Scientific Journal of Impact Factor (SJIF): 5.71

e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 5, Issue 04, April -2018

AN APPROACH FOR MITIGATING COMMUTATION FAILURE USING CAPACITOR COMMUTATED CONVERTER IN HVDC SYSTEM

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Abstract— *With the growing demand of electricity on a daily basis, we cannot rely on conventional electric authority systems like long-haul distributed power stations as well as complicated and heavy load / distribution networks. High voltage direct current (HVDC) transmission networks contain an enormously essential role in authority methods. Lacking the suitable study of the HVDC mechanism, it is impractical to attain an exact arithmetical model of the method and in the lack of proper modeling the influence transmitted in the HVDC system cannot be measured. The power transmitted through the HVDC system depends upon the competence of the controller and the converter station. A Capacitor-Commutated Converter (CCC) on the basis of HVDC method is projected in this study. Along with this, to regain the signals from distortion, the filter is applied to the distorted signals. Further, the simulation results evinces that the developed system surpasses the results of traditional HVDC system in terms of commutation failure mitigation.*

Keywords—*HVDC, Commutation Failure, CC Converter, Filters, Distortion.*

I. INTRODUCTION

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 [1].
The Voltage source convertor technique is implemented at multi-terminal DC grid and on the other hand the LCC HVDC technique produce optimum results as compare to Voltage Source Convertor while using it for distant locations and for ample amount of power transmission [2]. 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 [3]. 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 [4]. 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

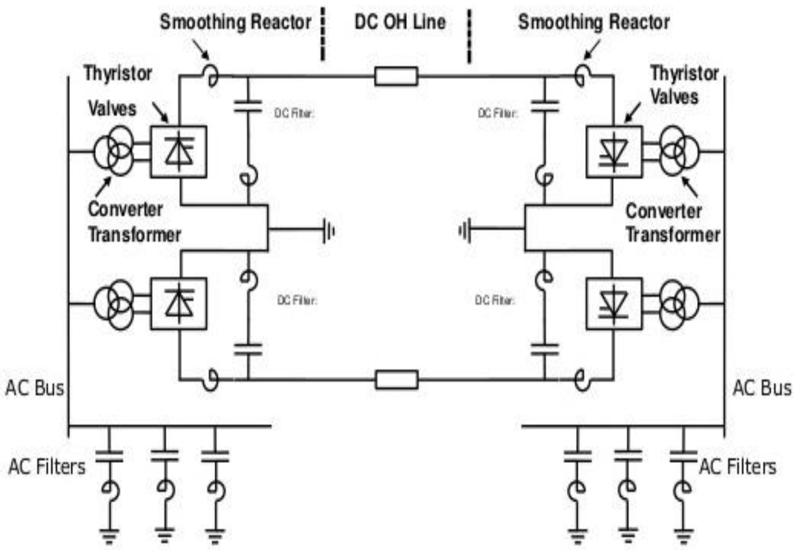

Figure 1 Basic HVDC single line Diagram[4]

Due to breakdown of commutation there is short term halt in power transmission and valves heating. The commutation breakdown may result in temporary cut off of power transmission and overheating of valves [5]. An abrupt increment can occur in power transmission lines between adjoining AC transmissions lines which might interrupt temporary firmness of structure. Commutation failures are normal vibrant actions which are accumulated in various practical systems [6].

1.1 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 [7]. Various techniques are used for conversion of signal; some of the techniques are described below.

1.1.1 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 [8]. 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. This thyristors combination is able to operate at high value of voltages. Thyristor's valves operate at 50 to 60 hertz frequency range and uses different control angle of trigger pulses for its operation [9]. 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.

1.1.2 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.

