RESEARCH ARTICLE OPEN ACCESS

# Transient Stability Performance Analysis of Power System Using Facts Devices

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**ABSTARCT**
Transient stability is increasingly important for secure loading. Transient stability evaluation of large scale power systems is an extremely intricate and highly non linear problem. An important function of transient evaluation is to appraise the capability of the power system to with stand serious contingency in time, so that some emergencies or preventive control can be carried out to prevent system breakdown, the fault current so produced is diverted to the capacitor by using dual-STATCOM controller, results proved that voltage is maintained nearly constant, surge currents decreased and oscillations in generator have damped and hence system stability and continuity of supply are enhanced. If for UPFC, replacing series controller with shunt controller, it works as dual STATCOM. It has advantages as series pulse controller is not required and same pulses can be given to both STATCOMs. The shunt controller is so designed to act as low impedance path for short circuit current, thereby surge currents can be diverted to VSC.
A general program for transient stability studies to incorporate FACTS devices is developed using MATLAB/SIMULINK.
**KEY WORDS**: FACTS,power system stability, UPFC,STATCOM.

## I. Introduction

The power system may be thought of as a large, interconnected nonlinear system with many lightly damped electromechanical modes of oscillation. If the damping of these modes becomes too small or negative, it can impose severe constraints on the system's operation. It is thus important to be able to determine their nature, find stability limits and in many cases use controls to prevent their instability.

Local oscillations are observed when one particular plant swings against the rest of the system or several generators at frequencies of typically 1 Hz to 2 Hz. With the power industry moving toward deregulation, long-distance power transfers are steadily increasing, outpacing the addition of new transmission facilities and causing the inter-area oscillations to become more lightly damped. During the last decade, FACTS devices have been employed to damp power system oscillations. Sometimes, these controllers are placed in the power system for some other reasons (to improve the voltage stability or to control power flow), then to damp power oscillations. However, when installed, supplementary control can be applied to existing controllers in order to improve damping, as well as satisfy the primary requirements of the device. In this paper a new control strategy for unified power flow controller is proposed. The next section describes the inter area oscillations in the interconnected power systems. Structure of the control system of the series part of the UPFC as described in [12] has been given in section V. In order to focus on the series part for its effectiveness for damping, we consider only controlling series injected voltage for damping control.

It is assumed that the control system has two supplementary inputs. Further damping enhancement can be accomplished by adjusting the proportional gain or adding a supplementary damping signal. The proposed control strategy has been demonstrated a on two area 4-generator interconnected test system. . The simulation results show the effect of active load change on oscillations. Also It has been shown that the UPFC with supplementary controller has a significant impact in damping inter-area system oscillations.

In this paper a new control strategy for unified power flow controller is proposed. The next section describes the inter area oscillations in the interconnected power systems. Structure of the control system of the series part of the UPFC as described in [12] has been given in section V. In order to focus on the series part for its effectiveness for damping, we consider only controlling series injected voltage for damping control. PI-type regulators control the series injected voltage.

## II. FACTS DEVICS:

Flexible AC Transmission System (FACTS) is a new integrated concept based on power electronic switching converters and dynamic controllers to enhance the system utilization and power transfer capacity as well as the stability, security, reliability and power quality of AC system interconnections. Basic types of facts controllers are controlled and operated in a way that it balances the unbalanced voltages, involving transfer of energy between phases.

***1. Objective of the Shunt Controllers***

Shunt controllers are similar to the series controllers with the difference being that they inject current into the system at the point where they are connected. Variable shunt impedance connected to a line causes a variable current flow by injecting a current into the system. If the injected current is in phase quadrature with the line voltage, the controller adjusts reactive power while if the current is not in phase quadrature, the controller adjusts real power. Examples of such systems are Static Synchronous Generator (SSG), Static Var Compensator (SVC). They can be used as a good way to control the voltage in and around the point of connection by injecting active or reactive current into the system.

