are in the 1,000–3,000 MW range. They use overhead lines, underground or submerged cables, or a combination of cables and lines. In addition to traditional HVDC, HVDC Light was introduced in 1997.It is used to transport electricity over short and long distances in lower power levels (between under 100 and 1,200 MW). Underwater and subsurface cables that are environmentally friendly and free of oil can be used with the technology. The newest innovation is ultrahigh-voltage direct current (UHVDC), which has a rated voltage of up to 800 kilovolts (kV). The biggest improvement in gearbox efficiency and capacity in more than 20 years may be seen in gearbox at this voltage.

Benefits of HVDC Using low losses over long distances, HVDC transmission is a reliable system that can transmit significant amounts of electricity. Additionally, it can stabilize the local grid and connect AC networks that are incompatible Fewer transmission lines are required with HVDC systems, saving money and space. HVDC systems may carry more electrical power over longer distances than an equivalent alternating current (AC) transmission system. Aside from dramatically reducing electrical losses over long distances, HVDC transmission is also very stable, is controllable, and can stabilize and connect AC power networks that would otherwise be incompatible. The HVDC market is expanding quickly and has taken on significant importance in many transmission grids, not least because it can link distant electrical generation sources to load centers where it is required, hundreds or even thousands of kilometers away. These sources are frequently emissions-free renewable sources like hydro or wind. HVDC gearbox systems enhance the stability and dependability of the entire electrical power system once they are deployed. The power converter, which acts as the interface with the AC transmission system, is the fundamental element of HVDC systems. Controllable electronic switches, often known as valves, convert current from alternating current (AC) to direct current (DC) and vice versa.

HVDC as renewable energy sources: Renewable energy sources like wind and solar must stabilize the network that receives their electricity and backup power, preferably in the form of hydropower, which is frequently produced far from wind and solar energy sources. Hydro, wind, and solar energy generating are examples of alternatives to burning fossil fuels for electricity and are frequently found in isolated areas. In order to guarantee high availability, minimal maintenance, and, of course, low losses, strong electrical transmission systems are required. The best long distance transmission options in terms of efficiency and technology are provided by HVDC transmission systems, which also integrate renewable energy sources and stabilize power grids. HVDC is a crucial part of the future energy system that will be powered by renewable energy sources because of its better control capabilities and essential technological qualities. The idea of continental HVDC grids is now being considered around the world due to an increase in deployed HVDC links and a growing demand for backup power for the frequently unstable power supply from renewable energy generation. It has a grid simulation centre in Sweden where problems in the neighbor AC networks are simulated and the sophisticated control system of an HVDC grid is evaluated in order to meet market expectations.

What is an HVDC grid? An HVDC grid is an electricity grid that can operate: - Independently of one or several disturbances (isolate a failure) - In different operation modes in the connected AC and DC systems Technology gap for full realization include: - Power flow control - Automatic network restoration - High voltage DC/DC converters Global rules and regulations for operation are required for market acceptance**.**

Why HVDC grids and not single HVDC links or AC? - A way of connecting large scale offshore wind to several load centers. - Loss reduction and increase power reduction versus, - Less visual impact.

What makes HVDC grids possible now? - HVDC light systems and components are mature. - An efficient HVDC breaker is available. It can sectionalize multi terminal HVDC systems into several protection zones to facilitate fault clearance with continuous transmission in the non affected areas.