1.1.3 Forced Commutated Converters. Another name for these converters is Voltage source converters. By using these types of converters various numbers of advantages can be described. For instance: supply of non-active networks (with no generation), autonomous controlling the generation of active power etc. This type of converter valves is created by using the semiconductor material which is easily to turn on and turn off. These are also called as Voltage sourced converters (VSC). Two kinds of semiconductor voltage sourced inverters are Gate Turn-Off Thyristor (GTO) and Insulated Gate Bipolar Transistor (IGBT). With the beginning of 80s, both type of transistor were frequently used in industrial applications. Operation of converter is attained by implementing the Pulse width modulation (PWM) [10]. With the help of PWM, different phase angles and various amplitude levels are generated and to attain this various transformed patterns of PWM [11]. Therefore to control the potential of active and reactive power simultaneously, PWM technique is recommended as it operates in a similar manner as non-matched component in transmission network does.

II. PROBLEM FORMULATION

When the converter valve constantly operates which must be turned off an unfavorable dynamic result is achieved that is a commutation defect. Thus, the current is not transmitted to the next valve in the firing sequence. By straining the inverter component the temporary interruption of broadcasting power takes place. Additionally, the direct current may amplify severely and direct to extra heating of the inversion valve. Therefore, the lifetime is reduced; many commutation defects takes place with voltage disturbance because of AC system malfunction and cannot be fully ignored. To avoid this defect the traditional mechanisms applied Thyristors and Vsc control separately. But the heating effect of Vsc could not reduce this failure completely. Furthermore, in the conventional techniques the super capacitors were applied to balance the voltage but this particular deliberated circuit advanced the difficulty 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

Several HVDC methods acquire line commutated converters. The order of reactive power is delivered by filter or capacitor banks which are linked 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 cumulative failure. Throughout previous decades the existing design is well recognized and verified. Therefore, if they worked as an inverter at fragile AC method then these existing converters experience commutation defaults. Thus, in proposed work, the CC Converter is used to replace the LC Converter. A CCC configuration for that terminal would result in an enhanced performance for the complete HVDC method since the risk of commutation defaults at AC network disturbances is lesser for CCC and the stability is improved for CCC comparative to traditional converters. With the CC Converter the projector method also functions the filtration to remove the noise.

IV. RESULTS

This section describes the results that are obtained after analyzing the traditional HVDC system without any prevention to the commutation failure. The simulation model below represents the system without any commutative prevention mechanism. In the existing systems, use of power electronic device makes their system more complex and expensive. Consequently, a new method has proposed where the rectifier and inverter are used rather than a specific circuit designed that reduces the complexity as well as cost of the system. In the proposed model DC fault is introduced for the simulation purpose.