**2. *Objective of the Combined Series-Series Controllers***

A combined series-series controller may have two configurations. One configuration consists of series controllers operating in a coordinated manner in a multiline transmission system. The other configuration provides independent reactive power control for each line of a multiline transmission system and, at the same time, facilitates real power transfer through the power link. An example of this type of controller is the Interline Power Flow Controller (IPFC), which helps in balancing both the real and reactive power flows on the lines.

***3. Objective of Combined Series-Shunt Controllers***

A combined series-shunt controller may have two configurations, one being two separate series and shunt controllers that operate in a coordinated manner and the other one being interconnected series and shunt components. In each configuration, the shunt component injects a current into the system while the series component injects a series voltage. When these two elements are unified, a real power can be exchanged between them via the power link. Examples of such controllers are UPFC and Thyristor-Controlled Phase-Shifting Transformer (TCPST). These make use of the advantages of both series and shunt controllers and, hence, facilitate effective and independent power/current flow and line voltage control.

## III. INFLUENCE OF INERTIA COEFFICIENT ON INTERAREA OSCILLATIONS

**A. Inter-area Oscillations** A problem of interest in the power system is the mitigation of inter-area oscillations that often arise between areas in a large interconnecting power network [13],[14]. These oscillations are due to the dynamics of inter-area power transfer and often exhibit poor damping when the aggregate power transfer over a corridor is high relative to the transmission strength [15],[16]. The oscillation of one or more generators associated with groups of generators in different areas oscillating against each other is called inter-area modes. The frequencies of the oscillations depend on the strength of the system and on the moment of inertia of the generator rotors. These frequencies are in the range of 0.1-1.0Hz, in most practical system. The inter-area oscillation limits the amount of power transfer on the tie-lines between the regions containing the groups of coherent generators.

**B. Generator Equations** The dynamic behaviour of generators within a power system is of fundamental importance to the overall quality of the power supply. the mechanical equations of a rotating machine are very well established and they are based on the swing equations of the rotating inertia. Generator dynamics is described by [17]. where M is the inertia coefficient; D is the damping coefficient; *Pm* is the mechanical power; *Pg* is the electrical real power; δ is the rotor angle and Δω = *d*δ *dt* is the rotor speed deviation. The swing equation relates the machine's rotor torque angle to the accelerating torque, which is the difference between the shaft torque and electromechanical torque. When there is an equilibrium between the mechanical shaft and braking electrical torques, the shaft speed will be constant. Any imbalances between the torques will cause the acceleration or deceleration of the machine according to the lows of motion of a rotating body [17].

$$M\frac{d\Delta\omega}{dt} = P_m - P_g(\delta) - D\frac{d\delta}{dt} \quad (1)$$

where M is the inertia coefficient; D is the damping coefficient; *Pm* is the mechanical power; *Pg* is the electrical real power; δ is the rotor angle and Δω = *d*δ *dt* is the rotor speed deviation. The swing equation relates the machine's rotor torque angle to the accelerating torque, which is the difference between the shaft torque and electromechanical torque. When there is an equilibrium between the mechanical shaft and braking electrical torques, the shaft speed will be constant. Any imbalances between the torques will cause the acceleration or deceleration of the machine according to the laws of motion of a rotating body.

$$T_{acc} = J\frac{d^2\delta_m}{dt^2} = T_{mech} - T_{elec} \qquad (2)$$

where
*Tacc* : Accelerating torque.
*J* : Combine moment of inertia of the generator and turbine.
δ*m* : Mechanical torque angle of the rotor.
*t* : time.
*Tmech* : Mechanical torque.
*Telec* : Electrical torque.
An increasing in the machine inertia constant decreases both the natural frequency and the damping ratio. Therefore the synchronous generators with small coefficient of inertia are preferred for large interconnected power systems.

