Mitigation of commutation failure using hybrid control of Line-commutated converters and Capacitor Commutated Converter in HVDC System

[1]Peer Azhar Iqbal, [2]Navnidhi Sharma
[1]Research Scholar, Department ofElectrical Engineering, E-Max Group of Institutions, Gola, Ambala
[2]AssistantProfessor, Department of Electrical Engineering, E-Max Group of Institutions, Gola, Ambala
Ambala, Haryana

***Abstract:** With the introduction of advancements in industrialization, the need for electricity generation with stable voltage and current generation. The High Voltage Direct Current i.e. HVDC is a system that is implemented in power grids to enhance the power generation capacity of the system but the HVDC system suffers from the issue of commutation failure. During commutation failure, the voltage of the power system goes down and current increases. Therefore, in this work, the HVDC system with hybrid converters is developed. For the purpose of hybridization, the Capacitor Commutated Converter and Line-Commutated Converters converter is used. The simulation is done by introducing the AC and DC fault on inverter and converter both. The results prove that the proposed fault mitigation system performs efficiently to reduce the fluctuations in voltage and current of the power system.*

Index Terms -** HVDC, Commutation Failure,* **Capacitor Commutated Converter, Line-commutated converters,** ***Filters, Distortion.

I. Introduction

The High Voltage Direct Current (HVDC) transmission system is used to transmit the ample amount of large amplitude voltage signal over the distant location. It came into existence a long ago and presently each and every nation is using this technology. For the purpose of power transmission, various types of HVDC systems can be implemented such as Voltage-Source-Converter (VSC) and line commutated converter (LCC). The Voltage source converter technique is implemented at multi-terminal DC grid and on the otherhand, the LINE-COMMUTATED CONVERTERS HVDC technique produces optimum results as compare to Voltage Source Converter while using it for distant locations and for ample amount of power transmission. Different obstacles were faced in Line commutated convertor HVDC system, for example when the voltage level was reduced to 10 to 15 percent and failure of commutate take place.

In order to transfer a large amount of DC power for longer distance, different types of HVDC configurations are required. Each and every HVDC configuration has its own advantages and these are application specific.HVDC system comprised of various components and all the components execute the task associated with them and produce optimum results. In figure 1 different components of HVDC system are represented along with the detailed description of all the components. The High Voltage Direct Current system consists of three different components as follow:

- Converter unit at both ends transmission as well as reception end.
- Transmission medium
- Electrodes