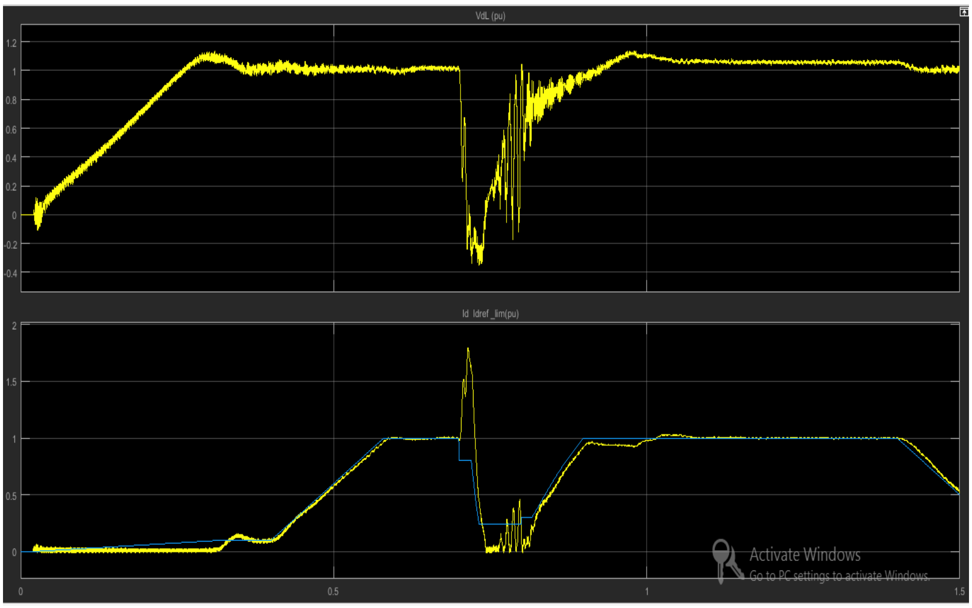

Figure 2 Analysis of Analysis of DC fault on inverter

Figure 2 represents the occurrence of commutation failure with the perspective of inverter. The graph represents the value of voltage and current where the DC fault is introduced at 0.7 and 0.8. The graph depicts that when the DC fault occurs, the voltage and current both gets affected by it as voltage decreases to -0.2 and due to this flaw, the current goes higher. A large number of fluctuations have been seen in both current and voltage.

The graph in figure 3 delineates the analysis of commutation failure on rectifier. The rectifier is used to convert the AC current to the DC. As per the observations, it is proved that due to the occurrence of fault or commutation failure , the voltage goes down to negative value and the current goes high as voltage and current are inversely proportionate to each other.

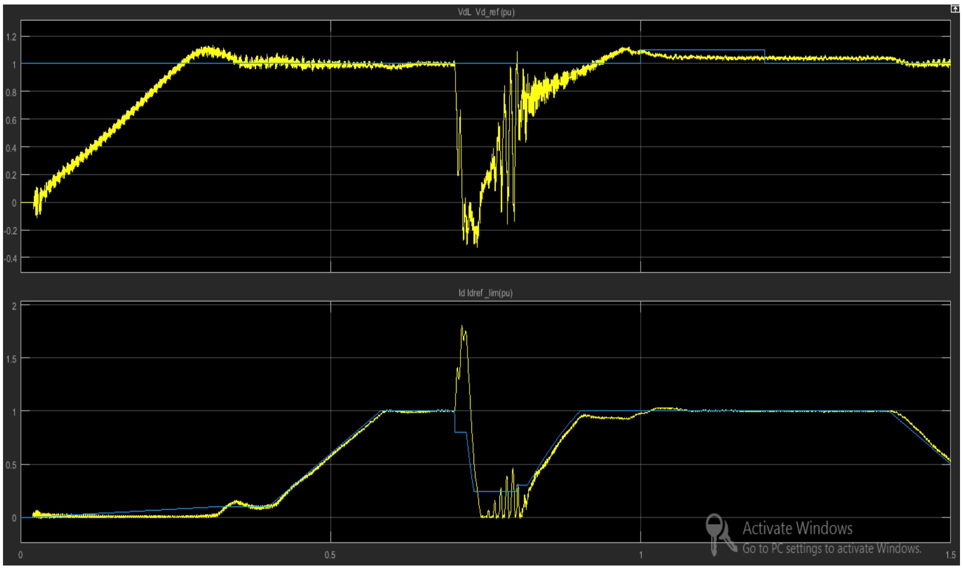

Figure 3 Analysis of Analysis of DC fault on rectifier

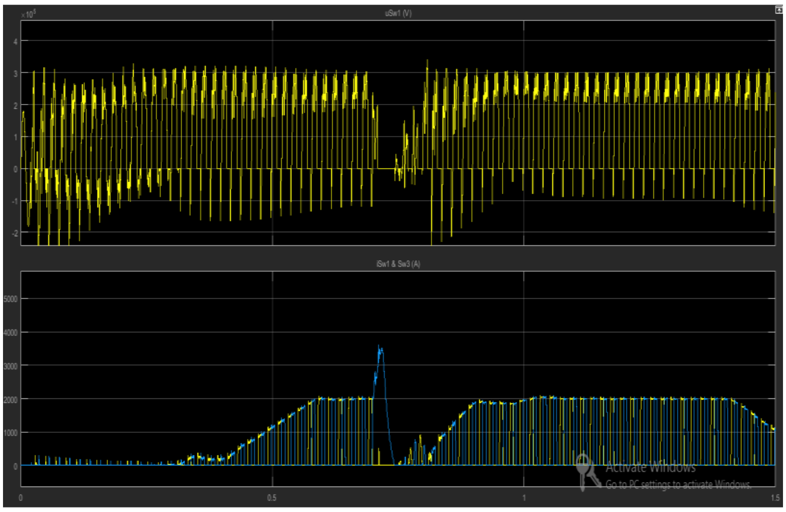

Figure 4 Analysis of DC fault Valve Voltages and Current

If the current and voltage gets affected due to the commutation failure, then there is a probability that valves also get affected by this fault. The graph in figure 4 shows the effect of commutation failure on valves. The graph explains that during fault occurrence, the valve stops generating valve and current.