## IV. Modeling of STATCOM controller:

The controller for STATCOM is shown in fig1. The voltage and current are referred from area2 generator represented with Vabc and Iabc. With these parameters, real and reactive powers are calculated. These power system is controlled independently by using transfer functions to derive direct and quadrature axis voltages. These direct axis voltage can control real power and quadrature axis will control the reactive power flow from STATCOM. The two phase voltages are converted into three phase (dq -abc) voltages and this reference voltage is fed to PWM converter to generate pulses to STATCOM. This controls the direction of current flow from STATCOM to system or vice-versa based on difference in voltage magnitude at reference point at STATCOM DC voltage. If at reference point, voltage is higher, current will flow to STATCOM and when at reference point are low, current flows from STATCOM. The voltage at reference point can be high due to Ferranti effect or sudden load throw off, lightning and voltage may decrease due to heavy loading or due to faults. The aim of STATCOM is maintain constant voltage magnitude at reference point, minimise inter-area oscillations and to enhance stability and reliability. The results are compared without STATCOM and with STATCOM for the circuit shown figure2 and figure 3. A three phase to ground fault occurs at 0.1 seconds and clears naturally at 0.2 seconds with fault resistance of 1mJ respectively between phases and ground. Three winding transformers are used; primary winding is connected to area1, secondary winding is connected to area2 and tertiary winding is connected to STATCOM1.

Similarly it is done to STATCOM2. The transformer voltages on area1 and area2 are 230kV and on STATCOM side is 20kV. A capacitor of1mF is connected common to both sides of IGBT based voltage source inverter.200Amps, when fault occurred; voltage became nearly zero in area1, where as in area2, it is 0.5kV and current was500Amps. When STATCOM is placed as it injects voltage and current as shown in . It can clearly be seen that fault current has mitigated and voltage on both sides are compensated by VSC. The voltage sag is less than 10% and current is almost uniform. There will be sub-transient and transient current waveforms with STATCOM controller.The Generator stator voltage (quadrature and direct axis) are in per unit (pu) and pu rotor speed is without STATCOM and for area 1 and in area 2 with STATCOM. The stator quadrature voltage for generator1 in area1 has decreased to 0.75p.u from 1p.u. during this transient time. With STATCOM, the quadrature and direct axis voltages are at equilibrium during and after fault.The stator output current in per unit quantities are with out and with STATCOM for area1 andarea2 generators. During equilibrium, stator output current is 0.5A; during transient is 3.6pu amps on area1 and 2.4pu on area2 without STATCOM. With placement of STATCOM, stator current is almost constant. The sub-transient and transient current can be reduced by taking a capacitor on VSC less than 3000uF. But it is not fully capable of mitigating oscillations caused due to such huge transients. In this analysis, the capacitor is 10000uF with 10kV rating. DC voltage across the capacitor bank at Voltage Source Converter (VSC-STATCOM). The voltage is nearly 8000V dc during normal conditions. When fault occurred at 0.1s, it has decreased to 7000V. This stored capacitor voltage is used to compensate the voltage on the source sides of area 1 and 2. Hence voltage is compensated .as
The damping's are very high without STATCOM, but is very less with it. The ripples formed are due to the fact that STATCOM capacitor is taking time to reach steady state.

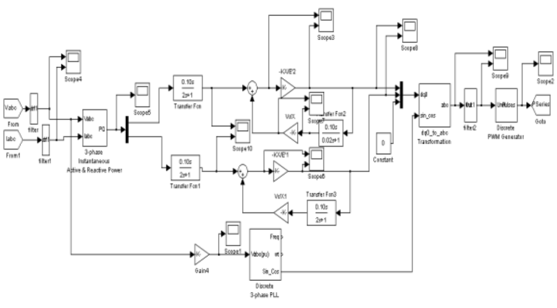

Fig1 matlab/simulink implementation of STATCOM controller.

