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# OPERATION AND PERFORMANCE ANALYSIS OF A FUZZY CONTROLLED MVDC LINK

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## ABSTRACT

*The operation of Fuzzy logic controller in medium voltage direct current (MVDC) link is described by using a DC link with medium voltage distribution network with back to back connected to AC system. This consideration is designed using MATLAB and demonstrate the dynamic performance of MVDC link. Here studies the real (P) and reactive (Q) power flows through the link, shows the voltage and currents at the both sides of the MVDC link and controlling of the currents in the system by using fuzzy logic controller in the inverter side.*

***KEYWORDS:*** *MVDC Link, Fuzzy Logic Controller, DC Distribution, Full Bridge*

## *Article History*

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## INTRODUCTION

The liberalization and climate change mitigation in the power industry has motivated a paradigm medium voltage DC (MVDC) distribution network. These has driven the need for MVDC distribution network for AC distribution network reinforcement, transmission/distribution level renewable energy (RE) integration, rail transport applications as well as urban and rural electrification. Unlike the conventional medium voltage AC (MVAC) system, the MVDC distribution system constitutes fewer power conversion stages making it more efficient presenting high prospects for future development hence proposed as an alternative to the AC distribution in commercial and industrial applications[1]. MVDC distribution system typically rated 1.5-30kV, may consist of intermittent RE and variable loads in a diverse system topology. The grid can be radial or mesh similar to the MVAC distribution [2].

As there is increase in use of renewable energy sources, the production is in DC voltages there is chance of distribute/transmission of power in DC [7]. As of implementation of DC appliances at consumers we can distribute the power DC power, by using MVDC distribution network we can distribute the power and it has more reliable and effective than the AC distribution networks.

The main objective of this paper is to give performance of the MVDC link between the two grid points and controlling of the MVDC link, current in the network with Fuzzy logic controller. By this gives the voltage and current wave forms for the AC network along with the active (P) and reactive (Q) power. The MVDC link is controlled and converted by using IGBT. For the thyristor triggering pulse width modulation is given with controlling of fuzzy logic controller it is connected in back to back. By using fuzzy logic current is controlled in inverter control operation.

In this paper, a Fuzzy logic-based controller has been proposed for the effective operation of the Voltage sourced converter (VSC) based MVDC link. Modelling and controlling of the entire circuit is carried out under the MATLAB/Simulink environment.

## TEST NETWORK

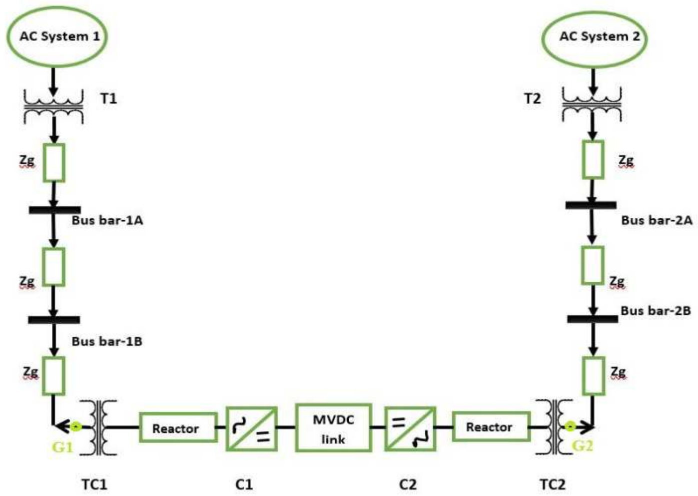


**Figure 1: Representation of Medium Voltage Distribution Network.**

As shown in figure 1, the MVDC link is incorporated between two Voltage sourced converters in DC distribution networks. AC networks 1 and 2 are modelled with identical three-phase voltage sources. These AC networks are fed from a delta-star grid transformer (T1 and T2) through the circuit breakers [3]. The transformer is grounded at its star point. The AC system consists of 3 three-phase pi-section lines with an impedance of $Z_g$ in each section. Lumped loads were connected at each bus bar. Two star-delta (Tc1 and Tc2) transformers, grounded at its star point were used as isolation transformers. Both Voltage sourced converters (C1 and C2) are connected to their respective isolation transformers through reactors [8]. Each VSC has six arms of IGBTs connected in abridge configuration. The DC link was capacitive grounded at each converter. These capacitors act as filters to reduce the ripple content presenton the DC side [2].This entire circuit represents the back-to-back connection of two AC networks with a DC link.