The graph in figure 5 analyzes the fluctuations occur at voltage at valve due to the fault occurrence. To mitigate this effect there is need to modify the present system to overcome the effect of fault.

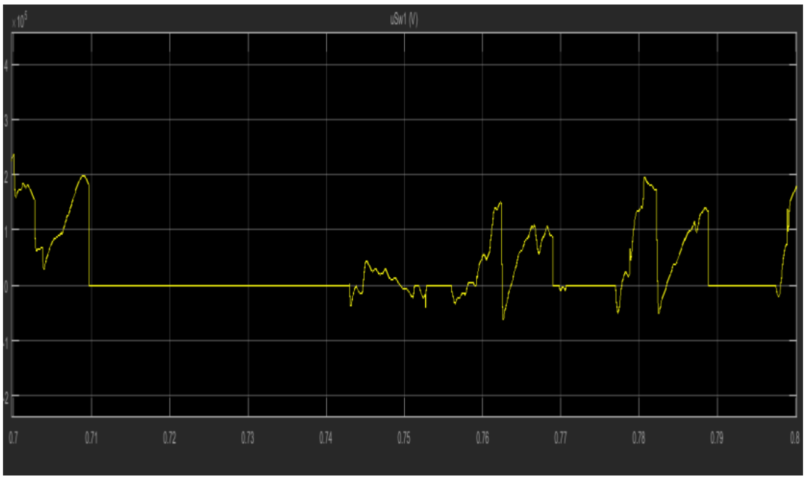

Figure 5 Analysis of DC fault on Valve Voltage

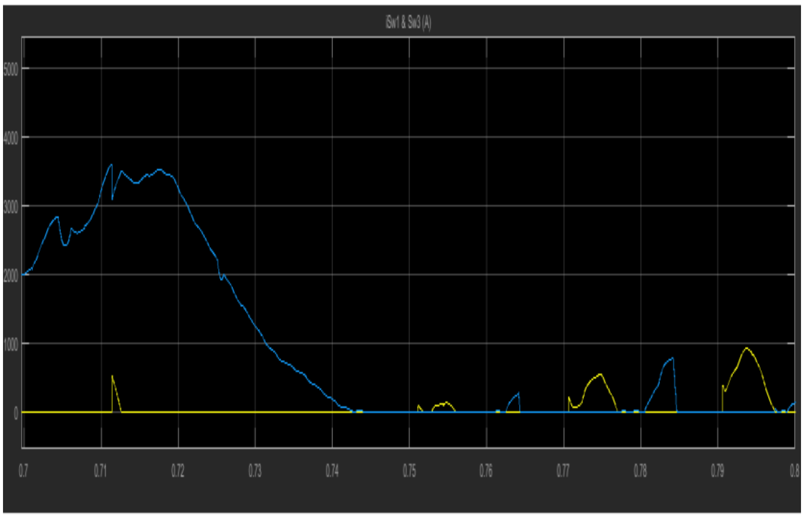

Figure 6 Analysis of DC fault on Valve Current

The below figure 6 shows the introduction of fault which occurs at 0.7 to 0.8 that reflects the number of variations in the system. Faults are the main cause of voltage dips which further increase the risk of commutation failure. The figure illustrate the large distortion in the valve currents which indicate the short circuit of the valve branches. The current and voltage are inversely proportionate to each other. The figure 6 exhibits the analysis of DC fault on Valve Current. When fault occurs the current generation becomes zero suddenly. To overcome this issue there is a need to develop a mechanism which can prevent the current and voltage from commutation failure. Thus, the proposed work designed a model which implements the CC converter to prevent the system from commutation failure. The commutation failure occurs in the system when a valve of converter continues to generating signal without transmitting current to the next valve. It mostly effect on inverter side. Because of this the switching among thyristors gets effected and leads to serious malfunction. So prevention of commutation failure is necessary.

