Use of Static Synchronous Series Compensator (SSSC) In Hybrid System

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Abstract- The focus of this research work is on a FACTS device known as Unified Power Flow Controller (UPFC), which can provide simultaneous control of basic power system parameters like voltage, active power flow, reactive power flow, impedance and phase angle. In this research work, simulation models for different multi machine systems are carried out, e.g. a hybrid power system, a power system with two synchronized hydro power stations etc., without UPFC & with UPFC located at the load end of the power system, has been developed. Simulation models have been incorporated into MATLAB based Power System Toolbox (PST) for their voltage stability analysis. These models were analyzed for voltage, active power flow, and reactive power flow and phase angle, with and without UPFC. The results of the power system with UPFC and without UPFC are compared and the conclusion is given at the end., a power transfer capability of long transmission line is limited by stability consideration.Oscillation of generator angle or line angle are generally associated with the transmission system disturbances and can occur due to step changes in load, sudden change of generator output, transmission line switching and short circuit. Different modes of rotor oscillation are local mode, intra-area mode and inter-area mode. The frequency of oscillations of rotor swings varies from 0.2 to 4 Hz. The lower end of frequency spectrum corresponds to inter-area modes, in which a large number of generators participated and their damping is difficult. This low frequency is important to damp as quickly as possible because they cause mechanical wear in power plants and cause power quality problem. If the electromechanical oscillations are not properly controlled in the electric power system operation, it may lead to a partial or total system outage. Instability problems in power systems that can lead to partial or full blackout can be broadly classified into three main categories, namely voltage, phase angle and frequency related problems. In early age this signal instability problem was solved by amortiseurs(shock absorber) winding implemented in generator rotors, later with the application of fast excitation system this was solved by development & utilization of Power System Stabilizer (PSS) and however in modern power system due to the connection of power grids in vast area, for inter area oscillation damping due to the ability of controlling line impedance, power flow and bus voltage, Flexible AC transmission Systems (FACTS) devices implementation offers an alternative solution. The focus of this research work is on a FACTS device known as Unified Power Flow Controller (UPFC), which can provide simultaneous control of basic power system parameters like voltage, active power flow, reactive power flow, impedance and phase angle. In this research work, simulation models for different multi machine systems are carried out, e.g. a hybrid power system, a power system with two synchronized hydro power stations etc., without UPFC &with UPFC located at the load end of the power system, has been developed. Simulation models have been incorporated into MATLAB based Power System Toolbox (PST) for their voltage stability analysis. These models were analyzed for voltage, active power flow, and reactive power flow and phase angle, with and without UPFC. The results of the power system with UPFC and without UPFC are compared and the conclusion is given at the end.

Index Terms- FACTS, STATCOM, Controller Design, PWM.

I. Introduction

In today's high complex and interconnected power systems, there is a great need to improve power utilization while still maintaining reliability and security. Reducing the effective reactance of lines by series compensation is a direct approach to increase transmission capability. However, a power transfer capability of long transmission line is limited by stability consideration [13].Oscillation of generator angle or line angle are generally associated with the transmission system disturbances and can occur due to step changes in load, sudden change of generator output, transmission line switching and short circuit [18]. Different modes of rotor oscillation are local mode, intra-area mode and inter-area mode. The frequency of oscillations of rotor swings varies from 0.2 to 4 Hz [2]. The lower end of frequency spectrum corresponds to inter-area modes, in which a large number of generators participated and their damping is difficult. This low frequency is important to damp as quickly as possible because they cause mechanical wear in power plants and cause power quality problem. If the electromechanical oscillations are not properly controlled in the electric power system operation, it may lead to a partial or total system outage [18]. Instability problems in power systems that can lead to partial or full blackout can be broadly classified into three main categories, namely voltage, phase angle and frequency related problems [3]. In early age this signal instability problem was solved by amortisseurs implemented in generator rotors, later with the application of fast excitation system this was solved by development & utilization of Power System Stabilizer (PSS) and however in modern power system due to the connection of power grids in vast area, for inter area oscillation damping due to the ability of controlling line impedance, power flow and bus voltage, Flexible AC transmission Systems (FACTS) devices implementation offers an alternative solution [19].