HVDC v/s HVAC On the following lines, it is compared HVDC with HVAC in some important items: 21 • Stability limits: In an AC grid, the difference in angles between two electric nodes determines how much power may be transferred between them. Additionally, the system's transient stability places a cap on the highest transferrable active power. When power is transferred in DC, these issues are not an issue. • Control of power flow: A HVDC link has the ability to maintain power flow despite grid electromechanical oscillations. • Lines compensation: In order to maximize the capacity of power transfer, it is necessary to compensate for long overhead AC lines. In order to make up for the effect of the inductances, a bank of capacitors is placed in parallel in the intermediate compensation stations. This will lessen the reactive power at the line's end and also lessen the voltage drop. • Due to environmental, health, or political concerns, the construction of new transmission lines has been restricted in heavily populated areas. For a given power, DC gearbox takes up less volume and space than AC lines. • Compared to an equal DC cable, an AC cable has higher cable resistive losses. However, compared to equivalent systems, power losses at converter stations in AC systems are lower. • Because DC transmission systems have higher terminal losses and investment costs but lower cable losses and cable costs, they are more cost-effective for long distances. • Unlike the comparable magnetic fields of HVAC lines, the magnetic fields from HVDC lines are insignificant. • Due to the lack of capacitive charging current in DC transmission, it is impossible to transmit huge amounts of power underground or under the sea for distances of more than 50 km. • Unlike AC, which can only connect two synchronous power systems, DC systems enable the connection of two asynchronous power systems. • The electrical nodes' short circuit intensity is not increased by HVDC. • Skin effect does not exist in DC. Additionally, DC results in substantially fewer corona losses. Over longer distances, an HVDC line has significantly fewer losses than an HVAC line. •Compared to HVAC lines, HVDC overhead wires experience less interference with neighbor area communication lines. 22 • The reactive power phenomena, which restrict the transmission capacity in AC, do not exist in DC. •The advent of renewable energy sources has led to an increase in the requirement for power transmission. Therefore, extra transmission lines are needed in order to prevent overcharging the already overloaded old lines. This issue is resolved by DC transmission cables. • The HVDC converter stations produce voltage and current harmonics, and reactive power is used throughout the conversion process. As a result, expensive compensating filters and devices for reactive power correction are required. • Controlling HVDC grids is more challenging than controlling HVAC grids. Moreover, multi terminal HVDC grids have higher levels of complexity. • In HVDC, it is impossible to convert the voltage level; instead, a higher level of isolation is needed. • In HVDC transmissions, the reactive power needed for the load must be generated at the line's end. • Transformers cannot be used to change the voltage in HVDC, but they can do it in HVAC. From this chapter and this part, several conclusions can be drawn. When transferring power over vast distances, whether using overhead lines or undersea cables, HVDC technology is particularly helpful. Additionally, HVDC is used to connect asynchronous systems because conventional HVAC connections cannot be made between them. Additionally, controllability is just one of many more benefits that HVDC transmission system has over HVAC. There is interest in HVDC technology due to all of these issues plus the ones discussed in the chapter. The advantages of HVAC systems, on the other hand, are in short and medium transmission connections, which can reduce or increase the voltage level and facilitate its distribution without the use of converters. For distances of less than 600–800 km in overhead lines, 80–120 km in cables, and 50 km via submarine cables, HVAC are more cost competitive. For all of these reasons, HVAC systems will continue to be used for a longer period of time, and HVDC actually complementsthem rather than poses a threat to them

Literature survey

General: The methods for locating HVDC line issues both domestically and outside are reviewed in this literature. First, the shortcomings of the existing approaches to identifying problems in HVDC transmission lines are looked at. It is observed that the most widely used applications of fault location in engineering are those based on the travelling wave theory. Although the fault location theory is fairly simple, it needs a high sample rate and has insufficient tolerance for high resistance. The fault location division technique of an AC transmission line is used as a model to classify and study the fault location concept of an HVDC transmission line. The two types of HVDC transmission line fault spotting methods are the travelling wave approach and the fault analysis method. Moreover, the advantages and disadvantages of each HVDC fault placement theory.

Wu.J et al (2022): In the modern power grid, high voltage direct current (HVDC) transmission technologies are essential for maximising resource allocation and balancing power grid functioning. Quickly completing HVDC transmission system fault diagnostics is essential for ensuring the reliability of the power grid's functioning and reducing outage duration. Based on past research on fault diagnostic methods of HVDC systems, this paper presents a complete description and analysis of the current fault diagnosis approaches from three perspectives: fault type, fault influence, and fault diagnosis. The construction of the digital power grid system has also led to a major increase in the type, quantity, and complexity of power equipment, rendering classical fault identification methods entirely unsuitable for the changing needs of the modern power system. Because AI techniques can simplify problems and increase their capacity for self-learning, they are the most effective tools for this purpose. This paper develops a knowledge graph technology-based fault diagnostic framework for HVDC transmission systems to address these problems, describing its fundamental mechanisms and principles as well as the technological foundations of its intelligent fault diagnosis decision-making.