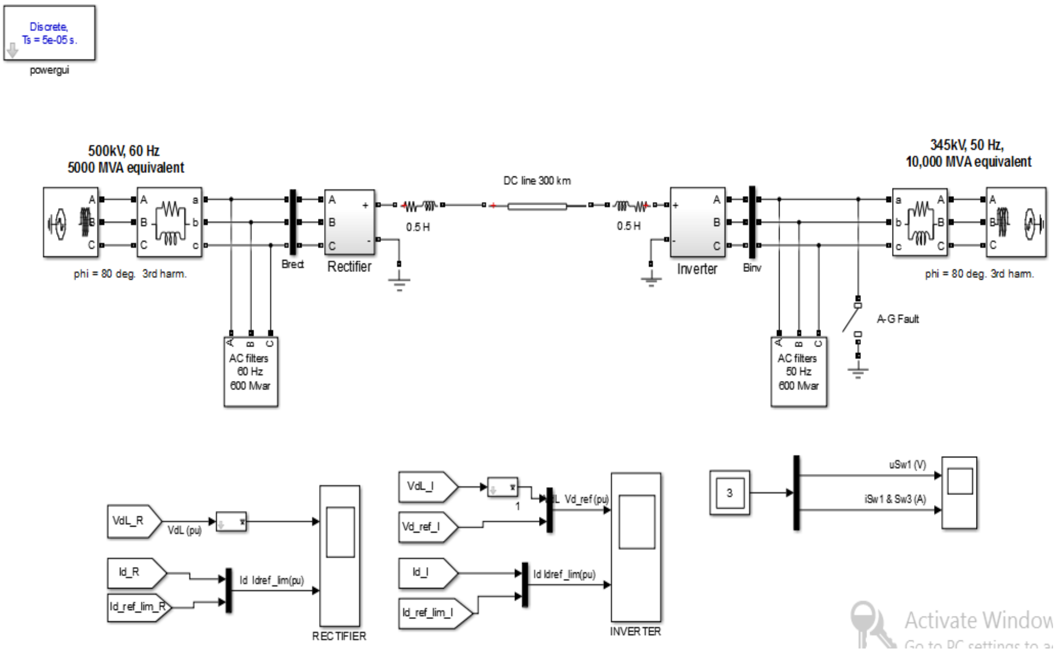

Figure 7 HVDC model with fault analyzer

The figure 7 represents the simulink model of HVDC system with fault prevention mechanism. The working of this model is similar as that of HVDC system. The rectifier and inverter are used to overcome the effect of commutation failure and the CC converter is also implemented. Along with this filters are used to remove the effect of noise in the signals. In simulation model, a power generation source is applied which generates the 3 phase power, after this, a rectifier is applied to convert the signals in order to compensate the transmission losses. A DC line is applied with the length of 300 km. On the other end the inverter is applied to convert the form of signals. Then a single line DC fault is introduced to analyze and prevent the system from the effect of commutation failure. The fault is introduced at 0.7 to 0.8.