The focus of this research work is on a FACTS device known as Unified Power Flow Controller (UPFC), which can provide simultaneous control of basic power system parameters like voltage, active power flow, reactive power flow, impedance and phase angle. In this research work, simulation models for different multi machine systems are carried out, e.g. a hybrid power system, a power system with two synchronized hydro power stations etc., without UPFC &with UPFC located at the load end of the power system, has been developed. Simulation models have been incorporated into MATLAB based Power System Toolbox (PST) for their voltage stability analysis. These models were analyzed for voltage, active power flow, and reactive power flow and phase angle, with and without UPFC. The results of the power system with UPFC and without UPFC are compared and the conclusion is given at the end.

II. Literature review

A number of Flexible Alternating Current Transmission System (FACTS) controllers are available today due to the rapid development in the field of power electronics. Generally, each of these controllers can act only on one of the three parameters (voltage, impedance and angle), that determine the power flow through a transmission line. But Unified Power Flow Controller (UPFC) is such a versatile FACTS device that has the capability of controlling all the three parameters simultaneously.Withthe rapid development of power electronics, it is possible to design power electronic equipment of high rating for high voltage systems, the voltage stability problem resulting from transmission system may be, at least partly, improved by use of the equipment well-known as FACTS-controllers.

In the transmission area, application of power electronics consists of HVDC power transmission and FACTS. HVDC is an economical way to interconnect power systems, which are situated in different regions and separated by long distances or those which have different frequencies. HVDC involves conversion of ac to dc at one end and conversion of dc to ac at the other end. Also, there is a widespread use of microelectronics, computers and high speed communication for control & protection of present transmission system. [2], [4]

FACTS being a new technology will play the principal role to enhance controllability and power transfer capability in an ac system. FACTS technology is not a single high power controller, but rather a collection of controllers, which can be applied individually or in coordination with others to control one or more of the interrelated system parameters. This technology has opened up new opportunities for controlling power and enhancing the usable capacity of present, as well as new and upgraded lines. Current through a line can be controlled at a reasonable cost enabling a large potential of increasing the capacity of the existing line and the use of FACTS controllers to enable the corresponding power to flow through such lines under normal and contingency conditions.

There are basically two type of analysis i.e. component oriented and system orientated. In the component orientated analysis, individual physical elements of a FACTS-controller are concerned. On the other side, the system orientated analysis needs answers on achievements that could be possibly gained by using a FACTS-controller. This research work is solely concerned with system wise aspects of the FACTS technology. In general form, system wise aspects are related to the enhancements of transmission network capability.

III. BASIC TYPES OF FACTS CONTROLLER

FACTS controller can be classified into four categories:

a) Series Controller (e.g. Static Synchronous Series Controller (SSSC))
b) Shunt Controller (e.g. STATCOM, D-STATCOM)
c) Combined Series – Series Controller
d) Combined Series – Shunt Controller (e.g. Unified Power Flow Converter (UPFC))

FACTS devices are used as power flow controller and the voltage source converter in a line ultimately resulting into oscillation damping. Series controllers are used to control power flow and oscillations damping in a line. Shunt devices are effective to control voltage. UPFC is a series-shunt controller that can control active & reactive power, voltage through a line. UPFC can also be used to analyze transient stability of a single machine system. [1], [2], [3], [4], [5]