## FUZZY LOGIC BASED CONTROL OF MVDC LINK

Fuzzy controller with Mamdani fuzzy inference system is suggested in this paper due to its robustness to control the operation of VSC connected MVDC link. Generally, the fuzzy logic controller consists of three parts.

- Fuzzification block ( Determines the input membership values )
- Fuzzy Inference System ( Evaluates the control rules )
- Defuzzification block ( Calculates the output )

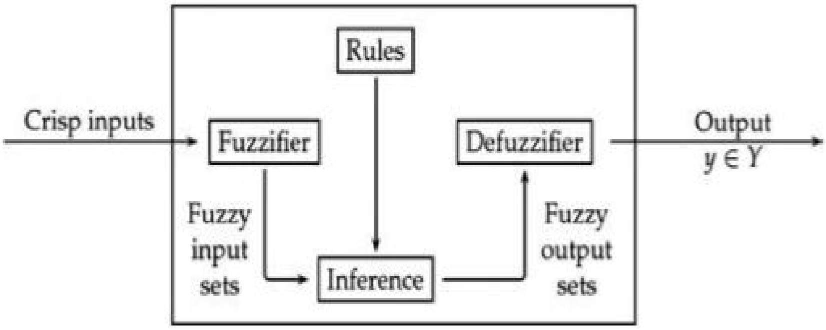


**Figure 2: Block Diagram of the Fuzzy Controller.**

Proper selection of gains in the fuzzy controller is very important to design it. This can be done through the trial and error method in many cases to achieve the best control performance.

In this paper, the input and output variables of the Fuzzy controller are computed based on the seven fuzzy subsets. The subsets have been named as NL (Negative Large), NM (Negative Medium), NS (Negative Small), Z (Zero), PS (Positive Small), PM (Positive Medium), and PL (Positive Large). These membership functions are sufficient to produce the desired results.

Error and change in error are taken as inputs of the Fuzzy controller for simulation. They are computed by considering rectifier and inverter voltage lines and have been calculated as outputs [5].The rules for the Mamdani FLC implementation is tabulated as shown in Table 1.

**Table 1: Rule Base for FLC Implementation**

| DE/ E | NL | NM | NS | Z | PS | PM | PL |
|---|---|---|---|---|---|---|---|
| **NL** | PL | PL | PL | PL | Z | Z | Z |
| **NM** | PL | PL | PM | PM | Z | Z | Z |
| **NS** | PL | PM | PS | PS | NM | NS | N M |
| **Z** | PL | PL | PS | Z | NS | NM | NL |
| **PS** | NM | PS | PS | NS | NL | NL | NL |
| **PM** | Z | Z | Z | NM | NM | NL | NL |
| **PL** | Z | Z | Z | NL | NL | NL | NL |