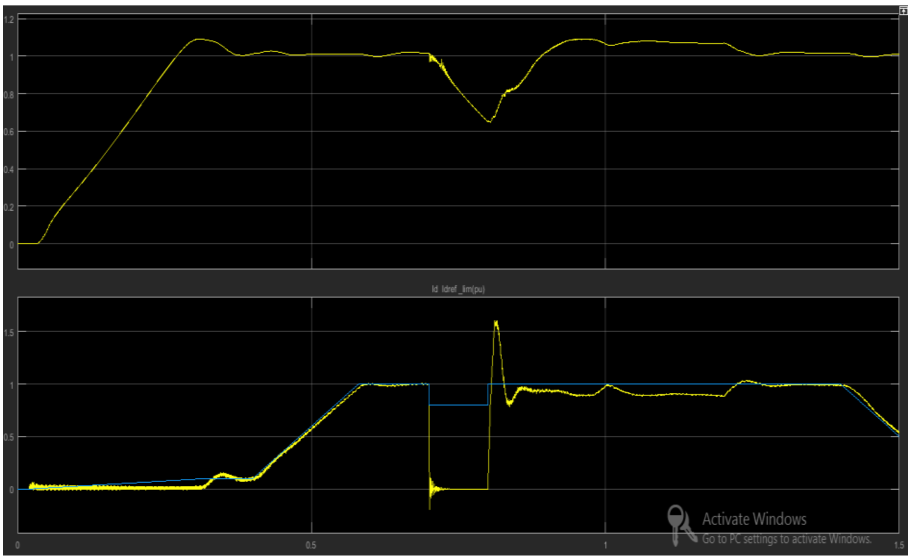

Figure 8 Inverter Voltage and Current by mitigating commutative failure

The graph in figure 8 depicts the effect of DC fault on voltage and current of inverter. 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 9 depicts the effect of proposed mitigating model on voltage and current generation power of rectifier.