The maintenance and reliability of the power system has become a major aspect of study. Present power systems have become complex and heavily loaded, due to which voltage instability has become a serious problem, leading to Voltage Instability a cause of system collapse from which the system cannot recover.The encouragement to the construction of HV lines, the amount of power transmission/km on HV line and the amount of power transaction as seen from economic side is much responsible for concern towards congestion in power system. Main reason for the cause of voltage instability is the sag in reactive power at various locations in an interconnected power system. Real and Reactive power compensation in transmission systems improve the voltage stability of the AC system and can avoid voltage collapse. The unified power flow controller (UPFC) is a pair of back to back power electronic inverters which control the real and reactive power flow in a transmission line. Maximum power transfer capability is achieved when the UPFC is operated at its rated capacity and conventional voltage and line-flow set point regulation is no longer possible.The voltage stability L- index and 3 line stability is used for operating the UPFC at rated capacity so as to optimize the power transfer. [6], [8], [13], [20], [23], [24]

A Unified Power Flow Controller (UPFC) is a typical FACTS device capable of instantaneous control of three system parameters. Unified Power Flow Controller (UPFC) is able to control both the transmitted real power and the reactive power flows at the sending- and the receiving-end, at the midpoint of the transmission line. A control structure with a predictive control loop and pre control signal for a dc-voltage control is used for better stability and transient performance of UPFC, in comparison with the classical decoupled strategy. [5], [6], [14], [15], [18]

Generation of electricity using wind power has received considerable attention worldwide in recent years. In the beginning, the wind energy was used for standalone purposes. But as the power demand is growing day by day, there is a need for connecting this wind power to te grid. A lot of methods are adopted for connecting this power to the grid. Here is also one strategy which can be used for connecting this wind energy to the grid. And after connecting to the grid, the analysis is done. [9], [10], [11]

The Unified Power Flow Controller (UPFC), with its unique combination of fast shunt and series compensation, is a powerful device which can control three power system parameters. In planning and designing such devices in power systems, power engineers must consider the impact of device internal limits on its performance. [20], [21]

IV. SIMULATION MODELS FOR PERFORMANCE ANALYSIS OF UPFC

4.1 CASE- HYBRID POWER SYSTEMS

4.1.1Without UPFC under 3-Phase to Ground Fault Condition

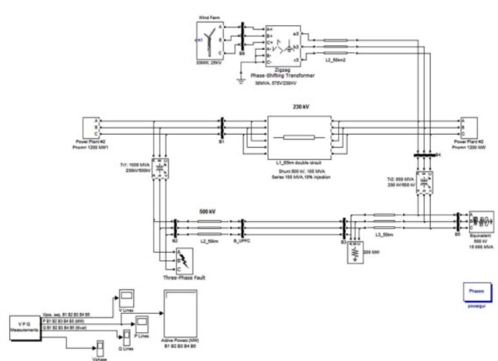

Fig.4.1. A hybrid power system under 3-phase to ground fault condition without UPFC

A three phase to ground fault is created at t=10 sec for 0.08 sec at bus 2 as shown in fig. 4.1. The active power, reactive power, voltage and phase angle curves with respect to time at all five buses (B1 B2 B3 B4 B5) are shown in fig. 4.1.1-4.1.8

