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OPTIMAL POWER FLOW AND FAULT ANALYSIS USING UPFC

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***Abstract*- A Power System is actually a vast system that requires an outstanding plan for maintaining the continual flow of electricity. When a fault occurs at the power system, number of difficulties arises because of transients in system. so to attenuate these transients, power electronics based devices like FACTS are utilized. A unified power flow controller (UPFC) is one among different power electronics controller which can dispense VAR compensation, line impedance control and phase shifting. The thought is to see potential of UPFC to require care of active and reactive power movement within the compensated line (including UPFC) and to shrink the fall-off of the bus voltage in case of grounding fault within the cable. power system block consisting of simulink is used for numerical analysis. Simulation outcomes from MATLAB reflects major improvement in the overall system's behaviour with UPFC in sustain the voltage and power flow even under severe line faults by proper injection of series voltage into the cable at the point of connection. outcomes shows how the UPFC contributes effectively to a faster regaining of the power system to the pre-fault conditions. [1][2]**

***Keywords*- FACTS, Simulation, UPFC (Unified Power Flow Controller), Faults, MATLAB**

I. INTRODUCTION

In today's era, Power systems consist of hundreds of buses and generators that make them huge, interconnected and complex. Installing new power stations primarily depends on many factors such as environmental factors as well as economic factors. The installation of new lines is very time consuming as well as costly. So, in order to fulfill the ever increasing load demands, we need to provide the transmission facilities from the existing system and design new ways to enhance the efficiency and transmission capabilities of existing systems. This need for expansion of power system capability has been a major problem from last two decades. In addition to it, improving the Power Quality of the system is another significant problem. Power Quality can be defined as to maintain the waveforms of current as well as voltage as sinusoidal at rated magnitude and frequency. This is majorly affected by the increase in use of non-linear loads, variable speed drives, and such other power electronics equipments. It is considered as a threat to safe and reliable operation of Power systems. One of the solutions for these problems is FACTS devices. In this paper, we are going to study and analyze the most efficient FACTS controller, i.e. UPFC (Unified Power Flow Controller). These devices provide very fast active and reactive power compensations to the system. Hence, these are utilized to provide power flow control, voltage support, increase transient stability and improve power oscillation damping. FACTS devices proved to be advanced solutions as well as cost-effective approach for new transmission line construction. [3]

There are various types of FACTS controllers which can help to make the future electric transmission smart. Some of the most common FACTS controller includes Thyristor Controlled Series Capacitor (TCSC), Static Synchronous Compensator (STATCOM), Static Series Synchronous Compensator (SSSC), and Static VAR Compensator (SVC).

They control the network condition in an in no time manner and enhance voltage stability and power quality. Voltage instability occurs in a system when the system cannot meet the reactive power demand. When the system is faulty, heavily loaded, and there are voltage fluctuations, an imbalance in reactive power occurs. The reactive power compensation is often carried out with the help of FACTS devices in the cable, which can feed or absorb reactive power into the system depending on the requirements. [4]
There are many advantages to FACTS devices, such as higher safe loading of existing transmission lines, greater control of power flow, lower environmental impact, damping of power swings, and potentially lower costs than most power booster alternatives. The most versatile of the FACTS devices is UPFC. It performs the functions of all other devices combined such as static synchronous compensator (STATCOM), thyristor switched capacitor (TSC) thyristor controlled reactor (TCR), and the phase angle regulator. UPFC mainly regulates the flow of active and reactive power by feeding a serial voltage into the cable. Both the magnitude and the phase of the voltage are often varied independently of one another. UPFCs are also used to improve the transient and low signal stability of the plant system. [5]

II. MODEL DESCRIPTION

Using of advanced solid state technologies like FACTS controllers help in making system more fast and reliable. They offer wide range of flexibility in system and allow better use of the existing power as well as in the transmission.

UPFC's proposal arrived in 1991 as it was conceived for real-time control and dynamic compensation of AC transmission systems. The UPFC was easily introduced into the existing conventional power transmission system and can control the parameters more or less effectively, which affects the power flow in the transmission line (i.e. voltage, impedance and phase angle). Alternatively, it can control both the active and reactive power flow in the line. [6][7]

The structure of the UPFC basically consists of two voltage powered converters using power switches, which operate from a common DC circuit of a DC storage capacitor. Now this arrangement works as an ideal AC / AC power converter where actual power can flow freely back and forth between the AC terminals of the two converters and each converter can independently or absorb reactive power at its own AC terminal.

