An SL2CC Approach for Eliminating Commutation Failure in HVDC System

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Abstract*— Significant amount of voltage with high amplitude can be transmitted over large distances by transmission systems referred as High Voltage Direct Current (HVDC) systems. For the purpose of transmitting power different versions of HVDC systems can be employed. On the basis of the requirement different methods such as Line Commutated Converter (LCC) dependent HVDC, Voltage-Source-Converter (VSC) methods can be used to implement such systems. Without reviewing the full fledge working of the HVDC system, it is not feasible to design the perfect mathematical model. The power transmission in HVDC highly relies upon the capability of the controller and converter employed on power stations. A hybrid converter based HVDC model is introduced in this work. The CCC and LCC converter is used for the purpose of hybridization. The AC filter is also deployed in order to regain the quality of the original signals. The simulation is performed by introducing the single phase DC fault to the system. The evaluated results proves the proficiency of the proposed work in terms of mitigating the commutative failure with the introduction of the DC fault.

***Keywords*—HVDC, Commutative Failure, DC fault, AC Filter, CCC converter, LCC converter.**

I. INTRODUCTION

HVDC system comprised of various components and all the components execute the task associated with them and produce optimum results [1].

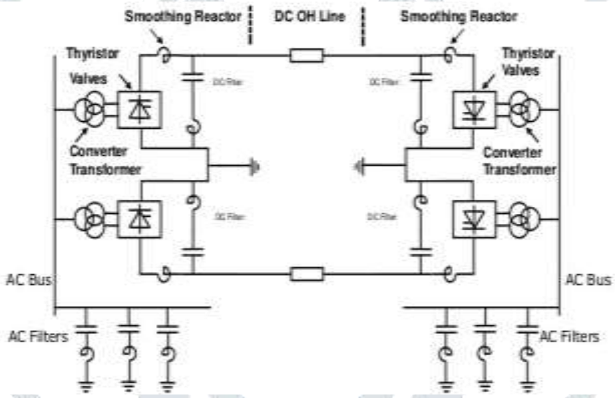

Figure 1 Basic HVDC single line Diagram

In figure 1 different components of HVDC system are represented along with the detailed description of all the components [2]. 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

1.1 The converter station

On the transmitter and the receiver section the converter stations are the replica of one another and that's why it contains the entire compulsory devices for the alteration of AC signal [3]. To the DC signal and vice-versa. Various important components of the converter are explained below [4].

1.2 Types of HVDC converters

The main operation that was considered in HVDC system is transmission of the electrical signal from rectifier unit to the transmission end where the signal can be transferred to the receiver end where the inverter unit will convert the DC signal into AC signal. Various techniques are used for conversion of signal; some of the techniques are described below [5].

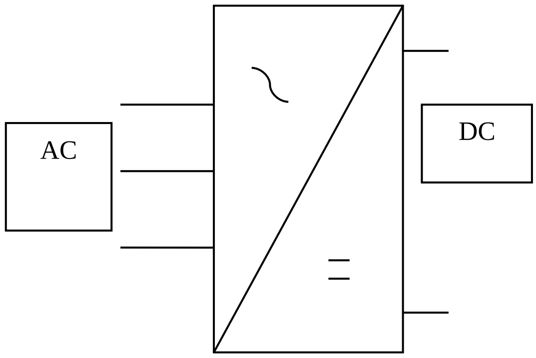

Figure 2 Converter symbol

1.3 Line Commutated Converters (LCCs)

In present scenario LCCs which are also referred as natural commuters are commonly used for High Voltage Direct Current transmission. Here the word 'line commutation' referred as line voltage used to monitor the operation of the thyristor. For line commutation operation the mercury arc valves as well as thyristor is used for the conversion process [6]. The Thyristors is semiconductor device whose switching operation can be controlled from external pulse and it is capable to transmit large amount of current signal and can stop the large value voltage signal. Different techniques of integrating various thyristors in series can be used to form the thyristor valves [7]. This thyristors combination is able to operate at high value of voltages. Thyristors valves operate at 50 to 60 hertz frequency range and uses different control angle of trigger pulses for its operation. The DC voltage signal of the bridge can be easily varied and this will provide different techniques to immediately control the power of signal to be transmitted [8].

1.4 Capacitor Commutated Converters (CCC)

This type of commutation is an improved version of commutation based on thyristors. In this type of commutation capacitors are used in series between thyristor valves and transformers used as converters. To determine the commutation operational efficiency, the commutation capacitors are interconnected with fragile circuit systems [9].

