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Enhancement of Power System Stability Using UPFC

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ABSTRACT: In recent years, power demand has increased substantially while the expansion of power generation and transmission has been severely limited due to limited resources and environmental restrictions. As a consequence, some transmission lines are heavily loaded and the system stability has become a power transfer limiting factor. Flexible AC transmission systems (FACTS) controllers have been mainly used for solving various power system steady state control problems. However, recent studies reveal that FACTS controllers could be employed to enhance power system stability in addition to their main function of power flow control. The unified power flow controller (UPFC) is the most versatile of the FACTS devices. Within the framework of traditional power transmission concepts, the UPFC is able to control simultaneously or selectively all the parameters that affect the power system stability. Hence UPFC is highly recommended by researchers to tackle of power system stability related issues.

KEYWORDS: Power system stability, Rotor angle stability, FACTS, UPFC, Coordinated control.

I. INTRODUCTION

Power system stability is a major issue in modern power system scenario and stability related problems are becoming more and more prominent day by day especially with the exponential growth of power system infrastructures. Despite the existence of numerous conventional techniques to tackle stability issues those are becoming obsolete with the advent of modern systems and devices as well as integrated system. Hence in order to tackle stability related problems modern ingenious techniques need to be developed to ensure reliable operation of power system.

Flexible ac transmission system is an ac transmission network integrating semiconductor based power electronic devices as well as different stationary controllers to increase the capacity of power flow and also expand the controllability of the system. FACTS technology opens up new opportunities for controlling power and enhancing the usable capacity of present, as well as new and upgraded, lines. There are various FACTS devices which can be employed to improve power system stability. The Unified Power Flow Controller (UPFC) is the most adaptive one. It cannot only perform the functions of the static synchronous compensator (STATCOM), thyristor switched capacitor (TSC), thyristor controlled reactor (TCR) and the phase angle regulator by coordinated control strategy but also provides additional flexibility by combining some of the functions of the above controllers. It can independently control both the real and reactive power flow in the line. That means it can be used for the real-time control and dynamic compensation of ac transmission systems, providing multifunctional flexibility required to solve many of the problems facing the power delivery industry. This is the main reason for which improvement of power system stability using UPFC is recommended by numerous researchers in the field of power system.

II. LITERATURE REVIEW

Power system stability issue is one of the major problems for secure operation of power system since its inception. When the issue of power system stability is put forth, in general it refers to transient stability as it is the stability issue which affects the power system to a large extent. With the invention of new types of devices,

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techniques as well as system configurations a number of new stability issues have emerged. These include frequency stability issues, inter-area oscillations, various different forms of voltage stability issues etc. [1-3].

FACTS controllers are capable of controlling the network condition in a very fast manner and this feature of FACTS can be exploited to improve the voltage stability, and steady state and transient stabilities of a complex power system. This allows increased utilization of existing network closer to its thermal loading capacity, and thus avoiding the need to construct new transmission lines. The FACTS controllers can be effectively used for better utilization of existing transmission system assets; increased transmission system reliability and availability; increased dynamic and transient grid stability and reduction of loop flows and increased quality of supply for sensitive industries [4-6].

UPFC consists of a series and shunt converter connected by a common DC link capacitor and operated by coordinated control strategy. UPFC performs simultaneously the function of transmission line real and reactive power flow control in addition to UPFC bus voltage shunt reactive power control. The parameters (voltage, impedance and phase angle) affecting power flow in the transmission line which can be controlled by using of the UPFC. The UPFC bus voltage/shunt reactive power and the dc link capacitor voltage are controlled by the shunt converter of the UPFC. The series converter of the UPFC injects a series voltage of adjustable magnitude and phase angle in the transmission line and controls real and reactive power flow in the transmission line. These capabilities of UPFC enable its use in power system for improvement of stability [7-12].

III. POWER SYSTEM STABILITY

Power system stability is the ability of an electric power system, for a given initial operating condition, to regain a state of operating equilibrium after being subjected to a physical disturbance, with most system variables bounded so that practically the entire system remains intact. The robustness of a system is defined by the ability of the system to maintain stable operation under normal and perturbed conditions. Instability in a power system may be manifested in many different ways depending on the system configuration and operating mode. The stability of an interconnected power system is its ability to return to normal or stable operation after having been subjected to some form of disturbance. Conversely, instability means a condition denoting loss of synchronism or falling out of step. Stability considerations have been recognized as an essential part of power system planning for a long time. With interconnected systems continually growing in size and extending over vast geographical regions, it is becoming increasingly more difficult to maintain synchronism between various parts of a power system.

Rotor angle stability refers to the ability of synchronous machines of an interconnected power system to remain in synchronism after being subjected to a disturbance. It depends on the ability to maintain or restore equilibrium between electromagnetic torque and mechanical torque of each synchronous machine in the system. Instability that may result occurs in the form of increasing angular swings of some generators leading to their loss of synchronism with other generators. Small disturbance (or small signal) rotor angle stability is concerned with the ability of the power system to maintain synchronism under small disturbances. The disturbances are considered to be sufficiently small that linearization of system equations is permissible for purposes of analysis. Large disturbance rotor angle stability or transient stability, as it is commonly referred to, is concerned with the ability of the power system to maintain synchronism when subjected to a severe disturbance, such as a short circuit on a transmission line. The resulting system response involves large excursions of generator rotor angles and is influenced by the nonlinear power-angle relationship. When power system stability issues are discussed, they refer to transient stability in general as it affects the power system to the highest extent.