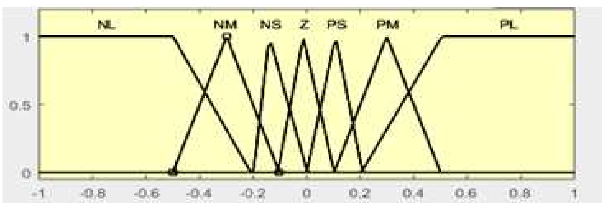


**Figure 3: Input Membership Function of Error Signal.**

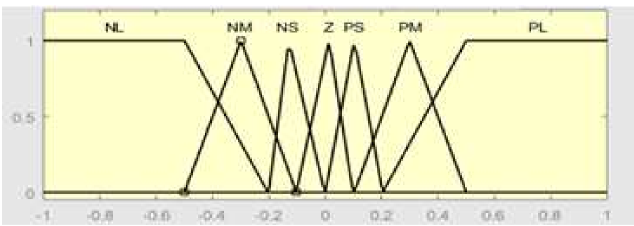


**Figure 4: Input Membership Function of Change in Error Signal.**

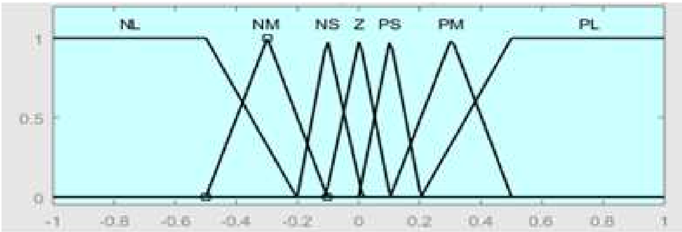


**Figure 5: Output Membership Function.**

## SIMULATION AND RESULTS

The performance of the DC link in the Distribution system is evaluated under normal and fault conditions. The circuit shown in figure 1 has been implemented in Simulink. The AC power from the two ideal three-phase sources has been transferred to the DC link through transformers. The rating of grid transformers is 33/11.5 kV and the AC section consists of three 1km lines having a resistance of 0.01273 Ω, the inductance of 0.9337 mH, and the capacitance of 12.74 nF. G1 and G2 are the corresponding grid connection points for AC systems 1 and 2. Two isolation transformers Tc1 and Tc2 are connected to these Grid points. Reactor connected to VSC having an inductance of 1 mH and 1 µF capacitor is placed on DC side to reduce the ripple content.

Fuzzy controllers have been employed in the control loops of VSCs [4]. These control loops take the rectifier and inverter voltages to generate reference error inputs to the fuzzy controller. A two-level PWM generator has been implemented to generate pulses to bridge configured IGBT converters.

Simulation results under normal and fault conditions are shown in Figures 6 – 19.

### Under Normal Condition

In this case, the performance of the MVDC link is evaluated under the unfaulted operation. Results were carried out for 0.2 seconds of simulation. The direction of power flow from AC system-1 to AC system-2 was considered as positive. Figures 6 and 7 show the voltages present at grid points G1 and G2. Only the magnitudes of voltage at these points are shown in figure 8. These values are constant for the entire simulation and the voltage at G1 is much higher than the voltage at G2.Figures 9,10,11,12 show the active and reactive powers through grid connection points G1 and G2 under normal operating conditions. The magnitudes of P and Q at points G1 and G2 are fluctuating during 0.2s of simulation.