## V. MATLAB MODELEING AND SIMULATION RESULTS

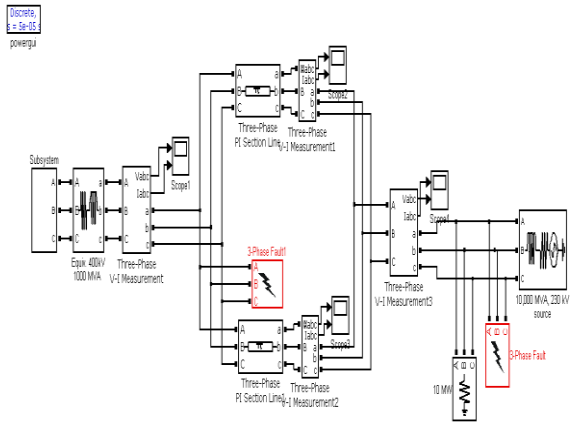

Fig.2 Matlab/Simulink power system analysis without compensation

The fig2 shows the power system with pi network transmission lines connected to three phase transformers at section A and section B which are inter connected to two sources and a three phase fault is produced in the interconnected system and here the simulation is carried out without any compensation to the power system under fault conditions,this is done to analyse the performance characteristics of power system under fault conditions.

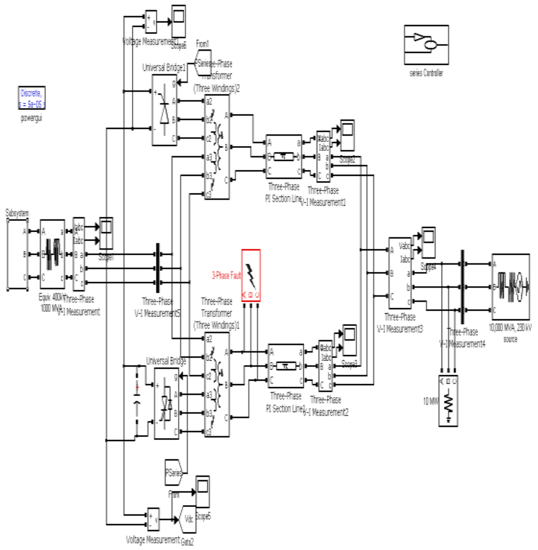

Fig3 Matlab/Simulink of Proposed power system analysis with compensation

Fig.2 and Fig3 shows the Matlab/Simulink Models of power system analysis with out compensation circuit and with compensation circuit, along with control circuit. The power circuit as well as control system are modeled using Power System Block set and Simulink. A synchronous machine of 13.8kv 200MVA is connected to a transmission line. The source of 10000MVA 230KV source block is connected to the same transmission line which is in pi connected, which are connected to a three phase tranformers. PWM voltage source inverter circuits and a DC capacitor connected at its DC bus. An IGBT-based PWM inverter is implemented using Universal bridge block from Power Electronics subset of PSB. Snubber circuits are connected in parallel with each IGBT for protection.
Here simulation is carried out for the power system without compensation and system with compensation technique.