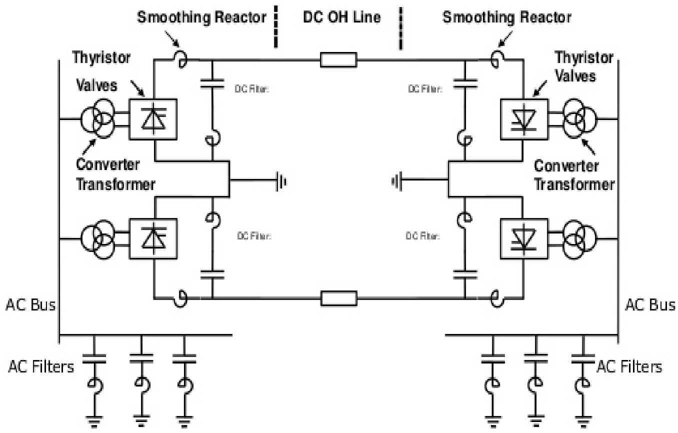

Figure 1 Basic HVDC single line Diagram

If a short circuit takes place then the HVDCsystem of transmission react in a different way whereas the AC transmission system reacts in a different way.The rectifier consists of the controller that manages to control the current at pre-fault value. In the case when the inverter controller is found to be working, then the value of the current for this case is retained in order to make the modification in it by rectifier with respect to a current margin. This signifies that value of current at which fault occurs is constant equivalent to the current margin (of the order of 0.1p.u). Though, the value of current at which fault occur is very less in comparison with currents in alternating current transmission line faults. To rectify fault it is required to make the value of current exactly zero and adequate time must be provided to arc path so that it should not contain any ion. In this time duration, the energy remained in the capacitor and inductor of the DC circuit must be discharged by using converters as these inductors and capacitors offer it remained energy to AC circuit. Due to a determined fault, if starting over is unsuccessful, then, in this case, the protection activity will de-energize the cable again. Generally, three attempts are made to start again mechanically with up surging dead time. The enduring error is implied when it does not restart even after three attempts and needs link shutdown until the error is recognized and clear. The usual removal of ions and starting the DC link again is equivalent to error clearance and it automatically closes the AC transmission cables. Major dissimilarity between these the two situation is that, though in AC lines breakers are used, in DC system the clearing of fault and starting of the system again is performed by using protective relays such as Direct current cable fault, Alternating current network faults,andConverter station faults.

II. PROBLEM FORMULATION

In the power grid system, when the valve of the converter that should be turned off but due to any reason keeps running then an unwanted event occurred which is named as commutation failure. In this case, the current is not preceded by the next valve in the sequence. Commutation failure is a disadvantageous dynamic event that leads to the fluctuation in voltage and current generated by the system. The commutation failure leads to the momentary interlude to the power transmission process. Additionally, the flow of direct current can lead to the extra heating of the conversion valves and resultantly it decreases the lifespan. In most of the cases, the commutation failures occur due to the failure of the AC block it is unavoidable. Thus, to prevent the commutation failure, the traditional method implements the thyristors and VSC control independently. On the basis of the traditional technique, it is concluded that the heating effect of VSC is not capable to manage the commutation failure fully. Moreover, supercapacitors were used in the existing systems for balancing of voltage but this specifically designed circuit enhanced the complexity of the model. As the complexity increases, so the model becomes expensive. The CC Converter was used for mitigating the commutation failure but it has various disadvantages as it increases the amount of harmonics in a system which will cause harmonic pollution to the power system. Along with this line-commutated converters, the converter was also used but it also suffers from various issues as while the single-phase ground fault happens at the AC bus, for line-commutated converters system the weak AC system cannot afford enough commutate voltage, and easily result in commutate failure. Thus there is a need to develop such a system which can overcome both issues of CC converter and Line-Commutated Converters converter.

III. PROPOSEDD WORK

A large number of HVDC systems comprised of line-commutated converters i.e. Line-commutated converters. In this converter, the need for reactive power is fulfilled by the capacitor banks that are deployed at the primary location of the converter. The previous section of this study represents a brief review of the issue that has been seen in traditional thyristors and line-commutated converters based commutation failure mitigation technique. During last few years, this mechanism has been seen quite productive advantageous to overcome the commutation failure but with the increasing advancements, the conventional controllers suffer from the issue of commutation failure when it operates for weak ac system. To overcome the drawback of the traditional technique, the proposedd work implements the hybrid converters to the HVDC system. The converter hybridization is done by using two most prominent converters i.e. Line-commutated converters and capacitor commutated converter. The capacitor commutated converter converter is selected because it is observed to be more stable than the line-commutated converters converter. The traditional weak ac system suffers from a single phase fault and three phase fault even in the presence of an line-commutated converters converter. Thus the capacitor commutated converter is used to overcome the issue of line-commutated converters converter.

It is observed that capacitor commutated converter is more stable than line-commutated converters, while the weak ac system befalls signal-phase fault or three-phase fault.capacitor commutated converter is less prone to commutation failure. The problems of line-commutated converters converter defined in above section can be overcome by using the cc converter as in weak system cc converter can guarantee the success of the inverter commutation, the adding commutation capacitor has a certain support to the bus voltage. Thus, in the proposedd work, the cc converter is hybridized with line-commutated converters converter. A hybrid configuration for that terminal would result in an improved performance for the whole HVDC system since the risk of commutation failures at ac network disturbances is lower for line-commutated converters and the stability is better for capacitor commutated converter compared to conventional converters.