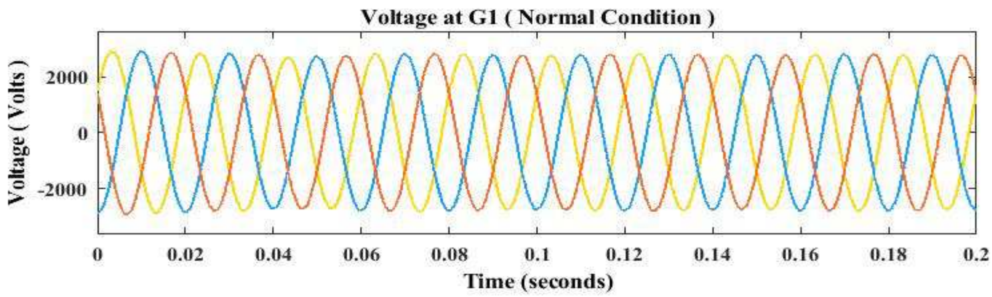


**Figure 6: Voltage at G1 Point.**

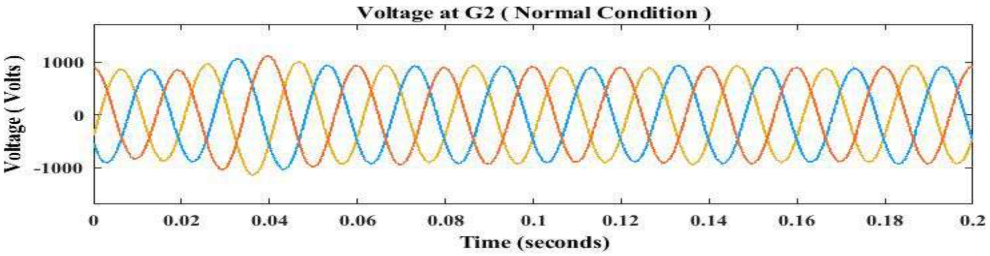


**Figure 7: Voltage at G2 Point.**

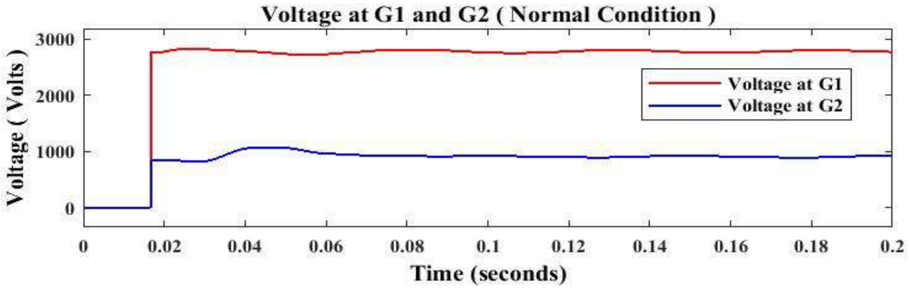


**Figure 8: Voltage Magnitudes at Grid Points G1 and G2.**

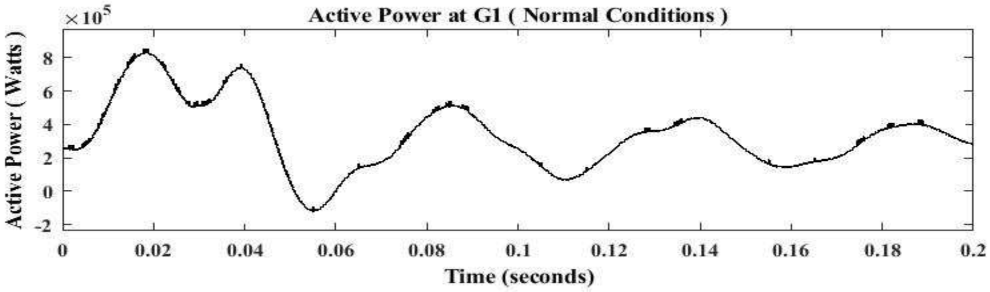


**Figure 9: Active Power P at G1 Point.**

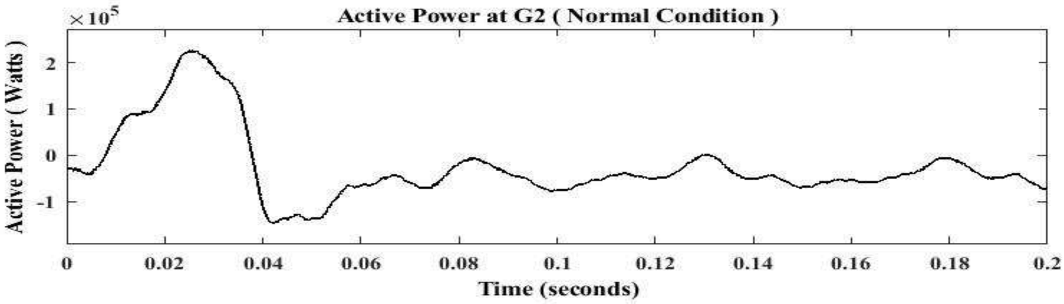


**Figure 10: Active Power P at G2 Point.**

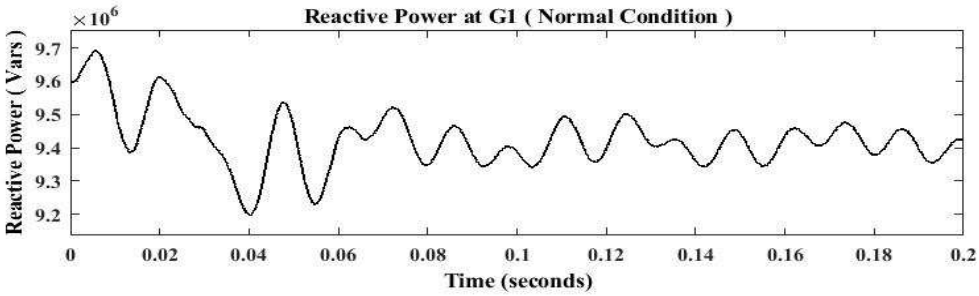


**Figure 11: Reactive Power Q at G1 Point.**

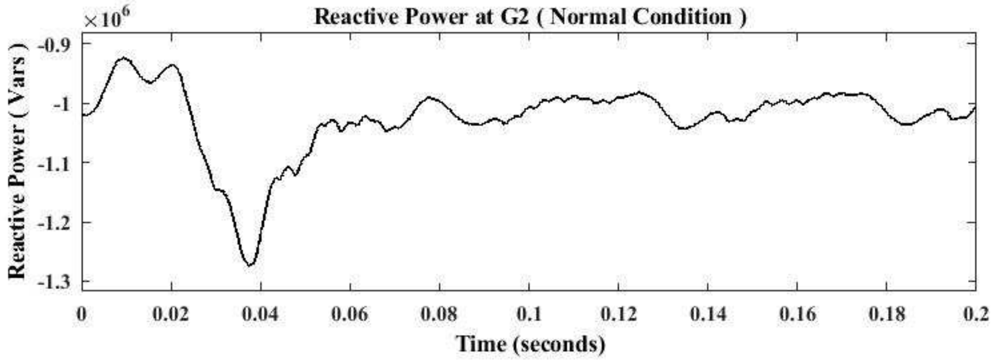


**Figure 12: Reactive Power Q at G2 Point.**

## Under Fault Condition

In this case, the behaviour of the MVDC link is analysed when a fault occurred in the AC network. An LLLG fault was created at grid point G1 during 0.05 – 0.15 sec of simulation. The AC voltage at points at G1 and G2 under abnormal operating conditions are shown in figures 13 and 14. The voltage at G1 is zero during fault and it is an unbalanced three-phase waveform at G2. As shown in Figure 15, the magnitude of AC voltage at G1 was zero during fault and then it is maintained as constant for the remaining time of the simulation.