III. OPERATION OF UPFC

Inverter two will perform the main operation of the UPFC by injecting an AC voltage Vpq with manageable magnitude Vpq ($0 \leq Vpq \leq Vpqmax$) and phase Ø ($0 \leq$ Ø ≤ 360), at the power frequency, serial with the road via an insertion transformer. The injected voltage is then taken under consideration by considering it as a synchronous voltage supply. This current within the cable flows through this voltage supply and ends up in real and reactive power exchange throughout the AC system. The real power that is changed at the AC terminal (i.e., at the terminal of insertion transformer) is transformed by the electrical converter into dc power that appears at the dc link as positive or negative real power. The reactive power changed at the AC terminal is generated internally by the electrical converter. The fundamental function of electrical converter one is to supply or absorb the power demanded by electrical converter two at the common dc link. This dc link power is regenerated back to AC and paired to the cable via a shunt connected transformer. Electrical converter one will generate or absorb governable reactive power, if that's desired, and thereby it will give independent shunt reactive compensation for the load. It's vital to notice that wherever there's a closed "direct" path for the power negotiated by the action of series voltage injection through Inverters one and two back to the load, the corresponding reactive power changed is equipped or absorbed domestically by inverter two and so it does not flow through the load. Thus, inverter one is usually operated at a unity power factor or be controlled to possess a reactive power exchange with the load independently of the reactive power changed with electrical converter two. This suggests there isn't any continuous reactive power flow through UPFC. [8][9]

IV. FAULTS

Electric Faults occur where there is a slight deviation from the basic nominal values of voltages and currents while the operation take place. These faults take place frequently for unstable systems, whereas under normal operating conditions, the equipment and the line carry safe values of voltages and currents which lead to stable operation of the system.

When a fault occurs, it causes unsafe values of voltages and currents to flow through the equipment and certain devices in the system. Hence, it is important to use relays, switchgears, circuit breakers for the protection in the system.

There are two sorts of faults in electric power system.

1. SYMMETRICAL FAULTS

These occur infrequently are generally very severe. These are of two types:

a.) L-L-L-G FAULT
b.) L-L-L FAULT

In this the system remains balanced and account for just 5 % of the faults but cause severe damage to the system equipment.

2. UNSYMMETRICAL FAULTS

These are commonly occurring faults. These are less severe than symmetrical faults. These are of three types:

a.) L-G FAULT
b.) L-L FAULT
c.) L-L-G FAULT

L-G occurs for 65-70 % of faults when the conductor comes in contact with the ground.

L-L faults occur for 5-10 % of faults when two conductors meet each other.

L-L-G occur for 15-20 % of faults and in this two-conductor come in contact with the ground.

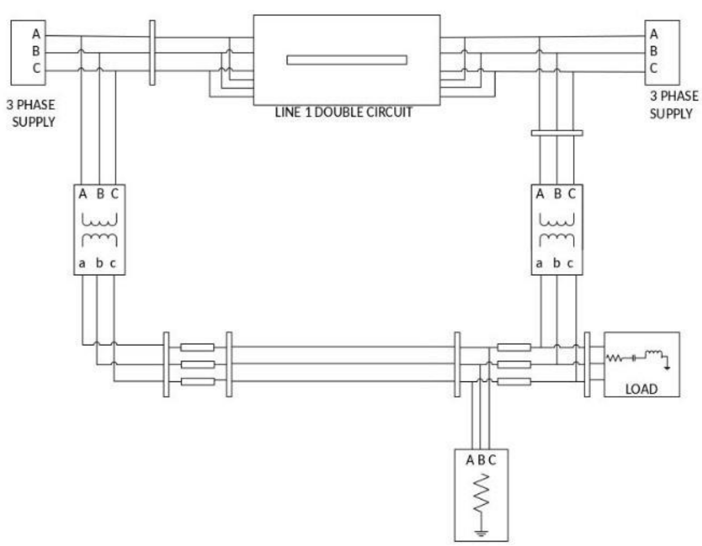
CAUSES OF ELECTRICAL FAULTS

INCONSISTENT WEATHER CONDITIONS- when heavy winds, rains, lighting strikes, salt deposition on conductors occur, it causes faults.