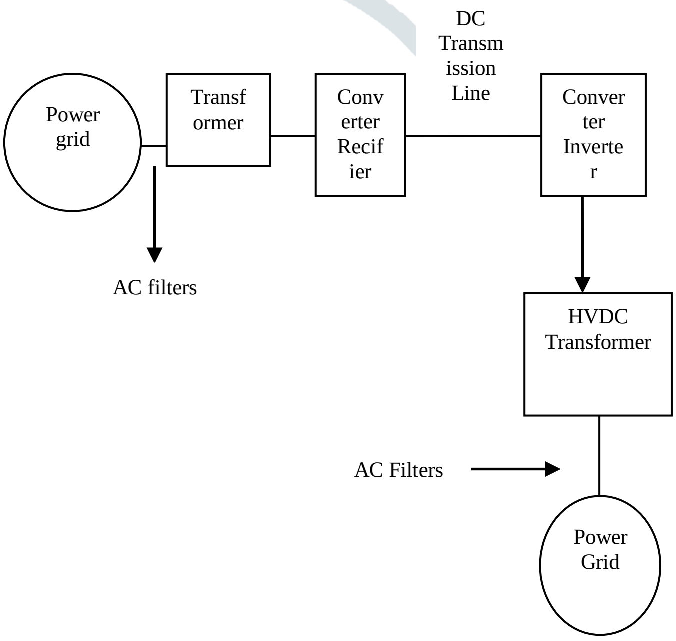

Figure 2 Framework of proposedd work

The figure 2 depicts the framework for the proposedd HVDC system which comprised of a power grid or power system that generates the power in the form of voltage and current. Further, the AC filter is applied for the purpose of signal filtration. Next, the transformer and converter rectifier is applied which to convert the alternate current to the direct one. Then the DC transmission line and inverter to convert the DC signals to AC signals. Then the proposedd HVDC system is deployed which is comprised of hybrid converters to mitigate the AC and DC faults. At last, the mitigated current and voltage are transmitted to the power grid.

IV. RESULTS

This section of the study describes the results that are obtained after implementing the proposedd HVDC system. The proposedd HVDC system implements the hybrid converters to overcome the issue of commutation failure. Along with this, for the purpose of simulation, the AC and DC fault is introduced to the system.

The figure 3 depicts the proposedd HVDC model with AC fault and similarly,figure 4 shows the HVDC model with DC fault. In the proposedd model as per the figure 3 and 4, it is observed that the inverter is applied for the AC fault and rectifier is applied for the DC fault.

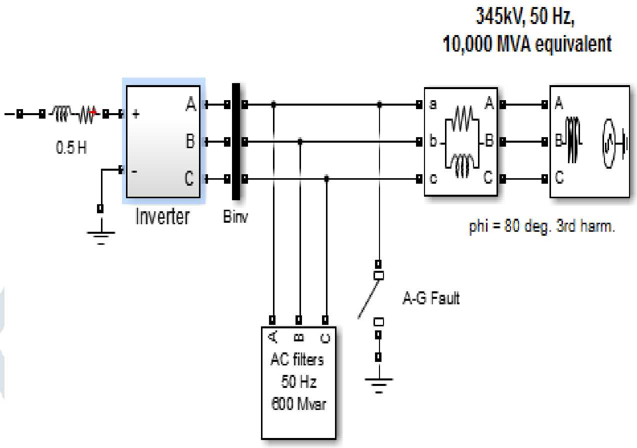

Figure 3 HVDC model with AC fault

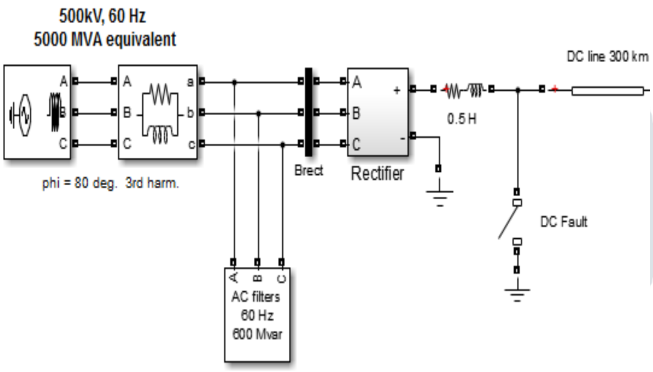

Figure 4 HVDC model with DC fault

The figure 5 depicts the inverter structure that is implemented for proposedd work. The inverter has a Capacitor Commutated Converter and Line-Commutated Converters converter respectively employed in its structure. Similarly, the figure 6 depicts the structure for rectifier that is comprised of line-commutated converters and capacitor commutated converter respectively.