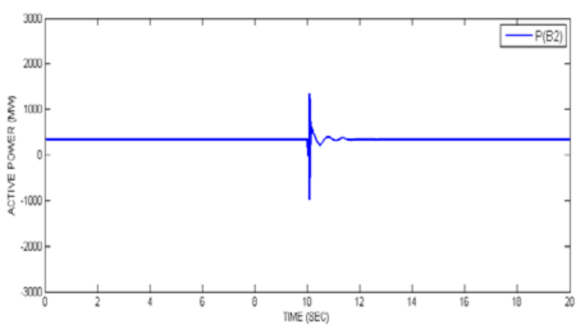

Fig.4.1.1. Active power at bus B2

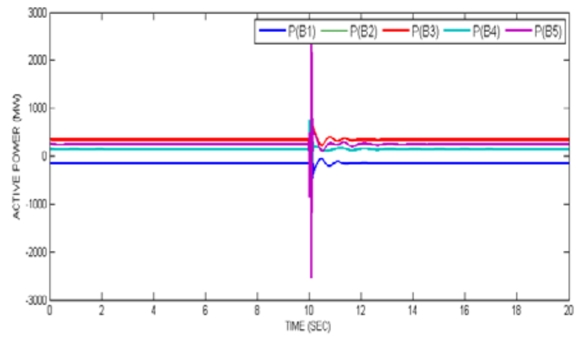

Fig. 4.1.2. Active power at different buses

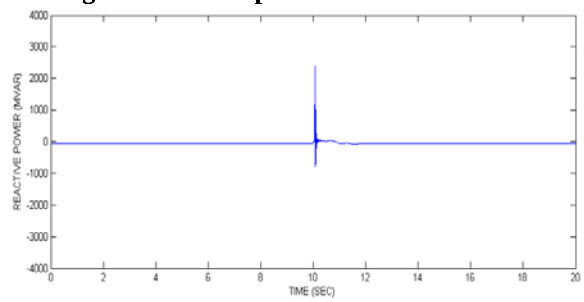

Fig. 4.1.3. Reactive power at bus B2

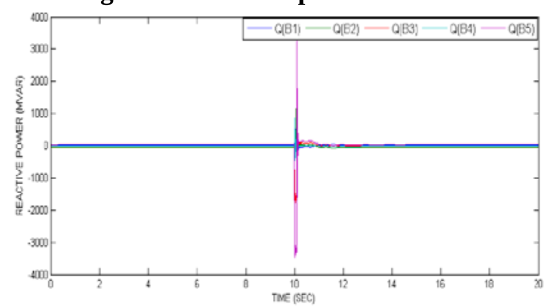

Fig. 4.1.4. Reactive power at different buses

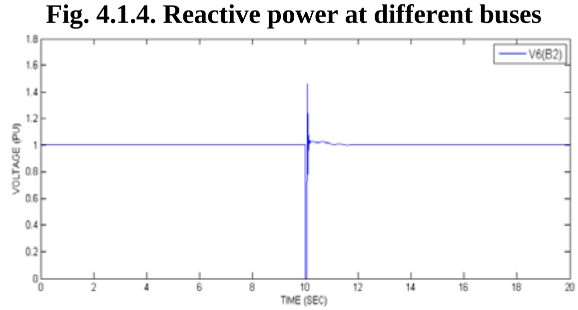

Fig. 4.1.5. Voltage at bus B2

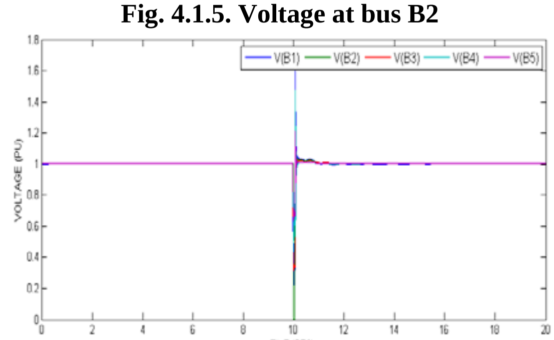

Fig. 4.1.6. Voltage at different buses

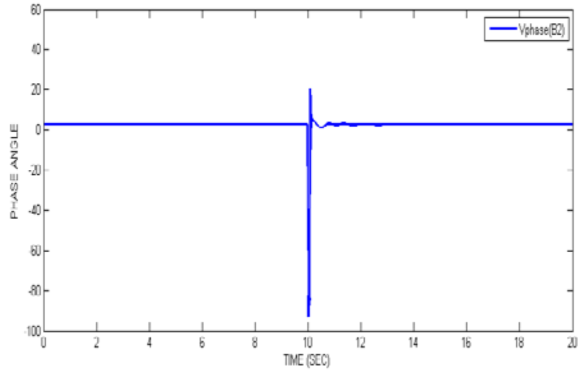

Fig. 4.1.7. Phase angle at bus B2

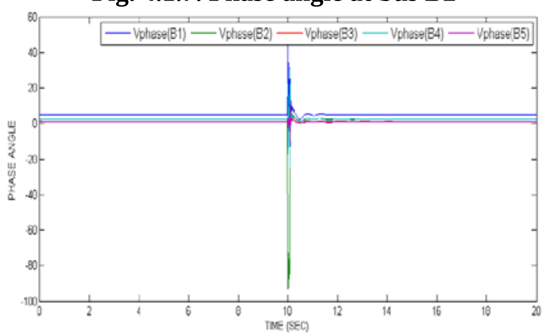

Fig. 4.1.8. Phase angle at different buses