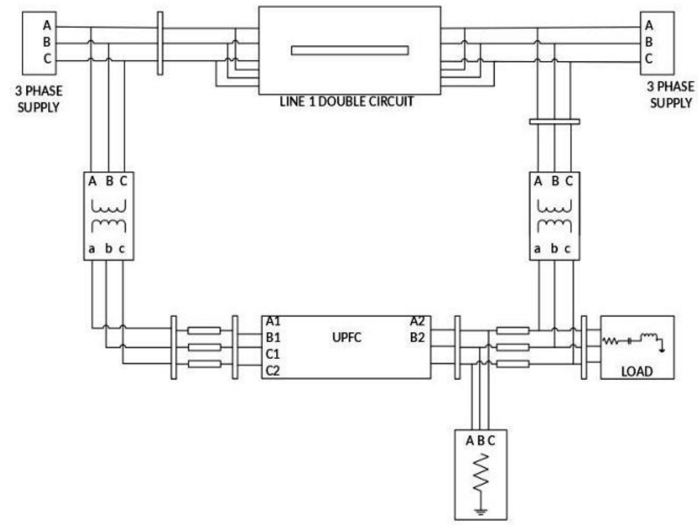
FAILURE IN EQUIPMENTS- when motors, generators, reactors, switching devices fail, they cause short circuit.

ERRORS CAUSED BY HUMANS- human also cause errors while doing maintenance and generally forget to place correct parts in the system. Delay in the maintenance also causes to wear and tear in the devices.

V. SIMULATION MODEL



Simulation Model without UPFC



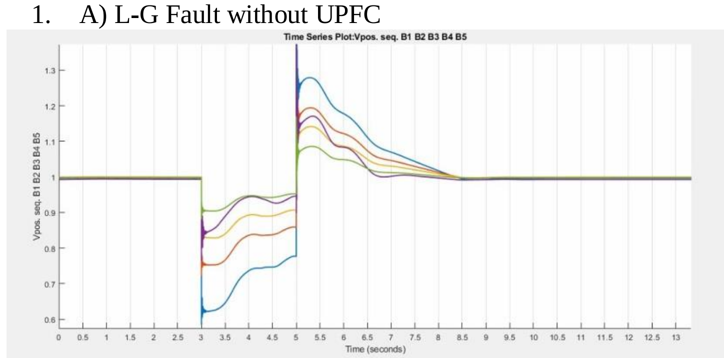
Simulation model with UPFC

VI. SIMULATION RESULTS

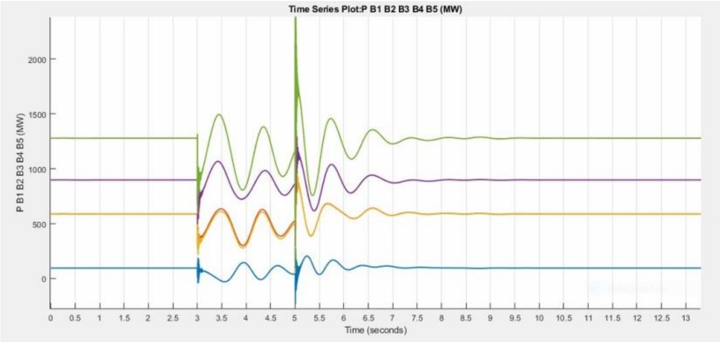
In this paper efforts have been made to detect how an UPFC can limit the effect of faults in the transmission of power in actual substations. The 500 kV/ 230kV transmission line is modeled in Sim Power System toolbox in MATLAB 2013, with UPFC installed, as displayed in Figure. The system comprises of five buses (B1 to B5) interconnected through transmission lines (L1 to L3) and two 500 kV / 230 kV transformer banks Tr1 and Tr2. Two power plants projected on the 230 kV system to generate 1500 MW which is transmitted to a 500-kV 15000-MVA equivalent and one load of 200-MW which is connected at bus B3.

In ordinary conditions, most of the 1200-MW generation capacity of power plant 2 is transmitted to the 500-kV by using 800-MVA transformer connected between buses B4 and B5. The transmission line L1 is a double line circuit of 65km. All other transmission lines L2, L3 are single line circuit of 50 km each. The paper has described thoroughly that the use of UPFC is best suited in this condition. [10][11][12]