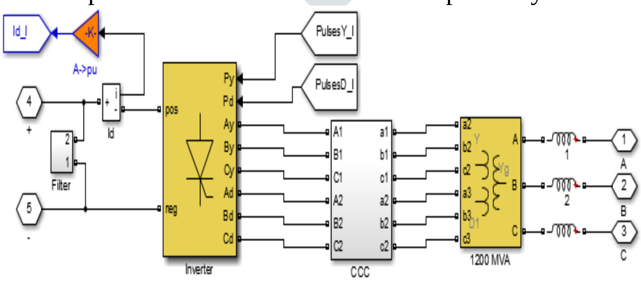

Figure 5 Inverter applied for the proposedd HVDC system

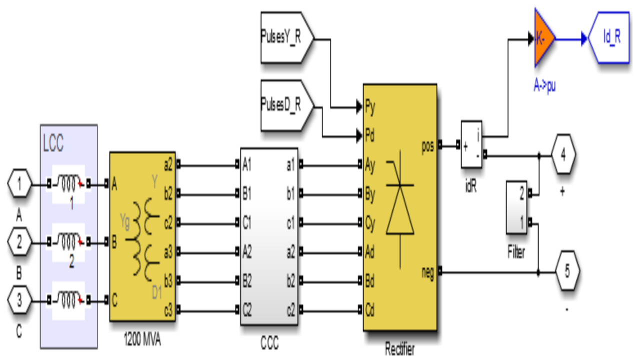

Figure 6 Rectifier applied for the proposedd HVDC system

Figure 7.1 depicts the circuit of Capacitor Commutated Converters. And Figure 7.2 depicts the circuit of Line Commutated Converters

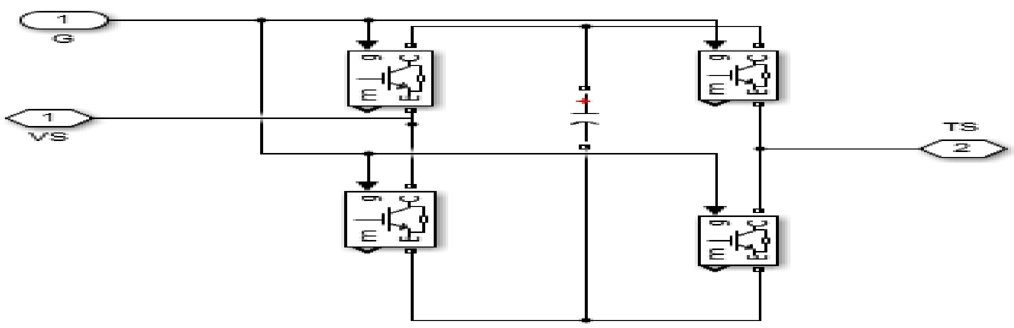

Figure 7.1 capacitor commutated converters

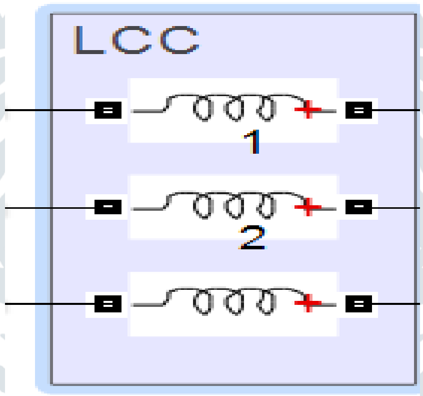

Figure 5.5 Line Commutated Converter

The graph in figure 8 and 9 depicts the current and voltage level when the AC fault occurs in the AC inverter and rectifier. It can be seen that during the occurrence of a fault, the voltage and current suffers from fluctuations and the voltage goes down to the negative values and consequently, the current increases drastically.