1.5 Transmission medium

To transmit large amount of power the overhead transmission lines can be used. It is commonly used transmission medium. This overhead transmission lines are usually bipolar, that means if one conductor have positive polarity then another will have negative [10]. Normally, for underwater submarine power transmission the HVDC cables are required. Generally the cables are solid in structure with oil filled inside them. In various conditions, solid type is cost-effective type. Its insulation consists of paper tapes and these tapes are filled with thickness oil [11]. In this type there is no restriction regarding the length and designs can be modeled for depths of about 1000 m [12].

II. PROBLEM FORMULATION

A commutation fault is a disadvantageous dynamic event that occurs when the converter valve, which should be turned off, continues to operate. Thus, the current is not transmitted to the next valve in the firing sequence. The occurrence causes temporary interruption of transmission power, stressing the converter device. In addition, the direct current may increase drastically and lead to additional heating of the conversion valve. As a result, the lifetime is shortened; most of the commutation faults are caused through voltage disturbance due to AC system failure and cannot be completely avoided. In order to prevent this failure the existing techniques used Thyristors and Vsc control individually. But the heating effect of Vsc could not reduce this failure completely. Moreover, super capacitors were used in the existing systems for balancing of voltage but this specific designed circuit enhanced the complexity of the model. As the complexity increases, so the model becomes expensive. Another issue was related to the noise that introduces to the current which indirectly degrades the performance. Considering this fact, there is a need of proposing a new technique which should be less costly and complex.

III. PROPOSED WORK

Most of HVDC systems consist of line commutated converters. The demand of reactive power is supplied by filter or capacitor banks which are connected on the primary side of the converter transformer. The above section defines the problem that exists in traditional system where LCC was used to overcome the commutation failure. This conventional design is well known and proven during last decades. However, such conventional converters suffer commutation failures when they operate as inverter at a weak AC system. Thus, in proposed work, the CC Converter is used along with LC Converter. A CCC 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 CCC and the stability is better for CCC compared to conventional converters.

Figure 3 depicts the framework for proposed work. The flow of the work is initiated by setting the power generator parameters and after that the AC filter is applied to the generated signals to remove the noisy content from it. After filtering the signals the rectifier is applied at the sender side. Along with this the proposed model comprised of hybrid converters i.e. LCC and CCC is applied. The converted signals are passed to the inverter and then again filtration of the signals is performed and filtered signals are passed to the receiver finally.

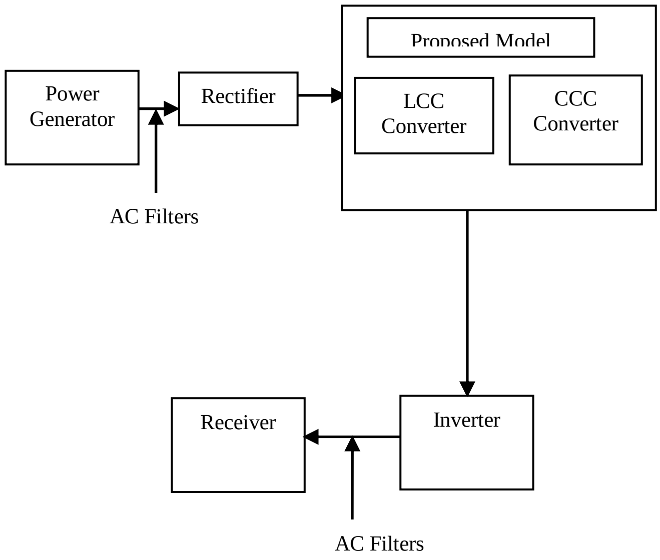

Figure 3 Framework of proposed work

IV. RESULTS

This study implements the hybrid converters to the HVDC system. The hybridization is done by using the LCC and CCC converters. This section organizes the results that are obtained after implementing the proposed work in MATLAB simulation platform. The graph in figure 4 depicts the voltage and current at rectifier that is observed after mitigating the commutative failure. In the proposed model DC fault is introduced for the simulation purpose. The effect is shown after mitigating the effect of commutative failure by implementing the proposed model. The graph depicts that the fluctuations or distortion has been overcome to a level as in traditional system the voltage goes to negative range and current increases suddenly, but in proposed model, the voltage did not affected that much. By introducing proposed model, it is observed that the valves which were short circuited during fault regain its switching characteristics and start working properly. Similarly, figure 5 depicts the effect of proposed mitigating model on voltage and current generation power of inverter.