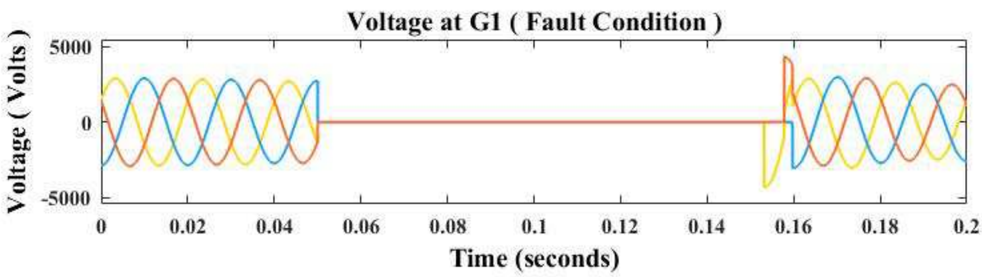


**Figure 13: Voltage at G1 Point Under Fault Condition.**

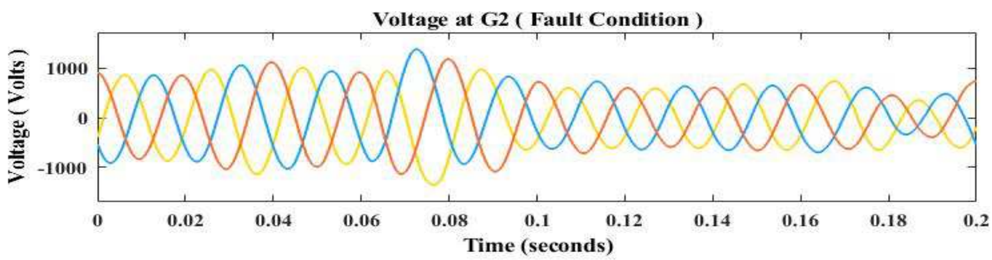


**Figure 14: Voltage at G2 Under Fault Condition.**

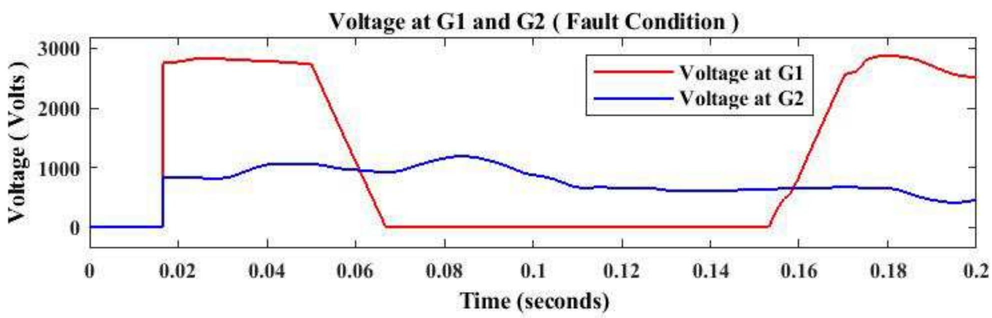


**Figure 15: Voltage Magnitudes at G1 and G2 Under Fault Condition.**

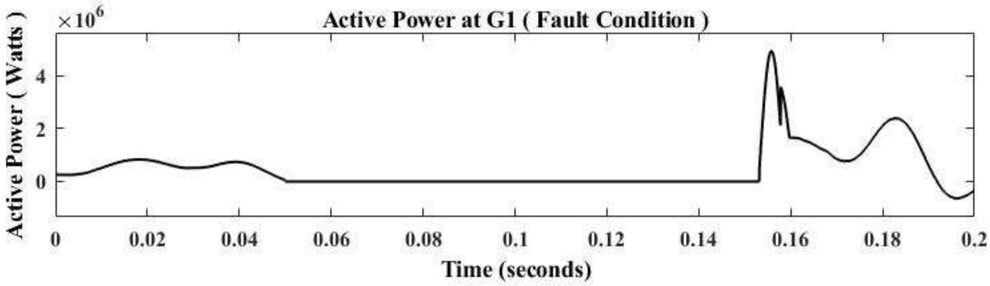


**Figure 16: Active Power P at G1 Under Fault Condition.**

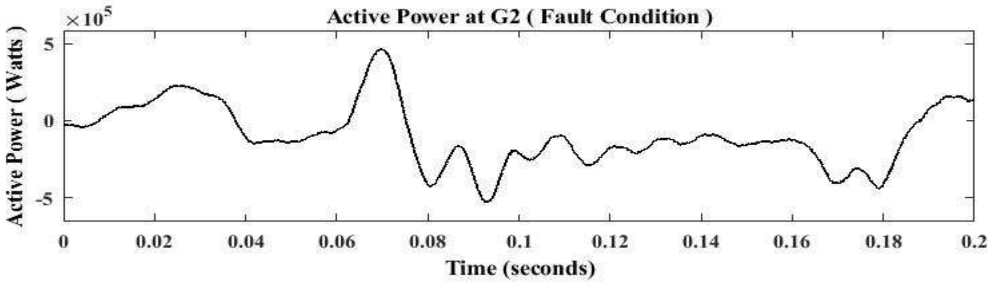


**Figure 17: Active Power P at G2 Under Fault Condition.**

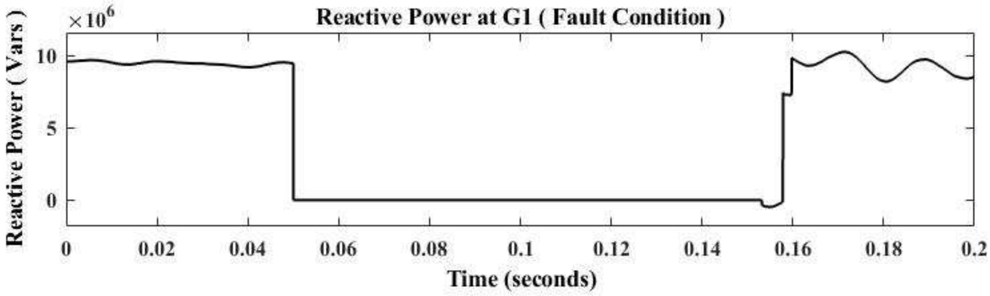


**Figure 18: Reactive Power Q at G1 Under Fault Condition.**

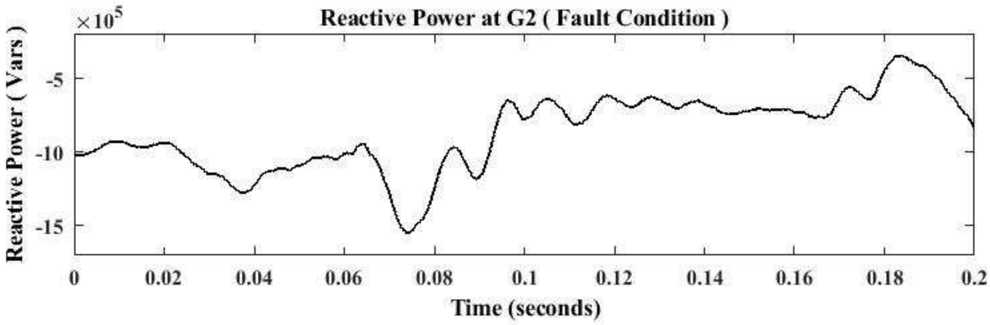


**Figure 19: Reactive Power Q at G2 Under Fault Condition.**

During the fault, the magnitudes of real power and reactive power through points G1 are zero as shown in Figures 16 and 18. After the fault, P and Q at G1 are raised to their maximum points and then fluctuated for the remaining 0.05s of simulation. Figures 17,18 show the magnitudes of real and reactive powers at G2 when the fault occurred at point G1.There is more impact of fault at G1 on real and reactive power through the points. The direction of power flow from AC network-1 to the AC network is negative during the fault. Thus the flow of power from the AC system to the DC system is reversed under fault operating conditions.

## CONCLUSIONS

Existing distribution networks are facing rapid growth of demand and generation. MVDC can be a flexible method for reinforcing the distribution network. It is able to facilitate maximum utilization of the available network and support future integration of renewable generation resources. The dynamic operation of an MVDC link, under normal and faulted network condition, was investigated. The simulation results show that the MVDC can provide flexibility in a distribution network by decoupling real(P) and reactive (Q) power flows through the link along with Voltage and Current in AC network under normal operation. However, further analysis is needed to understand its interaction with existing network devices duringafault.ItisimportanttoincludetheMVDClinkintothenetworkfaultanalysis to achieve its coordinated operation with the existing distribution automation.

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