Jawad et al (2022): Due to the high voltage direct current system, numerous suggestions have been made for assuring the system's safety. Studies in this field have mostly concentrated on DC and AC line faults, with a maximum of two switching converter failures taken into account. The main output of this research is a unique technique to HVDC system defect diagnosis that uses neural networks and the grey wolf optimization method. In this method, faulted and nonfaulted data are used to extract the properties of voltage and current signals in a compressed time window. After that, the deviations are detected using a neural network simulation. Modelling has been done for the rectifier in the HVDC system ,including its behavior, controllers, and required filters. In this study, the suggested approach was contrasted with others, including a self-organizing map, a learning vector quantization, a radial basis function, and an artificial neural network. To demonstrate the effectiveness of the suggested method, the accuracy, sensitivity, precision, Jaccard, and F1 scores were calculated and found to be 99.00%, 99.24%, 98.74%, 98.00%, and 98.99%, respectively. The concept showed promise as a mechanism for defect identification in HVDC networks once the simulation results were in.

V. H. Gonzalez-Sanchez et al (2021): Transmission network disruptions can result from a wide range of factors, including lightning strikes, defective electrical components, worn-out machinery, and human error. Nevertheless, the electrical systems must be able to continue to be safe and dependable at all times. Modern fault detection and isolation systems must therefore be outfitted with quick recovery strategies in the event of an issue. In order to achieve this, a number of methods for finding and pinpointing issues in power transmission and distribution networks have been developed. The methods can be divided into a few different categories, such as artificial intelligence-based methods, impedance-based methods, and methods that make use of transitory signals. In-depth descriptions of the most widely used techniques for fault localization and detection in transmission systems are given in this study. This approach has opened up new directions for investigation into the precise location of power transmission and distribution system issues.

Jian-Yu et al (2021): In order to identify the exact position of single-pole-toground problems in the transmission lines of MMC-HVDC systems, this work presents a fault location approach based on support vector machines (SVM). The propagating waveform is captured as a feature after a fault has developed, and the SVM's regression algorithm is utilized to determine its location. Given how challenging it is to locate high-resistance ground faults, this study starts by evaluating their waveform characteristics. In order to reduce the effect of grounding resistance on fault localization, three recommendations are offered after that. The active pulse waveform is used as a new feature.

Objective

The fundamental technical goal of this work is to put out a primary voltage control theory for a VSC-based HVDC multi-terminal network that connects offshore wind farms to the primary AC network. The control of the HVDC grid will be carried out using a simulation-based manner rather than the traditional control techniques like using state space matrices and frequency methods, it is vital to note. The proportional gain of the controller for the DC primary voltage droop regulator will be used to analyze this model. The best value of the proportional gain under a variety of circumstances will be ascertained by extracting and analyzing several magnitudes, including voltages, currents in the lines, currents in the loops, etc. To perform the above mentioned developments, I was expected to perform several tasks: • Literature review of HVDC grids. • Learn the control theory of VSC converters employed in HVDC grids. • Acquire Matlab-Simulink® knowledge. • Create models of VSC converters in Matlab-Simulink®. • Extract results of the multi-terminal HVDC grid. • Analyze the results extracted. • Arrive to some conclusions. Decide which is the best value of the proportional gain of the DC voltage regulator controller in function of voltages and currents.

Methodology

This chapter introduces the theoretical model necessary for constructing a comprehensive system model. The integration of electrical and control theories along with mathematical elements offer a detailed explanation of how these models are developed. The information laid out in this chapter is crucial for understanding the forthcoming section of the thesis, where the models will be tested through simulations and conclusions will be drawn from the outcomes.

Modeling of Voltage source converter:

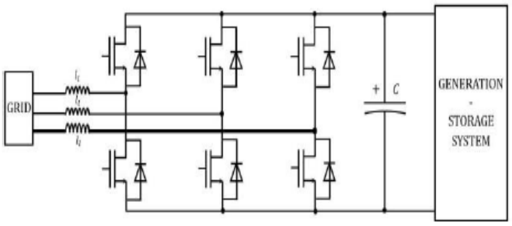


Figure4.1: System formed by the grid, the VSC converter and a generation/storage system.