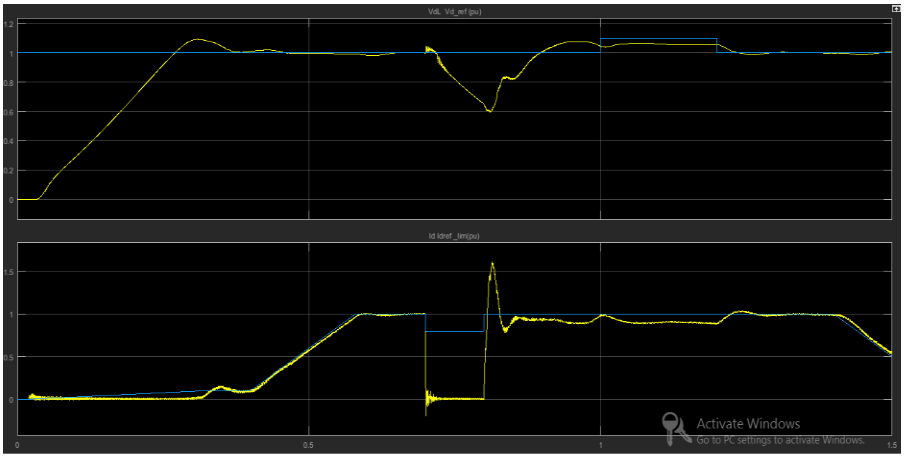

Figure 9 Rectifier Voltage and Current by mitigating commutative failure

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

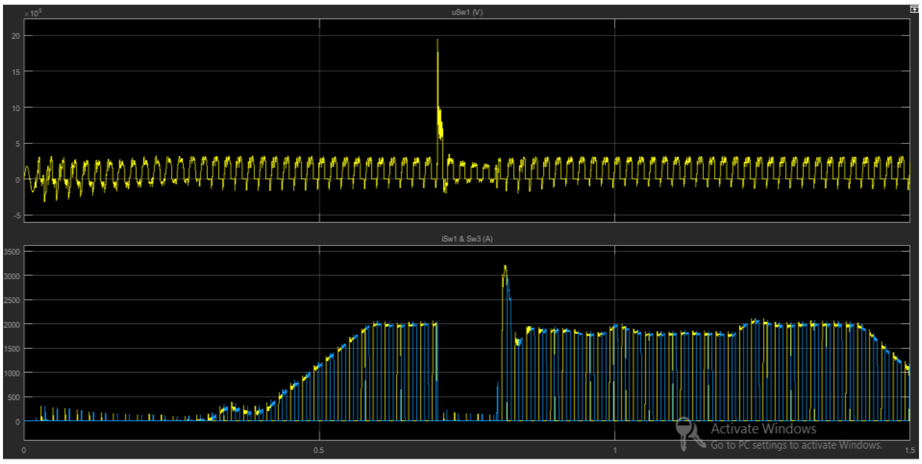

Figure 10 Valve Current and Voltage after mitigating the fault

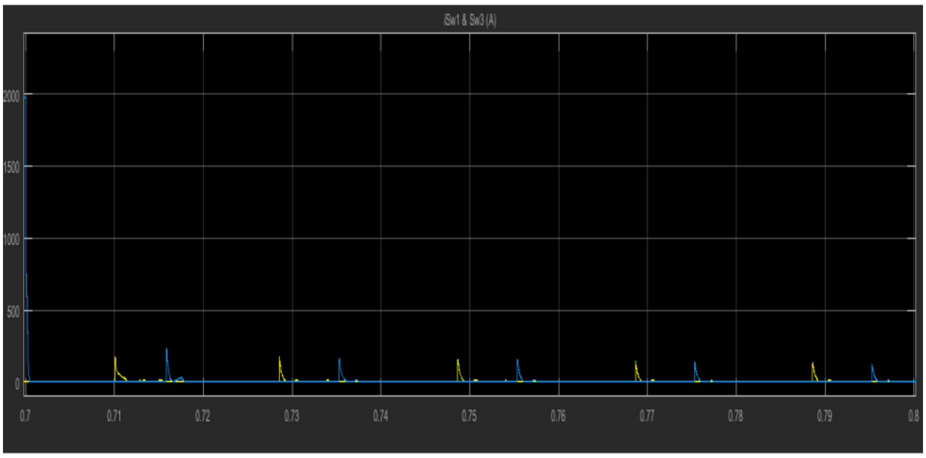

Figure 11 Valve Current after mitigating the commutative failure

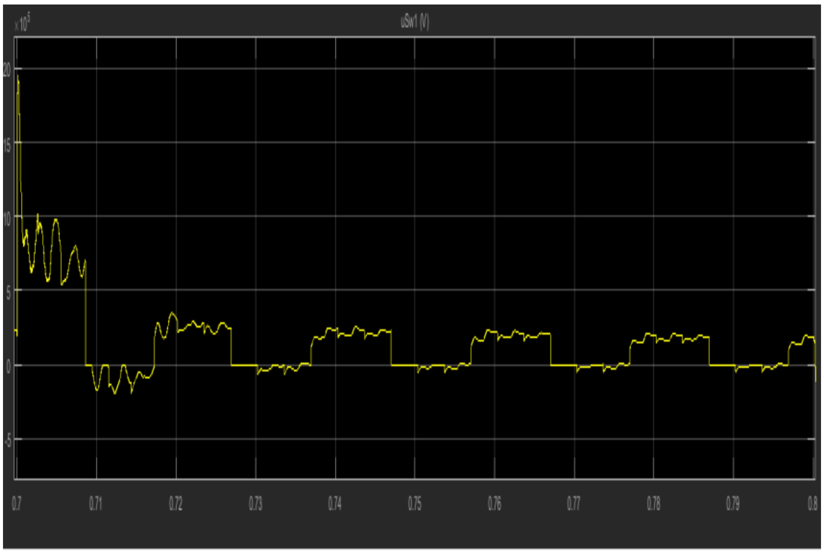

Figure 12 Valve Voltage after mitigating the commutative failure

The voltage and current at valves get improved after introducing the proposed model for mitigating the commutative failure in the system. The figure 11 and 12 delineates the current and voltage at valves level. This is observed that the fluctuation has been removed and a smooth current and voltage is generated.

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 at 0.7 to 0.8and with the application of this fault, the fluctuations happen. In the existing model, the commutation failure is 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 is used. Furthermore, DC filter has introduced in the system to overcome the problem of distortions in the system. It has been clearly shows 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 the present work, the capacitor circuit has used to inject the power to the system so in future this process can be done by Hybridizing the CC converter and LCC converter.

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