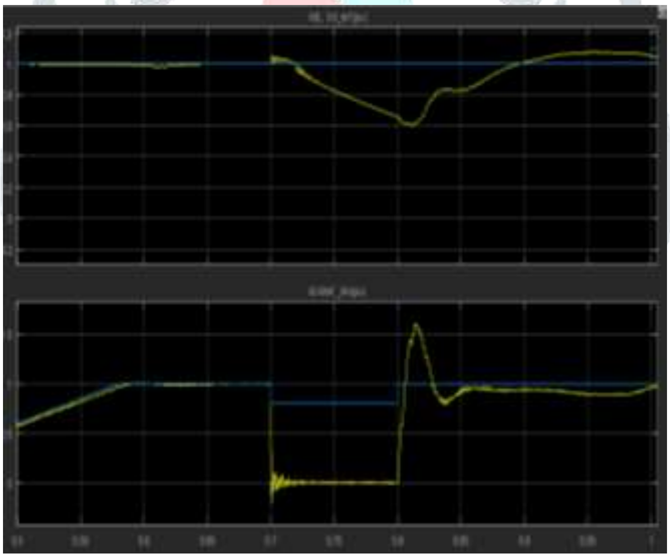

Figure 4 Rectifier Voltage and Current by mitigating commutative failure

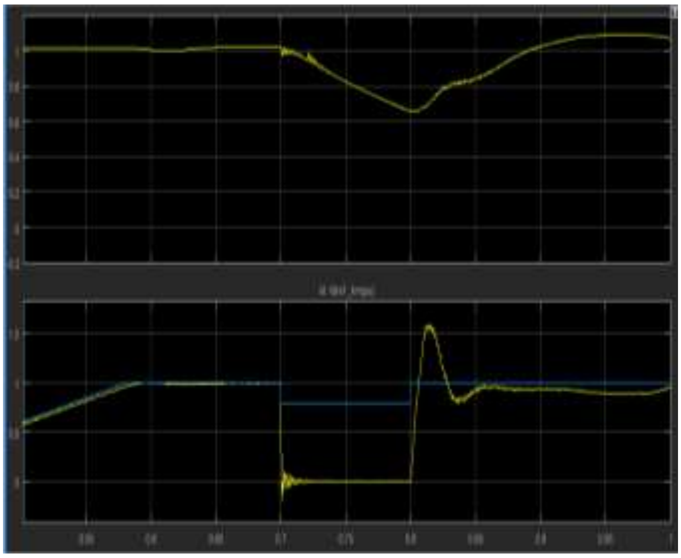

Figure 5 Inverter Voltage and Current by mitigating commutative failure

The figure 10 depicts the voltage and current of valve after mitigating the commutative failure by implementing the proposed HVDC model.

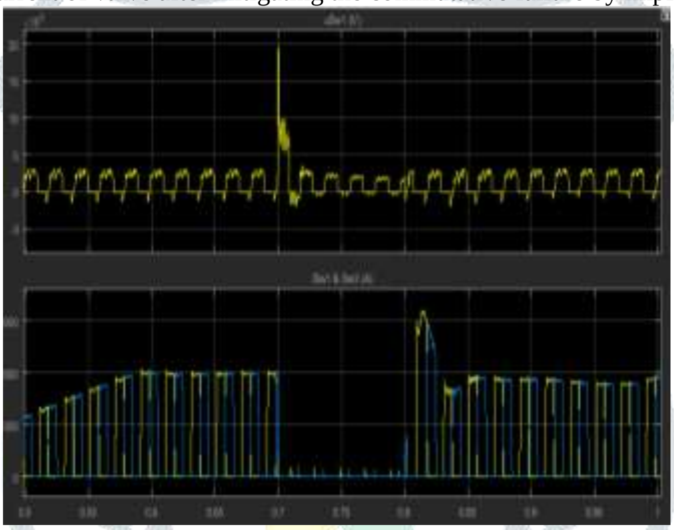

Figure 6 Valve Current and Voltage after mitigating the fault

The figure 7 depicts the inverter structure that is implemented for proposed work. The inverter has CCC and LCC converter respectively employed in its structure. Similarly, the figure 8 depicts the structure for rectifier that is comprised of LCC and CCC respectively.