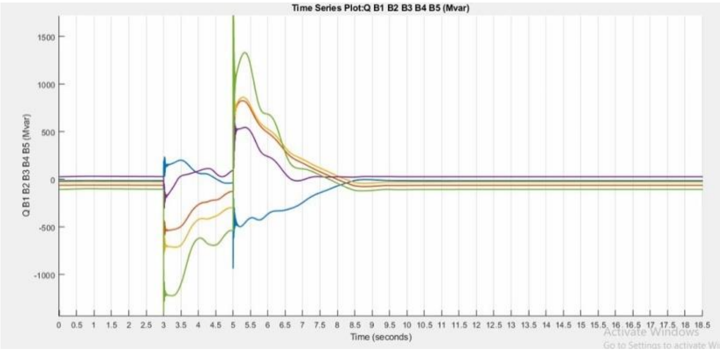
1. A) L-G Fault without UPFC



Voltage | transient t= 9.5-5=4.5sec

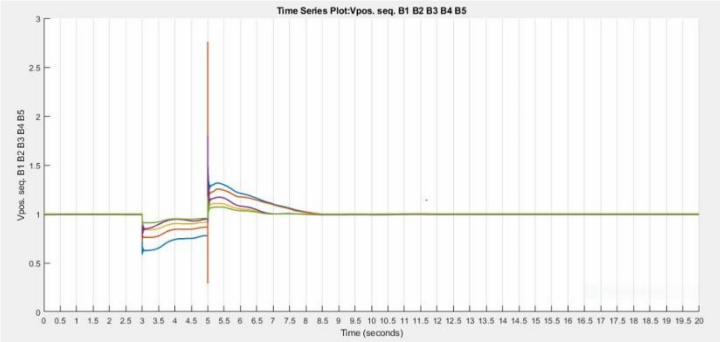


Active power | transient t= 9.5-5= 4.5sec

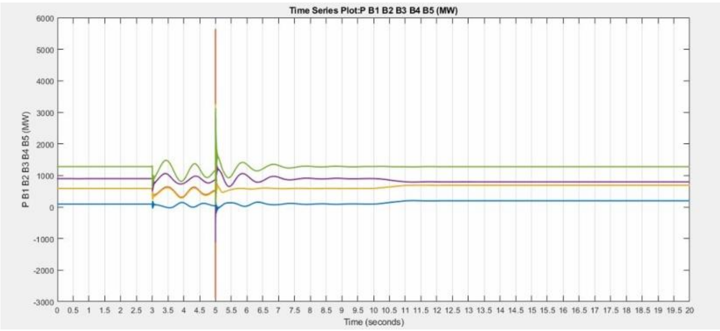


Reactive power | transient t= 9.5-5=4.5sec

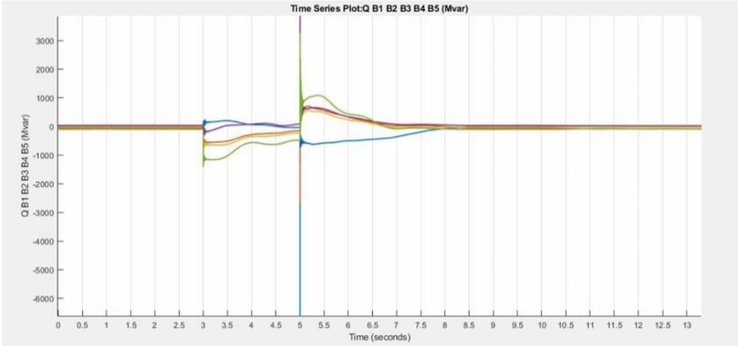
1. B) L-G Fault with UPFC



Voltage | transient t= 8.5-5=3.5sec

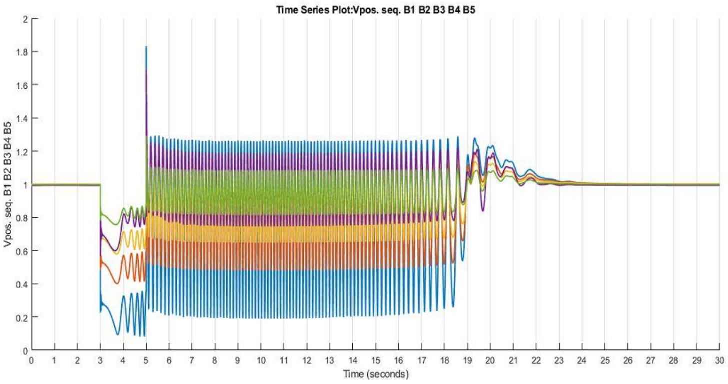


Active power | transient t= 11.5-5=6.5sec

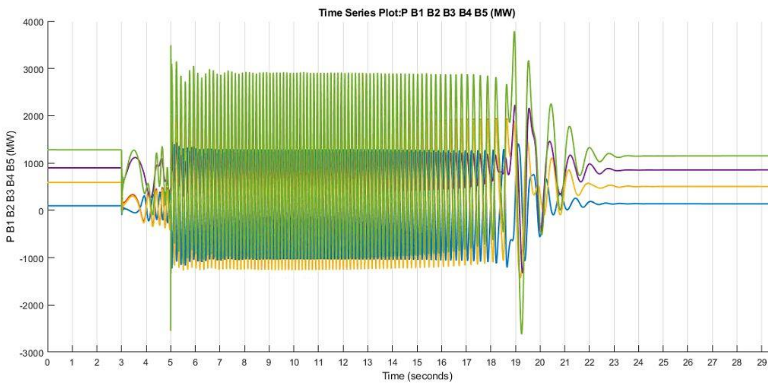


Reactive Power | transient t=8.5-5=3.5sec