Rotor speed in pu

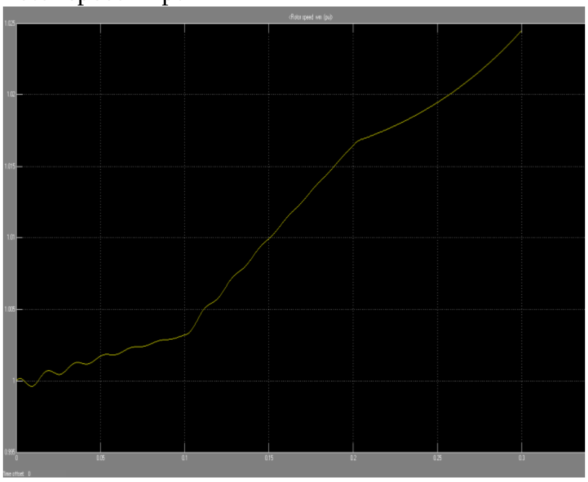

Fig4 simulation result of rotor speed in pu

Here the fig4 shows the rotor speed $w_m$ in pu

Stator current in pu

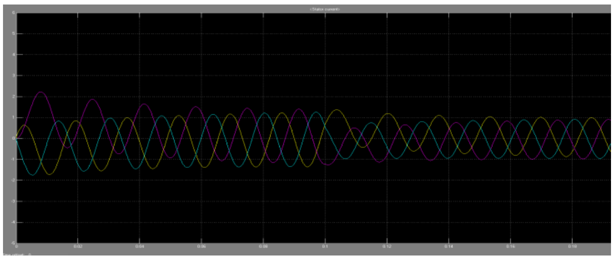

Fig5 simulation result of stator current in pu

The fig5 shows the stator current of synchronous machine

Va in pu

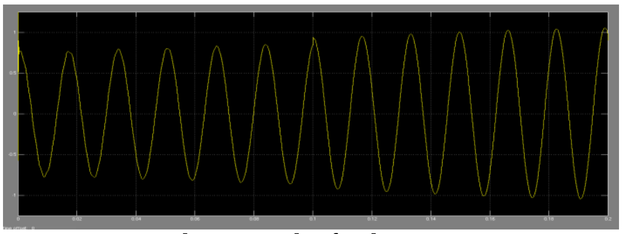

Fig6 simulation result of voltage va in pu

Scope1

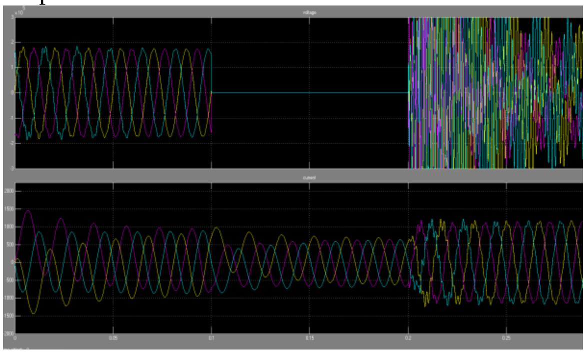

Fig7 simulation result of voltage and current of generator

The fig7 shows the voltage and current measurement of generator (13.8kv,200MVA) without compensation

Scope2 section A

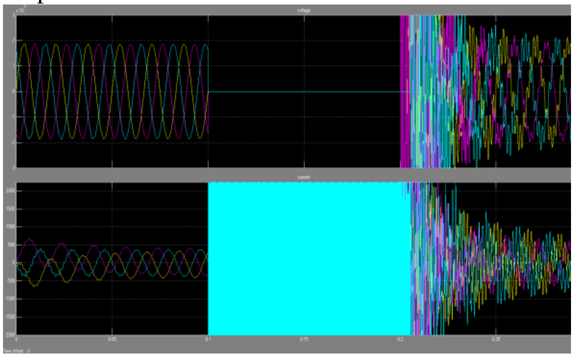

Fig8 simulation result of section A pi network transmission line

The fig8 shows the voltage and current measurement of section A transmission line without compensation under 3 phase fault condition

Scope3 section B

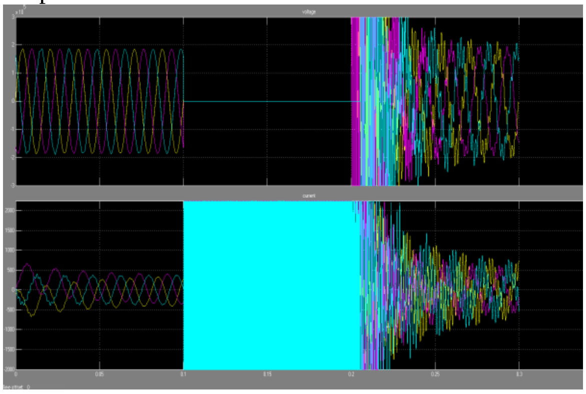

Fig9 simulation result of section pi network transmission line

The fig9 shows the voltage and current measurent of section transmission line without compensation under 3 phase fault condition.

Scope4

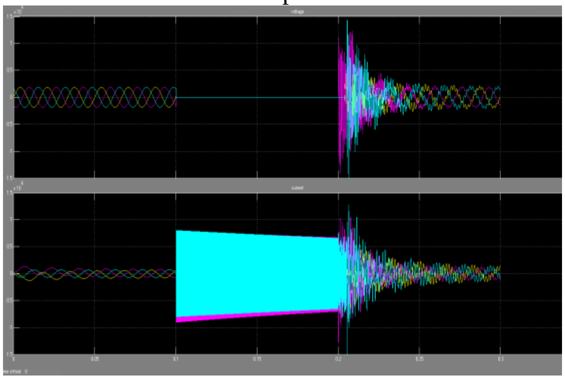

Fig10 simulation result of source voltage and current of source 10000MVA 230KV

The fig 10 shows the voltage and current measurement of source of 10000MVA 230 KV without compensation under 3 phase fault condition.