Modeling of a Voltage Source Converter The fundamental Voltage Source Converter (VSC) is a two-level structure. It facilitates power transfer between the AC and DC components, and consists of three segments, each housing two Insulated-Gate Bipolar Transistors (IGBT). The midpoint of these branches is linked to the grid via inductances, ensuring a seamless connection of the converter to the grid. When the switching of the IGBTs is adequately modulated, it is feasible to create the desired three-phase voltages on the AC side to manage the exchange of active and reactive power with the AC network. Finally, the DC side can be connected to a generation or storage system. Some applications incorporate an additional DC-DC stage to adjust the DC voltage output. In the case of HVDC-linked offshore wind farms, the produced power is converted at the offshore terminal before being injected into the HVDC link. A visual representation of the system described can be foundused, for simplicity. The VSC converter can apply voltages based on the switching of IGBTs. Nevertheless, to design an adequate control it is more convenient to create a simplified equivalent model. It can be obtained decoupling the AC and DC parts of the converter and it is possible to define two separate models. In the first one, the DC side is modeled as a voltage source and in the second one, shown in Figure , is modeled as a current source and a capacitor in parallel, while the AC sides in both models are modeled with three AC controlled voltage sources with an inductive filter. The inductive filter is necessary to cancel the high frequency and to remove harmonics that pollute the grid. Also, it is not possible to connect sources of the same type (no voltages sources in parallel and no current sources in series). The converter is a voltage source and the grid is other voltage source, therefore, it is necessary to install an inductance to connect the converter with the grid.

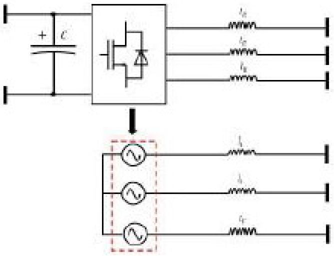


Fig 4.2 Equivalent of VSC AC side

$$I_{DC} = \frac{P_{DC}}{V_{DC}} = \frac{P_{AC}}{V_{DC}}$$

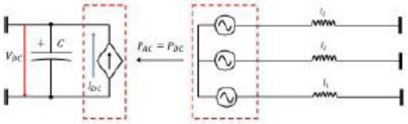


Figure 4.3: VSC lossless model

VSC control parts Here, it is presented a small summary of the VSC control parts. It is formed by the following parts:

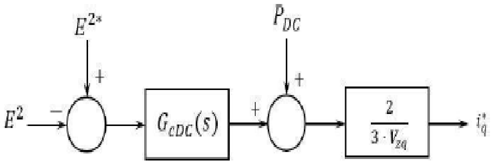
1. Phase-locked loop (PLL): This essential component tracks the phase angle of the grid voltage. It takes phase-neutral or phase-phase voltages of the grid as input. Determining the phase angle is crucial for establishing proper converter control and accurately applying the voltage in the current loop.

2. Current loop: This inner part of the controller structure controls the current flowing through the AC side of the converter. It enables tracking of current references set by the outer control layers and allows for limiting the converter currents. The current loop operates in a fast time domain (typically in the millisecond range) to promptly respond to rapid voltage changes such as short circuits or grid disturbances.

3. Outer loop: This upper control layer defines the converter's control mode. Generally, three control modes are distinguished: - Open loop control references for active and reactive power control. - Closed loop control for active and reactive/voltage power control. Reactive power and the associated voltage are only relevant on the AC side. - Closed loop control for DC voltage and reactive/voltage control.

4. Modulation: The VSC converter can apply reference voltages by modulating them using Pulse Width Modulation (PWM) or Nearest Level Modulation (NLM) techniques commonly used in HVDC MMC converters. 36 However, in this Thesis, modulation is not considered, as an averaged model of the power converter is employed. The averaged model assumes that the control action can vary continuously without discrete switching states typically associated with the power converter. The Inverse Park Transformation replaces the voltage modulation block in this case.

DC Voltage Regulator: The DC voltage regulator is a crucial component in controlling the voltage of the DC bus to ensure power balance between the generation source and the power injected into the grid . The DC voltage regulator operates at a much slower timescale compared to the current loop to ensure system stability. Its output provides the reference current i*q for the current loop. The control scheme proposed for this regulator is shown in equation, where E2 represents the squared voltage measured across the capacitor. E2 is the quantity to be controlled and is proportional to the energy stored in the capacitor, given by E = (1/2) * C * V^2, where C is the capacitance of the capacitor and V is the applied voltage. E2* represents the reference voltage squared, and the output of the controller is the active power injected into the capacitor, denoted as P*C. The power measured before the capacitor is represented as P*DC, and the power reference for the power converter is given by P* = P*C + P*DC. This P*, which provides the reference current i*q, is the active power component of the reference calculation mentioned earlier.



Models of grid converter control The complete models of grid converter controls are presented in Figures. The first model, shown in Figure it is used for injecting power into the grid assuming a constant DC voltage. The second model, depicted in Figure 4.20, is used to regulate the DC bus voltage (using the DC voltage regulator) and ensure power balance by ensuring that the power injected into the grid is equal to the power flowing through the DC side. These two controllers represent the offshore and onshore HVDC converters, respectively.