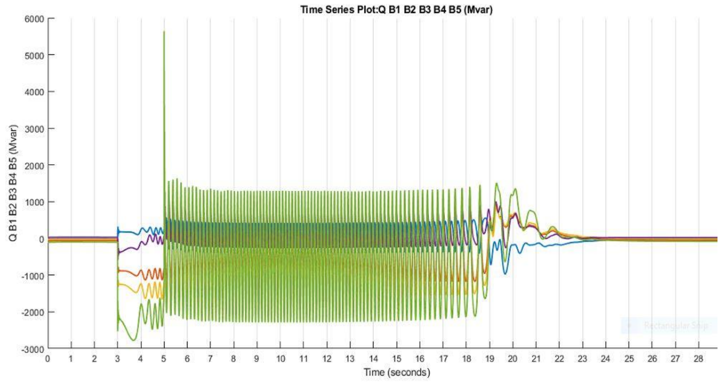
2. A) L-L-G Fault without UPFC



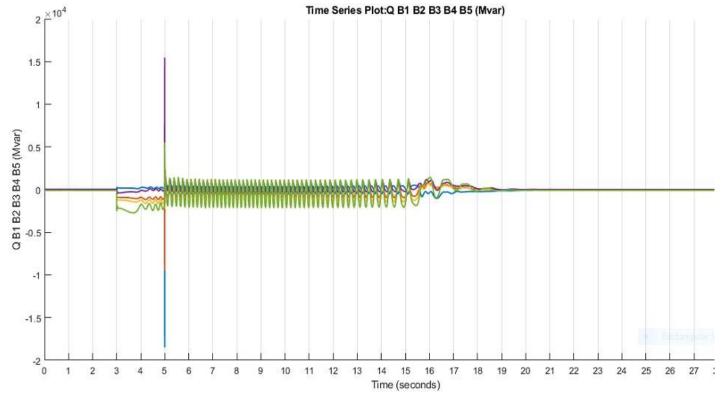
Voltage | transient t= 25-5= 20 sec



Power | transient t = 24-5 = 19 sec

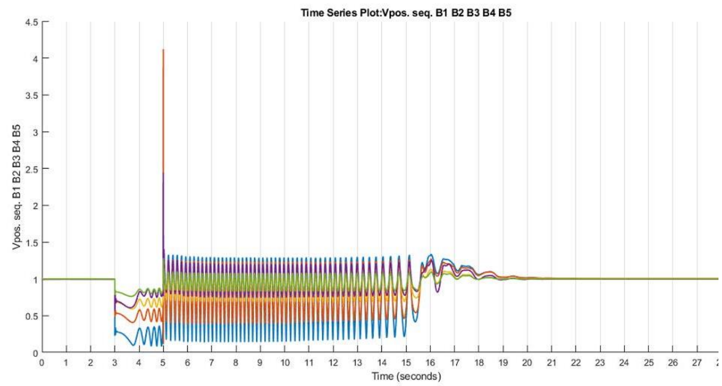


Reactive power | transient t = 24-3 = 21 sec

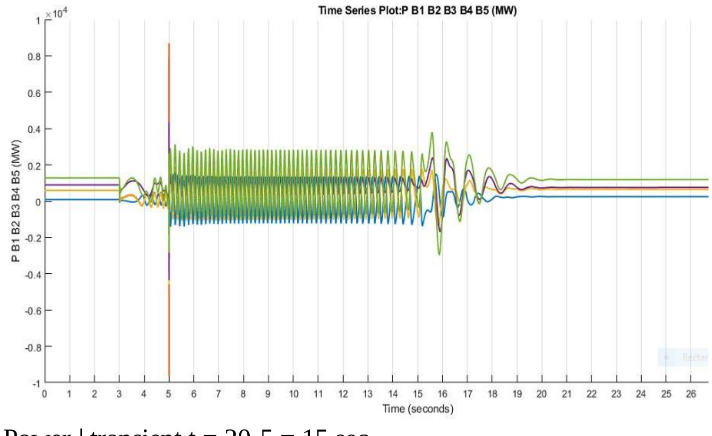


Reactive power | transient t = 20 – 5 = 15 sec

2. B) L-L-G Fault with UPFC

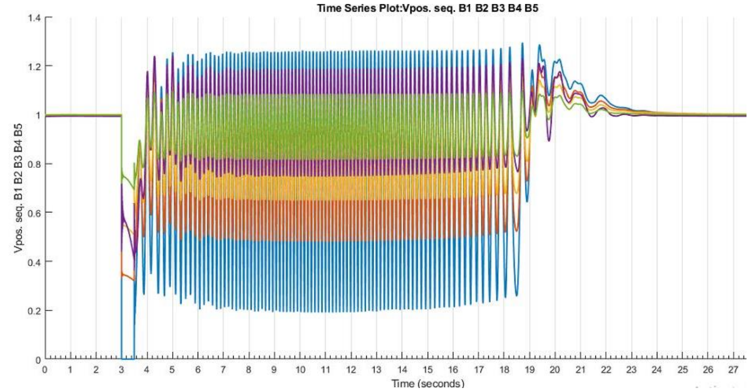


Voltage | transient t= 21-5= 16 sec

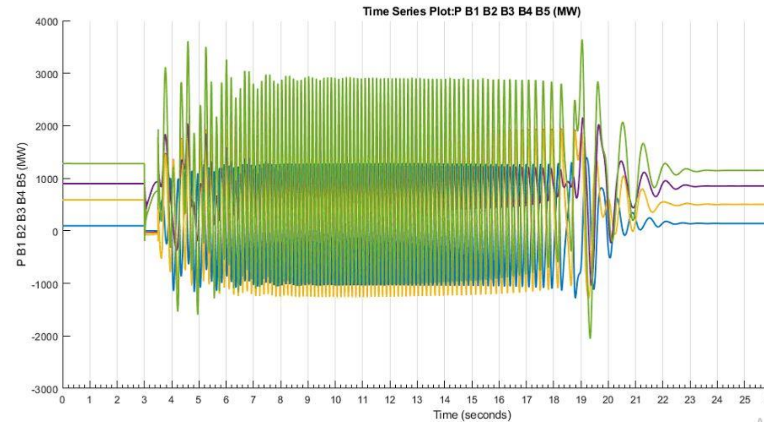


Power | transient t = 20-5 = 15 sec