Rotor speed

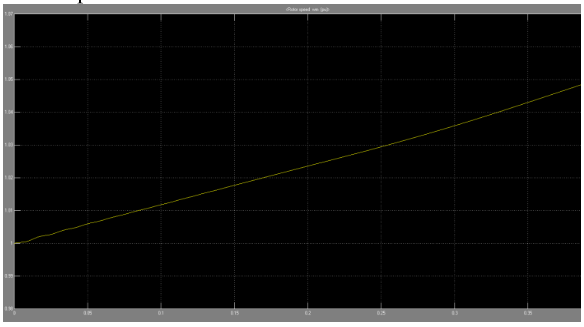

Fig11 simulation result of rotor speed in pu after compensation

Stator current

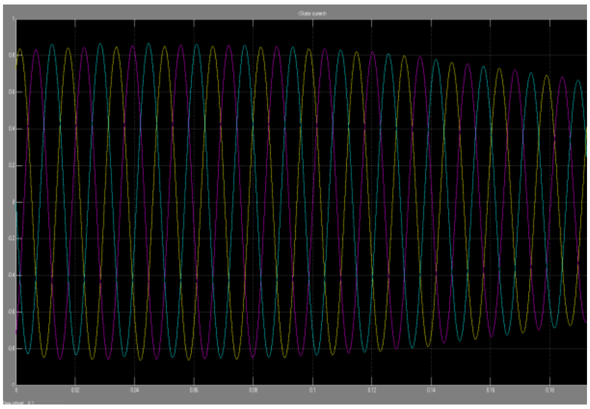

Fig12 simulation result of stator current in pu after compensation

The fig 12 shows the simulation result of stator current here the current waveform got balanced and improved whwn compared to the result without compensation ltage va pu

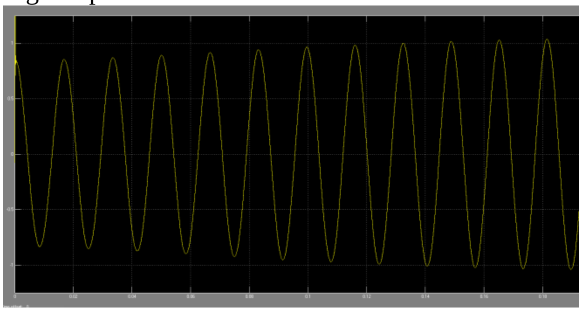

Fig 13 simulation result of voltage pu

Vf pu

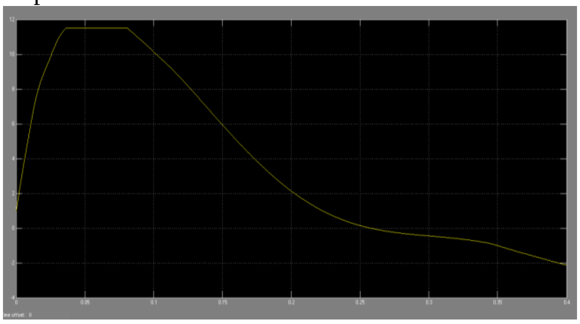

Fig 14 simulation result of voltage in pu

Scope1

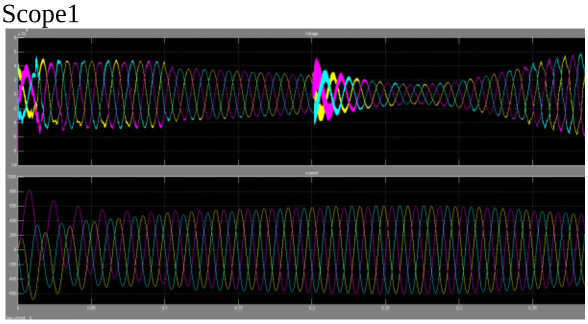

Fig15 simulation result of voltage and current of generator with compensation

The fig15 shows the voltage and current measurement of generator(13.8kv,200MVA) with compensation the voltage and current waveforms has improved without any dampings under 3 phase fault condition.