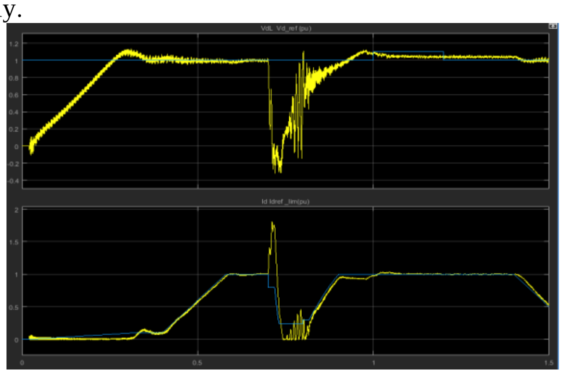

Figure 7 HVDC model with AC fault at Inverter

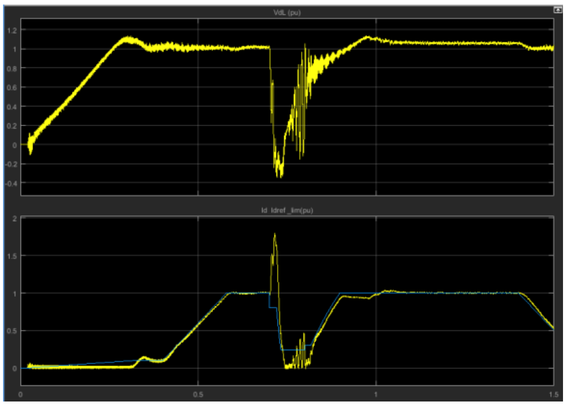

Figure 8 HVDC model with AC fault at Rectifier

The graph in figure 9 and 10 show the HVDC system with the occurrence of a DC fault at the rectifier and inverter side.

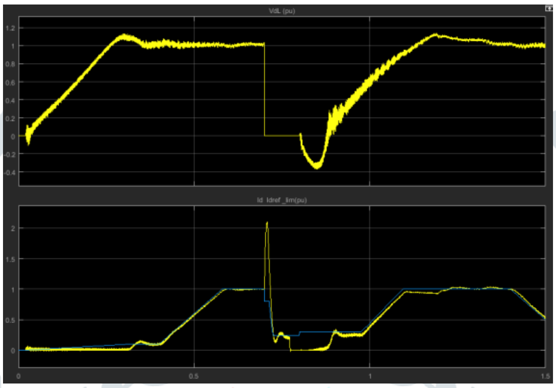

Figure 9 HVDC model with DC fault at Rectifier

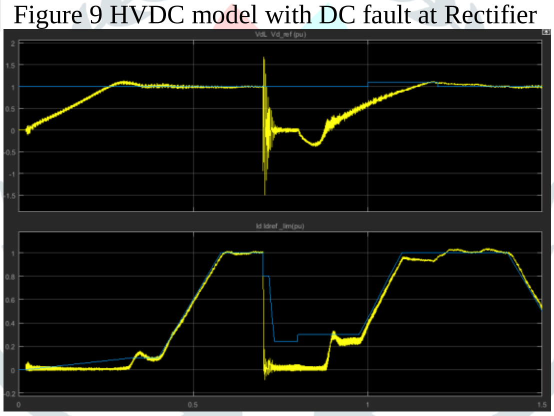

Figure 10 HVDC model with DC fault at Inverter

The graph in figure 11 shows the result of proposed HVDC model where the AC fault is mitigated at the inverter side. The graph makes it sure that after mitigating the AC fault at the inverter side by using the proposedd HVDC model with hybridized converters can recover the voltage and current to the reference current value to a greater extent. After applying the proposedd HVDC model, a stability has been achieved in generated voltage and current by the power system.