4.1.2Using UPFC Under 3-Phase to Ground Fault Condition

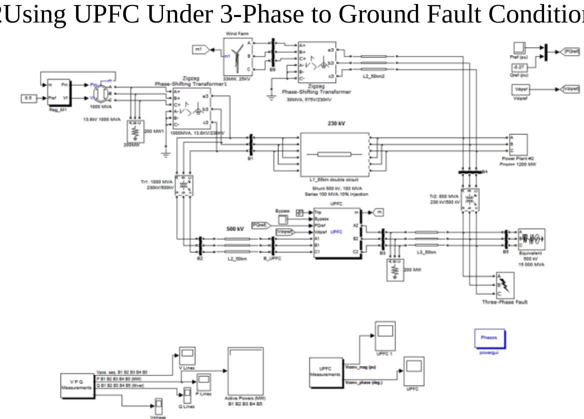

Fig. 4.2.A hybrid power system using UPFC under 3-phase to ground fault condition

A three phase to ground fault is created at t=10 sec for 0.08 sec at bus 2 as shown in fig. 4.2. The ratings of the various components used are given in appendix-F. The UPFC is made on at t=8sec and the power flow in the system goes from 5.87pu to 6.87pu. The active power, reactive power, voltage and phase angle curves, voltage at UPFC with respect to time at all five buses (B1 B2 B3 B4 B5) are shown in fig. 4.2.1-4.2.8.