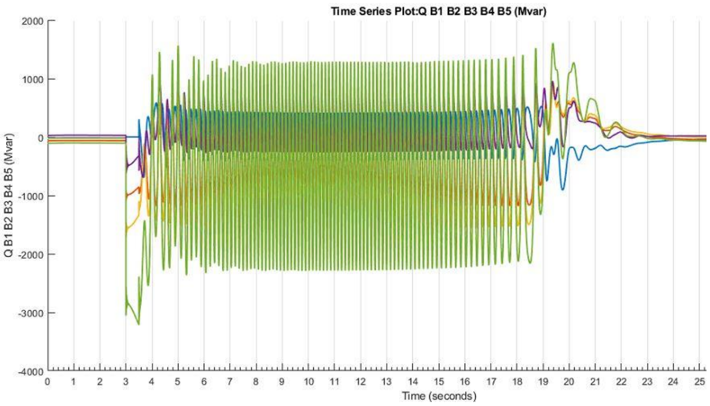
3. A) L-L-L-G Fault without UPFC



Voltage | transient t= 25-3.5= 21.5 sec

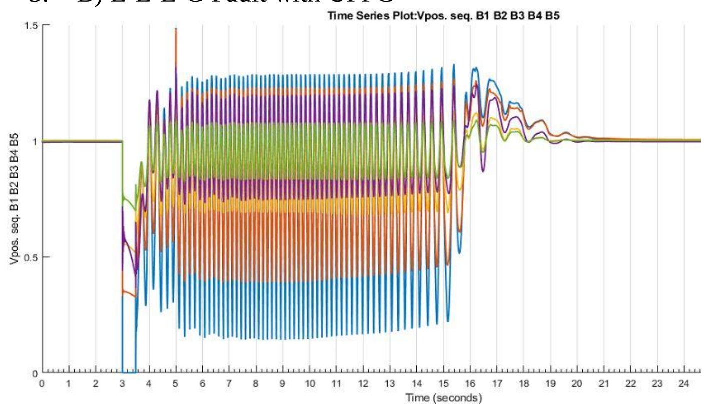


Power | transient t = 24-3 = 21 sec

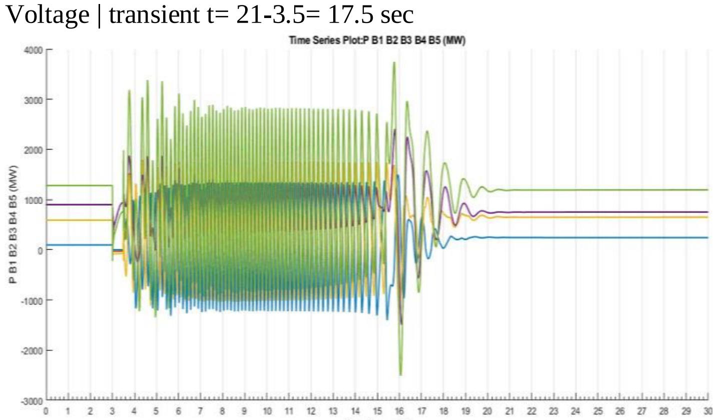


Reactive power | transient t = 25 – 3 = 22 sec

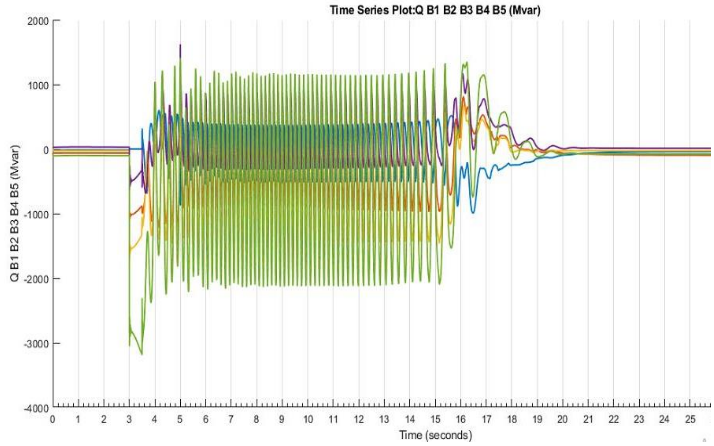
3. B) L-L-L-G Fault with UPFC



Voltage | transient t= 21-3.5= 17.5 sec

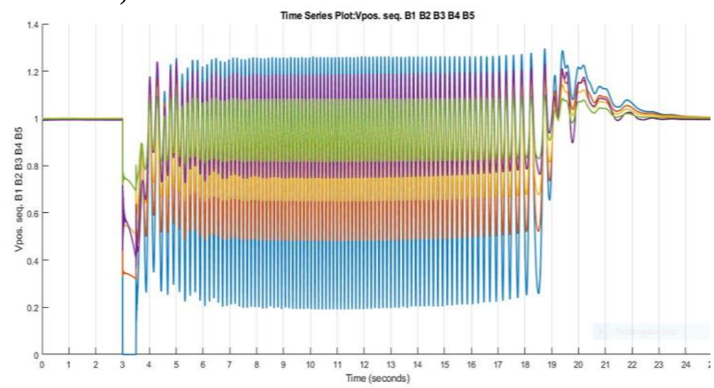


Power | transient t = 21 – 3 = 18 sec

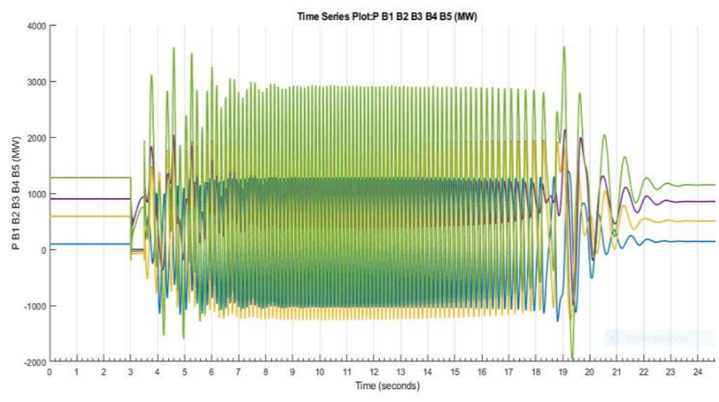


Reactive power | transient t = 21 – 3 = 18 sec