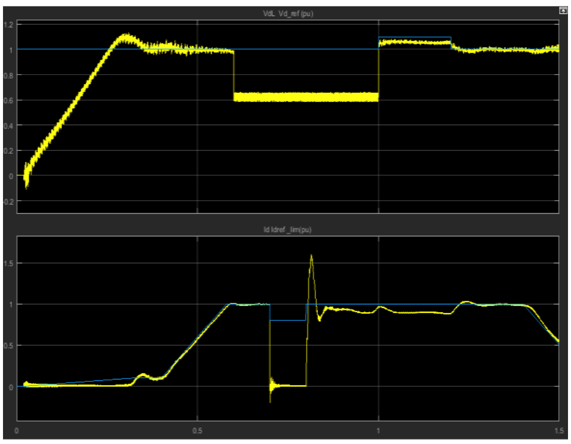

Figure 11 The Result of Proposed HVDC model with mitigated AC fault at Inverter

Figure 12 depicts the similar results for AC fault mitigation process in the rectifier. At the rectifier side, the desired amount of voltage and current is recovered even after occurrence of AC fault.

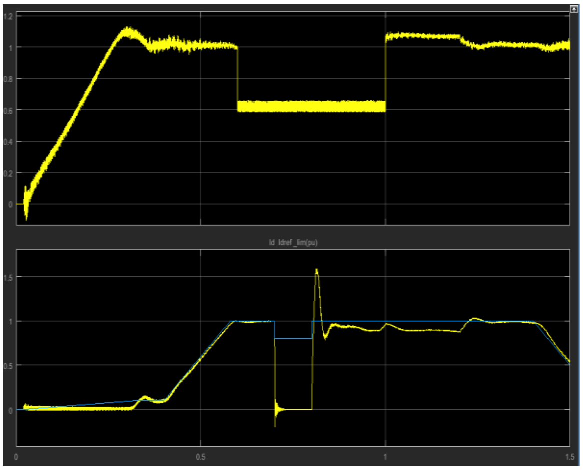

Figure 12 The Result of Proposed HVDC model with mitigated AC fault at Rectifier

The figure 13 shows the voltage and current of the AC valve that is evaluated after mitigating the AC fault by using the proposed HVDC model. The figure delineates that after mitigating the AC Fault the normal level of voltage and current is produced. Hence it can be concluded that the system did not get affected by the AC fault as the proposed HVDC model has the caliber to recover the losses.

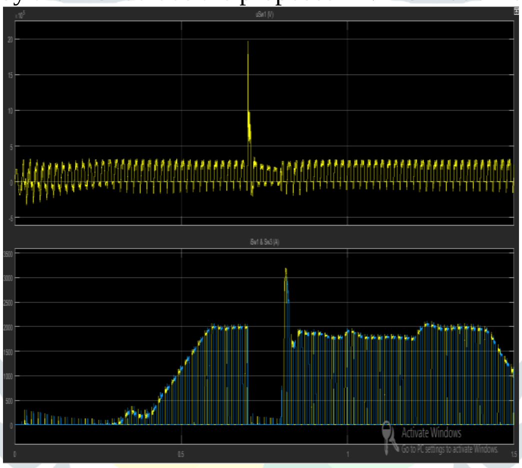

Figure 13 The Result of Proposed HVDC model for AC Voltage and Current

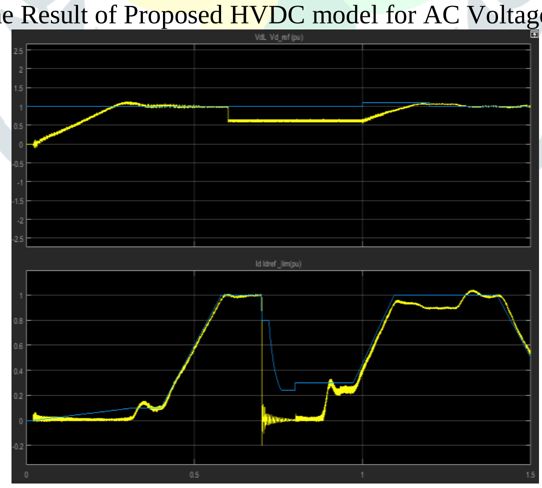

Figure 14 The Result of Proposed HVDC model with mitigated DC fault at Inverter

The graph in figure 14 and 15 shows the level of voltage and current that is obtained after mitigating the DC fault in the inverter and rectifier respectively. The figure 10 explains that after mitigating the DC fault at the inverter side, a high level of stability has been obtained in voltage and current respectively.