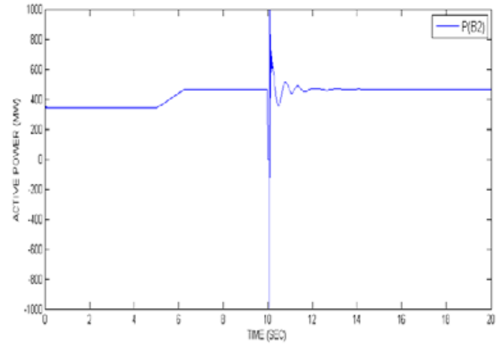

Fig.4.2.1. Active power at bus B2

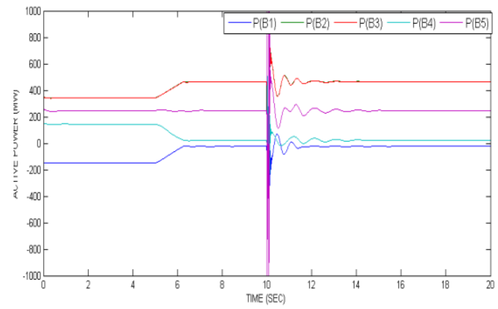

Fig. 4.2.2. Active power at different bus

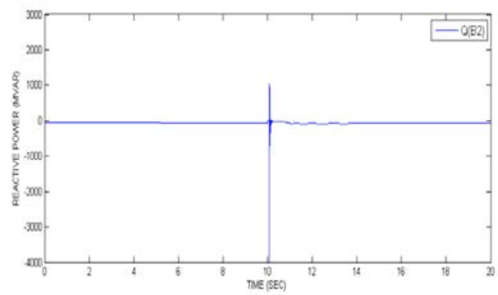

Fig. 4.2.3. Reactive power at bus B2

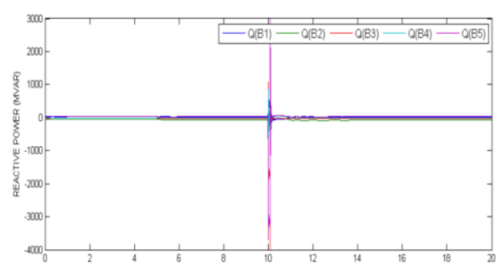

Fig. 4.2.4. Reactive power at different bus

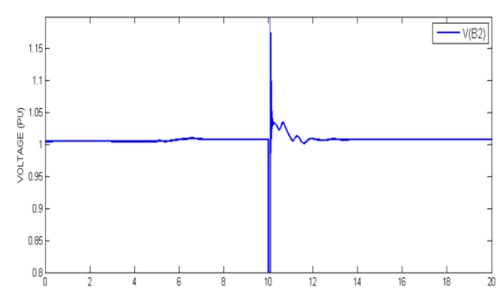

Fig. 4.2.5. Voltage at bus B2

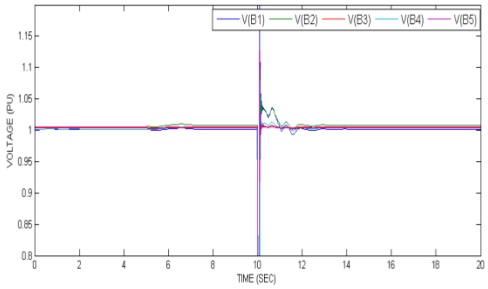

Fig. 4.2.6. Voltage at different bus

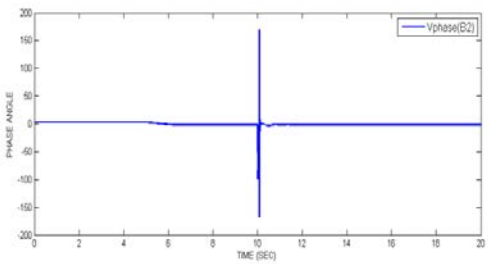

Fig. 4.2.7. Phase angle at bus B2

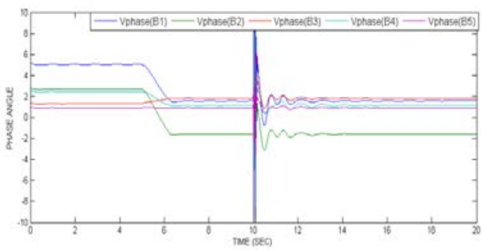

Fig. 4.2.8. Phase angle at different buses

V. Experimental Results and Discussions

Active Power Flow (MW)		
Buses	Without UPFC	With UPFC
Bus 1	-24.94	-24.32
Bus 2	464.28	464.25
Bus 3	462.98	463.17
Bus 4	18.60	20.44
Bus 5	241.35	243.44

Here as can be seen from the table that the UPFC don't have much impact on the active power flow of the system but in case of fault, the oscillations produced in the system are much less in magnitude and also the time of clearing the fault is less when the system is provided with UPFC. Similarly, we can find values of Reactive Power Flow and Phase angle with and without UPFC.

VI. Conclusion

In the simulation study, Matlab Simulink environment is used to simulate the model of UPFC connected to a 3phase system. The modeling of UPFC and analysis of powersystems embedded with UPFC has been presented, which is capable of solving large power networks very reliably with the UPFC. The investigations related to the variation of control parameters and performance of the UPFC on power quality results are carried out. In 22 kv study, the MATLAB environment using phasor model of UPFC connected to a three phase-three wire transmission system. This paper presents control and performance of UPFC intended forinstallation on a transmission line. Simulation results show the effectiveness of UPFC incontrolling real and reactive power through the line.

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