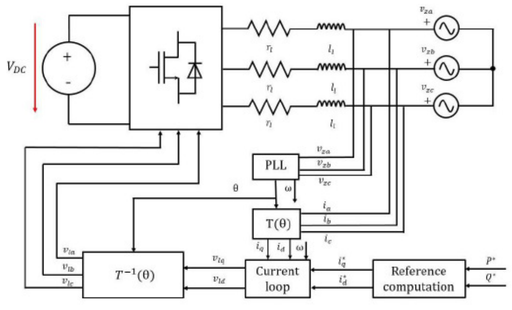


Figure 4.19: Scheme of the grid converter control with the DC side modelled as a voltage source

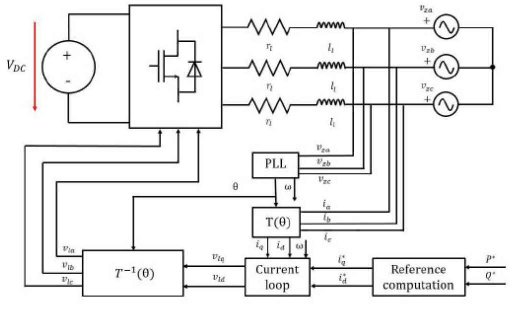


Figure 4.19: Scheme of the grid converter control with the DC side modelled as a voltage source

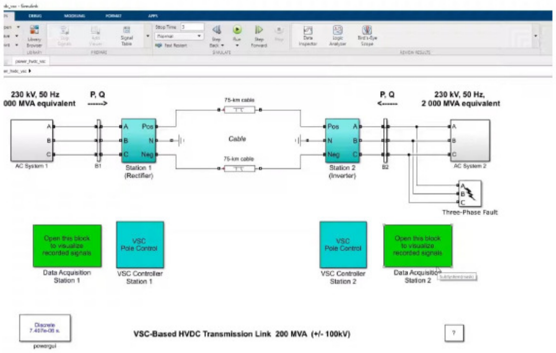
Results and Discussions

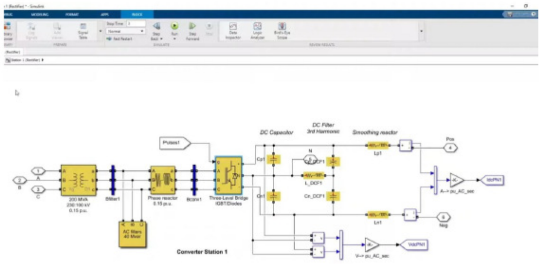
The different simulations performed in Matlab-Simulink® are described in this chapter. The theoretical component is briefly described, and goes into greater depth on the parameters and sources utilized in each simulation. The operation of a VSC converter is first simulated in various control modes. Next, various situations involving a multi-terminal HVDC grid are simulated in order to properly construct the network's principal voltage controller.

Modeling and simulation of VSC based High-voltage Direct current (VSC-HVDC) transmission link:

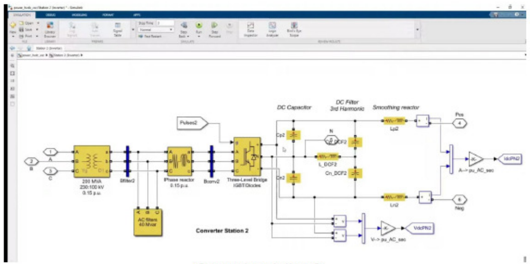
Here in this modeling and simulation of VSC based high voltage DC (VSC-HVDC)

Transmission link 200MVA. This shows the vsc based HVDC transmission link that is 200MVA, The rectifier And inverters are 3 level neutral point clamp that is NPC vsc converters using close IGBT diodes here. The rectifier and inverters are interconnected through the 75km cable all that is 2 pi sections are utilized here two 8mh smoothing reaction done here. A 3 phase programmable voltage source block is used in station one system. After running simulation there are 2 important blocks.