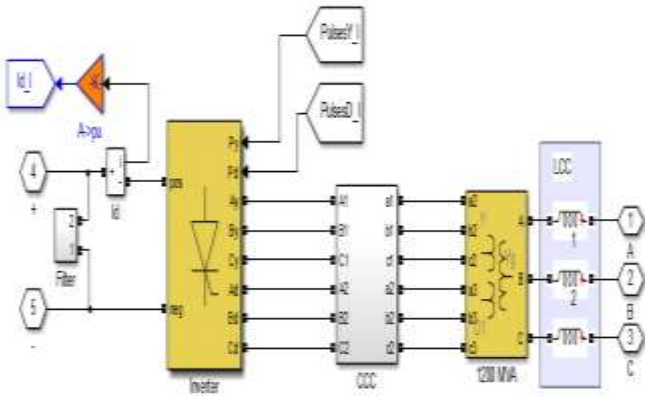

Figure 7 Inverter embedded for proposed model

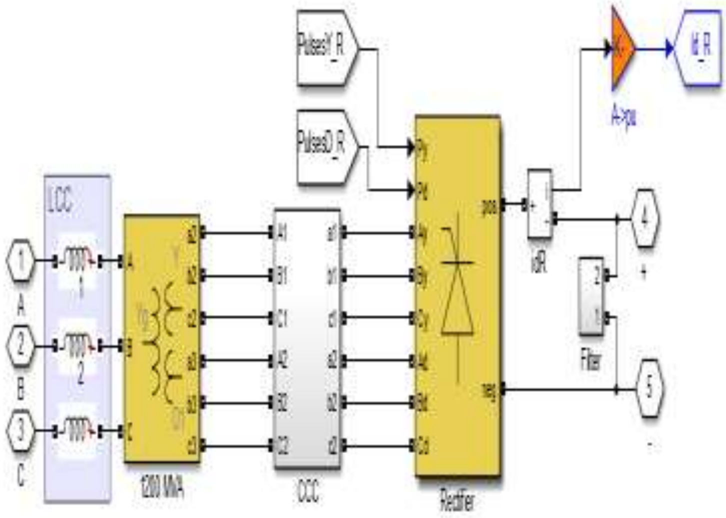

Figure 8 Rectifier embedded for proposed model

The figure 9 and 10 shows the rectifier and inverter structure without any commutative failure detection for DC fault. Such systems are not capable to overcome the issues that occurs due to DC Fault.

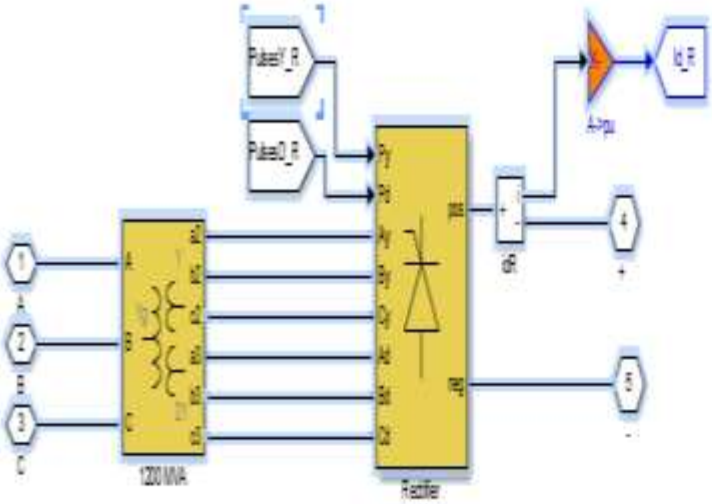

Figure 9 Normal Rectifier Structure

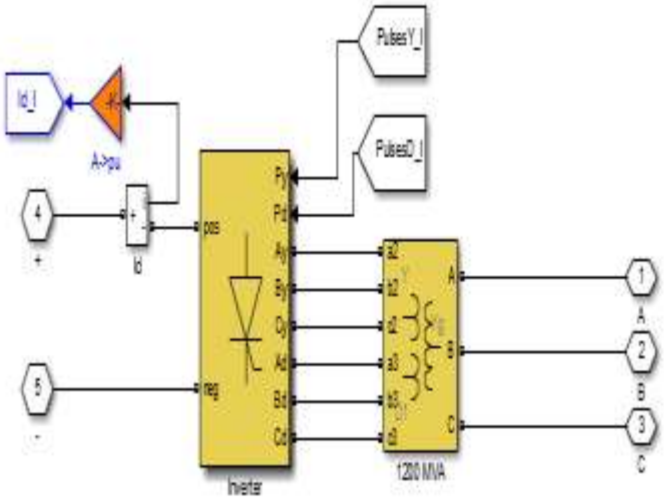

Figure 10 Normal Inverter Structure

The graphs in figure 11, 12 and 13 depict the current and voltage for rectifier, inverter and normal without mitigating the DC faults. On the basis of the graphs it is observed that if the DC fault is not mitigating then the current and voltage will suffers from high fluctuations and in this way there are high chances of short circuits in the power system.