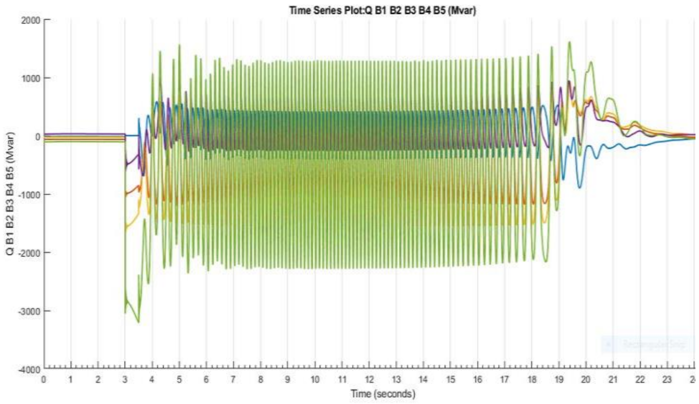
4. A) L-L-L Fault without UPFC



Voltage | transient t= 25-3.5= 21.5 sec

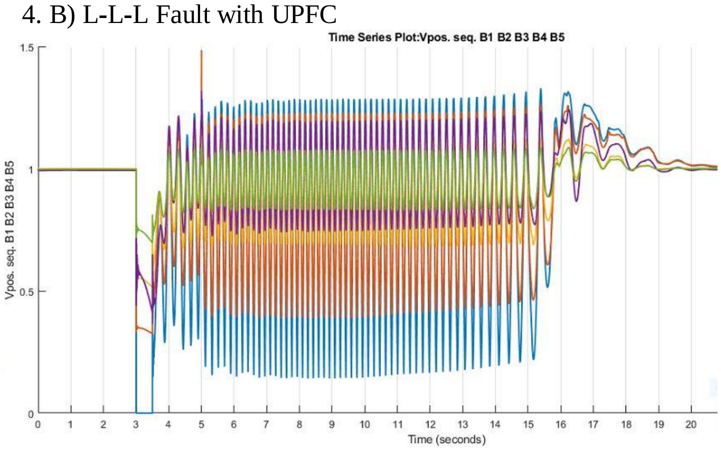


Power | transient t = 24 – 3 = 21 sec

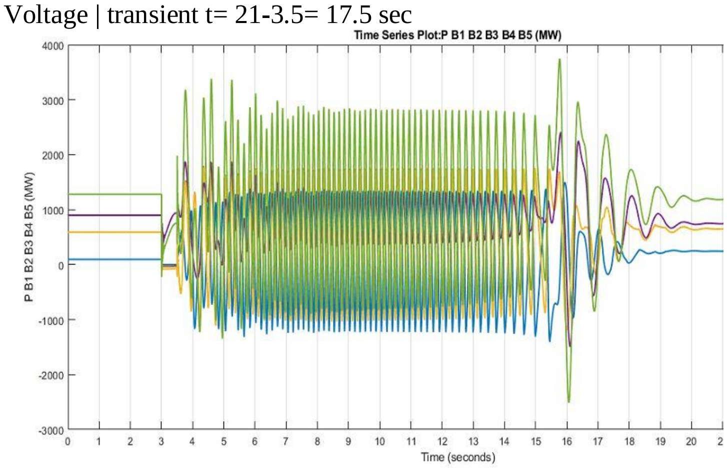


Reactive power | transient t = 24-3 = 21 sec

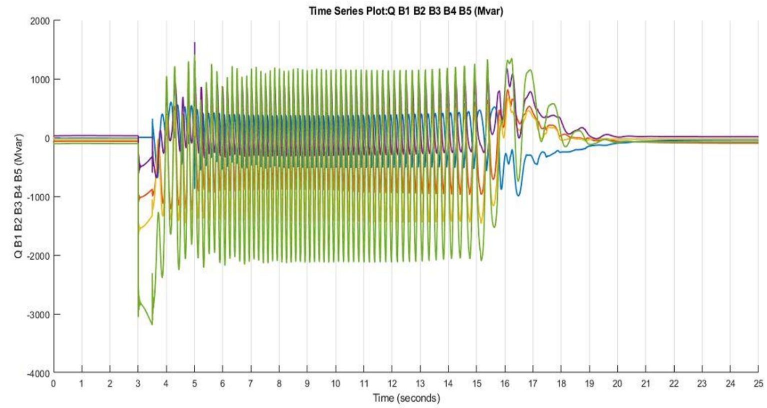
4. B) L-L-L Fault with UPFC



Voltage | transient t= 21-3.5= 17.5 sec



Power | transient t = 20.5 – 3 = 17.5 sec



Reactive power | transient t = 20.5 – 3 = 17.5 sec

VII. CONCLUSION

It has been observed that the transient time in case of voltage, power and reactive power has been reduced significantly by the use of UPFC. It regulated the flow of real and reactive power and stabilized both the magnitude and phase of the voltage along with the transient time. Hence, UPFC is a really good alternative to traditional techniques used and it can be easily incorporated in present systems as it is less expensive than most of traditional alternatives of transmission line reinforcements.

VIII. ACKNOWLEDGEMENT

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