On the rectifier side, the DC fault is mitigated by using the proposedd work and the results are shown in figure 15. After mitigating the DC fault the voltage goes higher and current also gets stable.

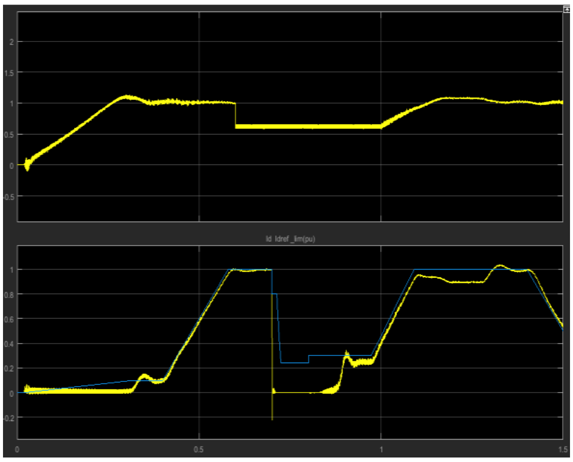

Figure 15 The Result of Proposed HVDC model with mitigated AC fault at Rectifier

In a power system, if voltage and current get affected due to the occurrence of faults whether it is AC or DC, then there are chances of valves of getting affected are also higher. The graph in figure 16 shows the voltage and Current for DC valve that is observed after mitigating the DC fault at the inverter and rectifier side. It is observed that after mitigating the fault, the valve generates the voltage and current effectively.

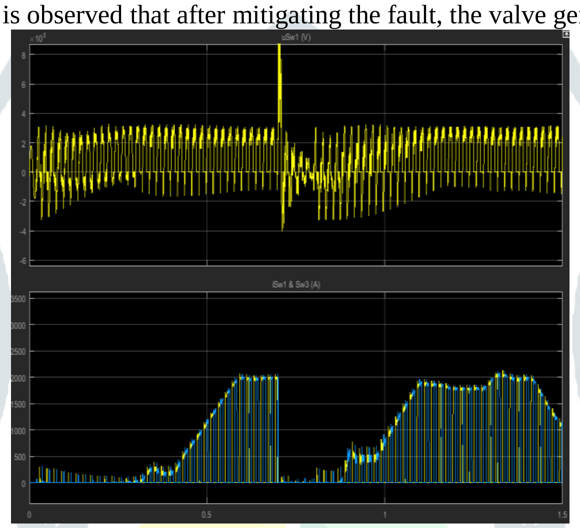

Figure 16 The Result of Proposed HVDC model for DC Voltage and Current

V. CONCLUSION

To sum up, this work analyzes and mitigates the effects of AC and DC fault on voltage and current generated by the HVDC system. For the purpose of fault mitigation, the hybridized converters are applied to the HVDC system. In order to create the hybrid converters, the LINE-COMMUTATED CONVERTERS and CAPACITOR COMMUTATED CONVERTER converter is considered. In proposed work, for analysis, the AC and DC fault is introduced at both sides i.e. rectifier and inverter. On the basis of the simulated results, it is observed that the voltage and current get more stable after mitigating the DC fault in comparison to the AC fault. Along with this, the filters are also used to reduce or remove the effect of signals distortion as it can also lead to the flow of inappropriate current and voltage. The present work could be enhanced in near future by working on switching and controlling by using the fuzzy inference system. This can lead to the fast switching process when a fault occurs in the system.

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