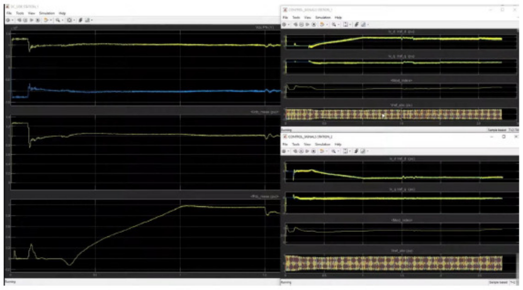




Converter station 1



Converter station 2



O/p for DC and station 1 and 2

Simulation of the VSC converter with the DC side modeled as a voltage source: The output of the VSC converter's simulation, which simulated the DC side as a voltage source, is shown in this section. Active power and reactive power references are injected before the current loop to test the VSC converter's reaction, with some adjustments to their values made during the simulation period. In Figure 5.1, it can be observed the scheme of this VSC converter With the equations and presented in Chapter 4, it is possible to obtain the value of Kp(P LL) and pLLshowed in Table 5.2 defining the other parameters of these equations.

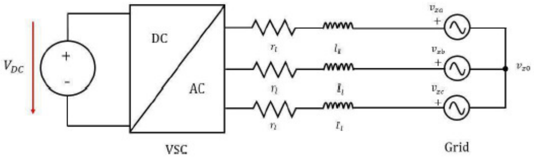


Figure 5.1: Scheme simplified of VSC with the DC side modelled as source.

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Parameters	Symbol	Value	Units
Closed current loop time constant	τ	0.010	s
PLL time constant	τ_{PLL}	0.0045	s
PLL constant gain controller	K_{pPLL}	1.36	-
Coupling resistance	r_l	0.5	Ω
Coupling inductance	l_l	0.0054	H
AC side voltage (phase-phase)	U_{ab}	400	V
DC side voltage	V_{DC}	800	V

Table 5.2: Simulation parameters of DC side modelled as a voltage source.

Simulation of the VSC converter with the DC side modeled as a current source and a capacitor: In this section are presented the results of the simulation of the VSC converter with the DC side modelled as a current source and a capacitor in parallel. The DC voltage regulator can be implemented using P or PI controllers. In this simulation, it has been choose, a P controller with GcDC (s) = KpDC , where KpDC> 0, as it would be the main controller for future simulations. A renewable energy source, such as an offshore wind farm, is used as the current source to pump intensity into the DC side of the VSC converter. In order to maintain power balance, the generation system must inject electricity into the electrical grid, and the VSC must manage the DC voltage with a DC voltage regulator. The diagram of this VSC converter is shown in Figure 5.8, and a more through diagram.

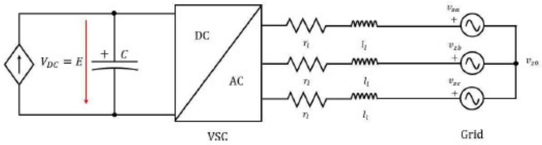


Figure 5.8: Scheme simplified of VSC with the DC side modelled as a current source and a capacitor.

Parameters	Symbol	Value	Units
Closed current loop time constant	τ	0.001	s
PLL time constant	τ_{PLL}	0.0045	s
PLL constant gain controller	K_{pPLL}	1.36	-
Coupling resistance	r_l	0.5	Ω
Coupling inductance	l_l	0.0054	H
AC-side voltage (phase-phase)	U_{ab}	400	V
DC-side nominal voltage	V_{DC} = E	800	V
DC voltage reference from DC voltage regulator	E^{2*}	$(800)^2$	V
Constant of DC voltage regulator	K_{pDC}	10	H

Table 5.9. Simulation parameters of DC side modeled as a current source and a capacitor.

Simulation of a multi-terminal HVDC grid
After the VSC performance has been demonstrated, a multi-terminal HVDC grid made up of four elements is simulated, two of which are offshore wind farms. As shown in Figure 5.16, the network converters go by the names Wind Farm Voltage Source Converter (WFVSC) and Grid Side Voltage Source Converter (GSVSC). This simulation's goal is to create a GcDC (s) controller that satisfies all control requirements by identifying the best KpDCIn Table 5.15, the grid's parameters are detailed.On the one hand, WFVSC converters use VSC technology to link the multiterminal HVDC grid with the offshore wind farms' alternating current grid. These converters' primary job is to rectify (AC-DC) the voltage of the offshore wind farms' alternating current grid. The offshore wind farms' active and reactive power is managed using WFVSC converters. It is believed that these converters provide the HVDC grid with all of the active power produced by the offshore wind farm's production equipment. Additionally, in the unlikely event that it becomes essential, they are able to inject reactive power into the offshore wind farm's alternating current grid.