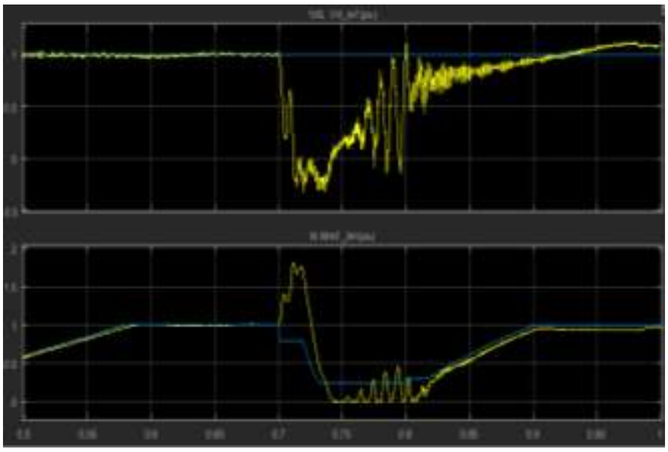

Figure 11 Rectifier Voltage and Current without mitigating the DC Fault

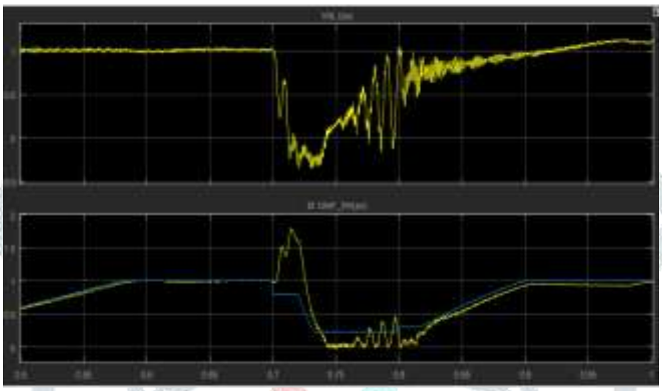

Figure 12 Inverter Voltage and Current without mitigating the DC Fault

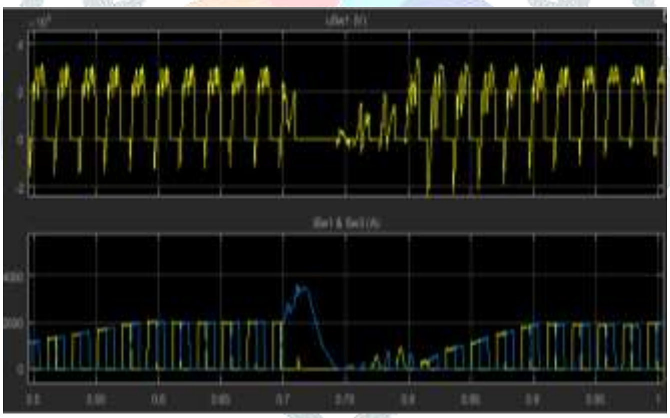

Figure 13 Valve Current and Voltage without mitigating the fault

V. CONCLUSION

This study has analyzed the effect of Faults over the HVDC system. Initially single phase DC fault has introduced in the system. From the simulation analysis, the numbers of fluctuations are analyzed over different faults. It has shown that a system with DC fault have high number of fluctuations. For the experimental analysis, DC fault has applied and with the application of this fault, the fluctuations happen. In the existing model, the commutation failure was an issue where the voltage goes down and current increases. By the analysis of the proposed model, the variations are reduced at some extent so as the commutation failure. For this purpose the CC converter and LCC converter is used. Furthermore, AC filter has introduced in the system to overcome the problem of distortions in the system. It has been clearly shown that the application of proposed model reduces the distortion with more stability. The model has been analyzed over different faults; filter has introduced to remove the effect of distortion. Moreover, the capacitor circuit is also presented for the deduction of commutation failure in the HVDC model. As in proposed work, the single phase DC fault is introduced and the simulation is performed similarly in future more amendments can be done in this work by introducing the three phase DC fault to it.

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