Scope2 sectionA

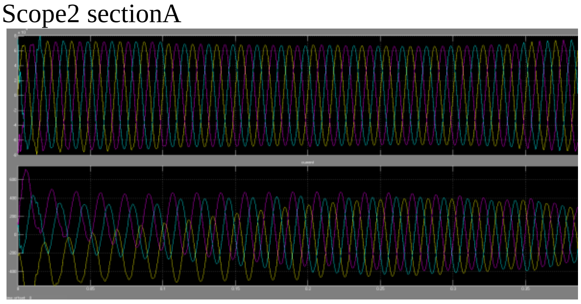

Fig16 simulation result of section A pi network transmission line

The fig16 shows the voltage and current measurement of section A transmission line with compensation under 3 phase fault condition the voltage and current has improved after compensation

Scope3 section B

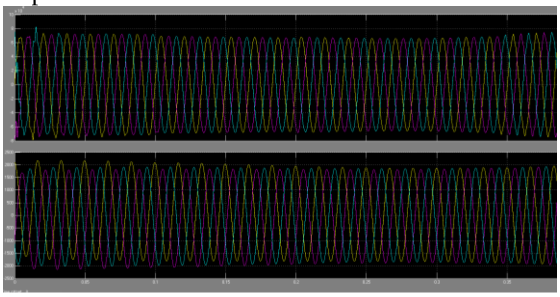

Fig17 simulation result section pi network transmission line

The fig17 shows the voltage and current measurement of section B transmission line with compensation under 3 phase fault condition the voltage and current has improved after compensation

Scope4

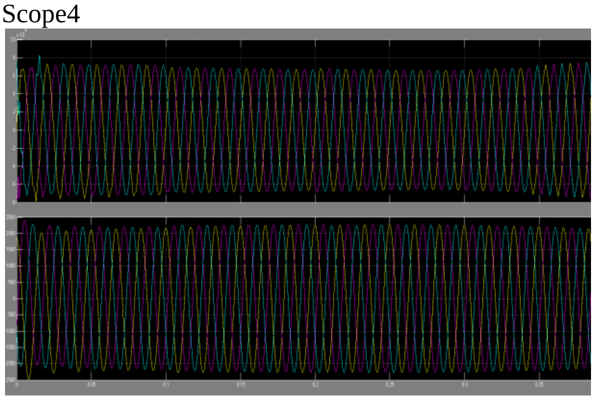

Fig18 simulation result of source voltage and current of source 10000MVA 230KV

Fig18 shows the voltage and current measurement of source of 10000MVA 230 KV with compensation under 3 phase fault condition the voltage and current waveforms are improved and balanced by compensating.

## VI. CONCLUSION AND FUTURE SCOPE

This paper has demonstrated how important it is for a large electrical system to have a well designed FACTS device so that the system can operate. If a severe three phase to ground fault occur in the midpoint of the system, voltage in area1 and area2 has dropped to zero and the current has drastically increased, results in large oscillations in generator real power without any controller. It can be observed with STATCOM, these oscillations in real power during such transients were mitigated. The system regains its normal state after transients die out is due to the action of PSS and AVR. If STATCOM is not available, PSS fail to operate, this leads to instability and may also cause the generator to damage if proper action is not taken. In power stations, the relays will identify such situations and will trip the system from supplying power.This leads to load shedding and severe inconvenience to the customers. It can be observed that surge currents can be bypassed to STATCOM which helps in maintaining nearly constant voltage and current. Working of STATCOM depends on the impedance of the line, capacitor ratings, voltage that has to compensate ,MVA rating of STATCOM transformer and reactive power of the system. Generator stator current has controlled with STATCOM and surge currents are mitigated. Different facts devices like SSSC, TCSR Can also be used for the power system stability, FUZZY LOGIC techniques can be used for controlling these FACTS devices for fast operation.

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