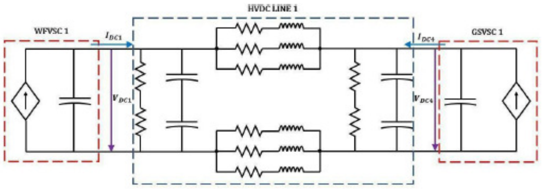


Figure 5.21. Scheme of the connection between WFVSC1 and GSVSC1

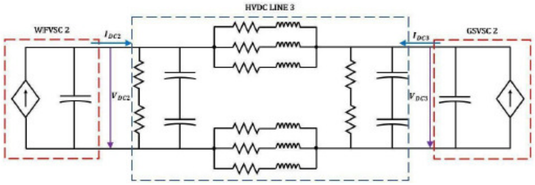
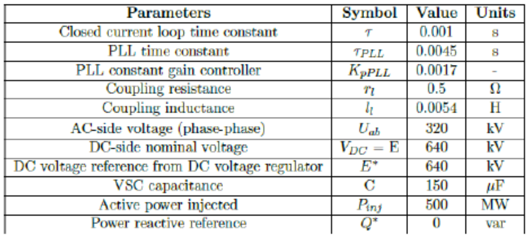


Figure 5.22: Scheme of the connection between WFVSC2 and GSVSC2

It's crucial to note that WFVSC converters don't influence the HVDC grid in any way. GSVSC converters, on the other hand, link the multi-terminal HVDC grid to the onshore alternating current grid. Their primary job is to convert the alternating current of the onshore grid from the multi-terminal HVDC grid's direct current while maintaining the currents' respective frequencies. The multi-terminal HVDC grid's voltage can be regulated utilizing the VSC control technique described in Chapter 4 as another function. Additionally, the multi-terminal HVDC grid can use this control technology to handle all of the active power generated by offshore wind farms. Depending on the voltage control architecture, this active power is routed via GSVSC converters. WFVSC1 and GVSC1 are connected by line 1, WFVSC and GVSC are connected by line 2, and WFVSC2 and GVSC2 are connected by line 3. The GSVSCs can share the active power produced by the two offshore wind farms using this distribution. If necessary, GSVSC converters can inject reactive electricity into the onshore system. The lines in the four-terminal HVDC grid are modeled as shown in Figure 5.17. The parameters of the cable model, which are listed in Table 5.18, have been extracted.



Parameters	Symbol	Value	Units
Closed current loop time constant	τ	0.001	s
PLL time constant	τ_{PLL}	0.0045	s
PLL constant gain controller	K_{pPLL}	0.0017	-
Coupling resistance	r_l	0.5	Ω
Coupling inductance	l_l	0.0054	H
AC-side voltage (phase-phase)	U_{ab}	320	kV
DC-side nominal voltage	$V_{DC} = \mathrm{E}$	640	kV
DC voltage reference from DC voltage regulator	E^{*}	640	kV
VSC capacitance	C	150	µF
Active power injected	P_{inj}	500	MW
Power reactive reference	Q^{*}	0	var

TABLE 5.15, Simulation parameters of the HVDC grid of four terminals

Conclusion

The work's objectives, which were outlined in Chapter 1, have been met. The building of a multi-terminal HVDC grid in Matlab-Simulink® and the investigation of the various proportional gains (KpDC) of the P controller from the DC voltage regulator constitute the key contributions of this project. In various settings, these KpDC have been examined in relation to the primary electrical magnitude. This thesis outlines a design process for a primary voltage DC controller for multiterminal HVDC grids so that an electrical analysis can be carried out afterwards. Additionally, the non - linearities of the model are captured by this methodology. This thesis outlines a design process for a primary voltage DC controller for multiterminal HVDC grids so that an electrical analysis can be carried out afterwards. Additionally, the non - linearities of the model are captured by this methodology. However, the converter current saturations and AC voltage sags could be included in a later work. First of all, it has described a VSC converter's properties as well as its control mechanisms, including all of the associated mathematics. Following that, two separate grid converter models operating in various control modes were detailed and simulated using the same parameters as one literature reference to see whether the models were correctly tracking the references. The control design methodology is derived once the multi-terminal HVDC grid model has been created. There have been three instances of simulations performed: the first one used the same The second KpDC for the two GSVSC converters was a separate KpDC, and the last KpDC was the disconnecting of one of the GSVSC converters. Within each of these scenarios In relation to a calculated rise in the nominal values of these electrical magnitudes, the maximum permissible values for each electrical magnitude have been established. The analysis entailed examining the admissibility in relation to the values of KpDC during the transient response and the steady state. The HVDC transmission is constantly being improved upon and is utilized extensively in applications using renewable energy sources. The investigation and analysis of the HVDC transmission system during pole-to-pole short circuit faults and pole-to-pole faults in the DC transmission are presented in this work earth faults. The DC interpolation fault is chosen for analysis because it is considered one of the most dangerous faults in any transmission system. The characteristics of the fault were studied from the moment of the fault until its 79 steady state is reached. It can be seen that with this type of failure, the system configuration changes over time. The HVDC transmission system was simulated with MATLAB Simulink and the system was tested under normal and fault conditions. This method uses the ratio of instantaneous energies to determine failure. The fault transmission resistance does not affect the method due to the ratio. This approach is based on the detection of electrical quantity data at both ends of the DC line to determine the location of the problem. Synchronous clock does not affect this because it does not depend on the measuring time. The approach was found to be simple and easy to implement, and is both accurate and flexible in identifying problems with DC lines. As a result, the results of this study have some implications for the problem of fault location in DC power lines. From the above techniques, it is clear that RFC is more accurate than ANN and other algorithms.

FUTURE SCOPE

It will take more time to determine how well the model scales up for huge bus systems and increasing the accuracy of it. RFR, DNN, and HT models produced superior results when failures in streaming networks are predicted. Since it continuously beat the competition, the RFR model is suitable for real-time situational awareness deployments to track the faults' duration and position while handling incomplete data. HVDC are going to be huge in upcoming years surely for the Urban to the rural areas. Environmental Impact This chapter analyzes the economic, social and environmental sustainability of this project. in qualitative and quantitative analysis is provided for some parts. In other parts only a is offered qualitative analysis. Financial sustainability This project is an academic work, so there is no financial benefit in the near future. However, the results obtained in this thesis can be useful for future researchers in this field or students who wish to do other academic projects such 80 as TFM (Thesis) or TFG (Thesis). It is about a project initiated by CITCEA-UPC and possibly its results contributing very little to the vast amount of knowledge and input generated in ETSEIB and UPC. The budget is quite realistic and it can be observed in Chapter 6 that the main part is a human resource. This part is expensive because of the related information engineer, it is logical that an engineer develops at a high level in exams 6 years and their salary is not the same as that of an employee without higher education. Although balanced, the whole budget is reasonable and apparently UPC can handle this amount from the project. The main disadvantage is that it is not possible to receive financial benefits in the short term, e.g most of the research projects carried out in universities. Social sustainability From one perspective, this project can be very altruistic because it does not track it financial benefit. Its main purpose is to promote the development of scienceand technology specifically in the electric field. For this writer, the most important thing is to apply the basics tie to is studying for a master's degree in electrical engineering and is learning new concepts and theory. Control and simulation of power converters in HVDC network After this thesis, the author can confirm that he has acquired a lot of new theory and he was able to use rational thinking to solve problems. Above all, this project wants to advance the management of HVDC networks, which they will be in connection with the growth of renewable energy in the near future. However this is just a small study that combines known theory with modeling and experimentation Simulink. This thesis is one of the articles published in the scientific community that can be read from references Environmental sustainability CO2 was calculated to know the environmental impact of the project. The footprint created through the use of Mars Home, the computer used to write and complete the thesis models and simulations in Simulink. The computer consumes an average of 70 W of current and is used for 784 hours as described in Chapter 6. Based on the total consumption of the computer, the carbon dioxide emissions are calculated. This energy using the procedure described in [18]. Amount of carbon dioxide emissions in 2018 is 321 g CO2/kWh. Considering the average power values and the number of hours of use, it goes Method to calculate grams of carbon dioxide emission. The total emission of the project is 17616.48 g CO2. The obtained results allow us to compare this amount, for 81 example, in grams of the car's carbon dioxide emissions. Only 176 km driven in one car corresponds to 17616 kg of CO2, the same amount of emission in our project, which lasted 4 months The project is sustainable with the results achieved in this chapter. Environmental impacts at the site of offshore wind farms This section briefly explains the various aspects to keep in mind while positioning offshore wind farm. The environment has many properties [19] that can be influenced construction of offshore wind farms, but the most important are: • Natural abiotic factors. • Biodiversity and protected areas. • Public sea-land area. • Fishing activities and fish stocks. • Social and economic heritage. •Cultural heritage. Control and simulation of power transformers in HVDC networks • Environmental security. • Landscape. sports, cruise lines and areas with elements of cultural interest.

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