IV. UNIFIED POWER FLOW CONTROLLER (UPFC)

Flexible ac transmission system is an ac transmission network integrating semiconductor based power electronic devices as well as different stationary controllers to increase the capacity of power flow and also expand the controllability of the system. There are various FACTS devices developed for different functionalities to improve controllability, flexibility, reliability and power flow capability of the power system. Gyugyi proposed the unified power flow controller (UPFC) concept in 1991. The UPFC was devised for the real time control and dynamic

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compensation of ac transmission system, providing multifunctional flexibility required solving many of the problems facing the delivery industry. It employs coordinated control strategy as explained below to improve power system stability issues.

In the presently used practical implementation, the UPFC consist of two switching converters which are essentially voltage source converters using GTO thyristor valves, as illustrated in figure 1. These back to back converters labelled converter 1 & converter 2 in the figure 1 are operated from a common dc link provided by a dc storage capacitor. This arrangement functions as an AC to AC converter in which the real power can freely flow in either direction between the ac terminals of the converter and each converter can independently generate or absorb reactive power at its own ac output terminals. From the conceptual viewpoint, the UPFC is a generalized synchronous voltage source (SVS), represented at the fundamental (power system) frequency by voltage phasor V_{pq} with controllable magnitude V_{pq} ($0 \leq V_{pq} \leq V_{pqmax}$) and angle ρ ($0 \leq \rho \leq 2\pi$) in series with the transmission line. In this functionally unrestricted operation, which clearly includes voltage and angle regulation, the SVS generally exchanges both reactive and real power with the transmission system. Since, as established previously, an SVS is able to generate only the reactive power exchanged, the real power must be supplied to it, or absorbed from it, by a suitable power supply or sink. In the UPFC arrangement the real power exchanged is provided by one of the end buses.

Converter 2 provides the main function of UPFC by injecting an AC voltage V_{pq} with controllable magnitude V_{pq} ($0 \leq V_{pq} \leq V_{pqmax}$) and phase angle ρ ($0 \leq \rho \leq 2\pi$) at the power frequency, in series with the line via an insertion transformer. The injected voltage is considered essentially as a synchronous voltage source. The transmission line current flowing through this voltage source results in real and reactive power exchange between it and the power system. The real power exchanged at the ac terminal (i.e. at the terminal of insertion transformer) is converted by the converter into DC power that appears at the DC link as positive or negative real power demanded. The reactive power exchanged at the AC terminal; is generated internally by the converter.

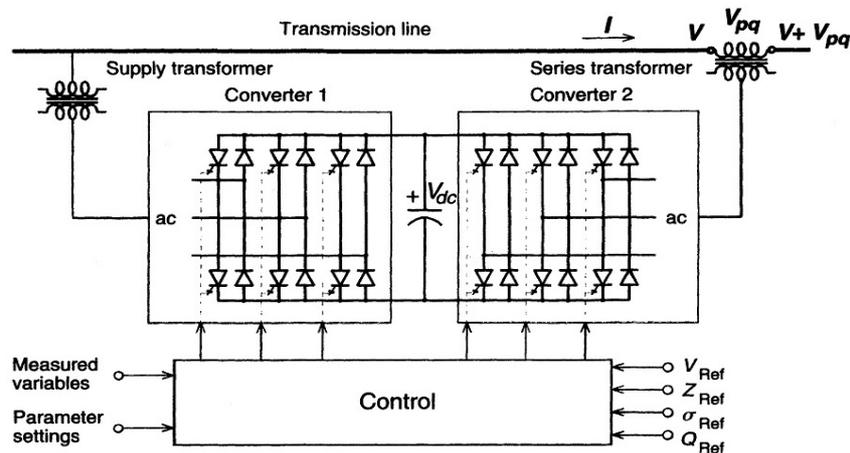


Fig.1.Implementation of UPFC

The basic function of converter 1 is to supply or absorb the real power demanded by the converter 2 at the common DC link. This DC link power is converted back to ac and coupled to the transmission line via a shunt connected transformer. Converter 1 can also generate or absorb controllable reactive power, if it is desired and thereby it can provide independent shunt reactive compensation for the line. It is important to note that whereas there is a closed direct path for the real power negotiated by the action of series voltage injection through converter 1 and converter 2 back to the line, the corresponding reactive power exchanged is supplied or absorbed locally by converter 2 and therefore it does not flow through the line. Thus converter 1 can be operated at a unity power factor or be controlled to have a reactive power exchange with the line independently of the reactive power exchanged by the converter 2. This means there is no continuous reactive power flow through the UPFC.

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V.SIMULATIONS AND RESULTS

A simulink model of the test system is designed on MATLAB platform taking suitable parameters into consideration. The system, as shown in figure 2, is connected in a loop configuration that consists essentially of five buses (B1 to B5) interconnected through transmission lines (L1, L2, L3) and three 500 kV/230 kV transformer banks Tr1, Tr2 and Tr3. Two power plants located on the 230 kV system generate a total of 1500 MW which is transmitted to a 500 kV 15000 MVA grid and to a 200 MW load connected at bus B3. The plant models include a speed regulator, an excitation system as well as a power system stabilizer (PSS). A fault is introduced on line L1 near bus B4. It is a three phase fault of L-L-L-G type with a fault resistance of 0.01 ohm and ground resistance of 0.001 ohm respectively. The transition time is from 0.01 second to 0.15 second respectively.

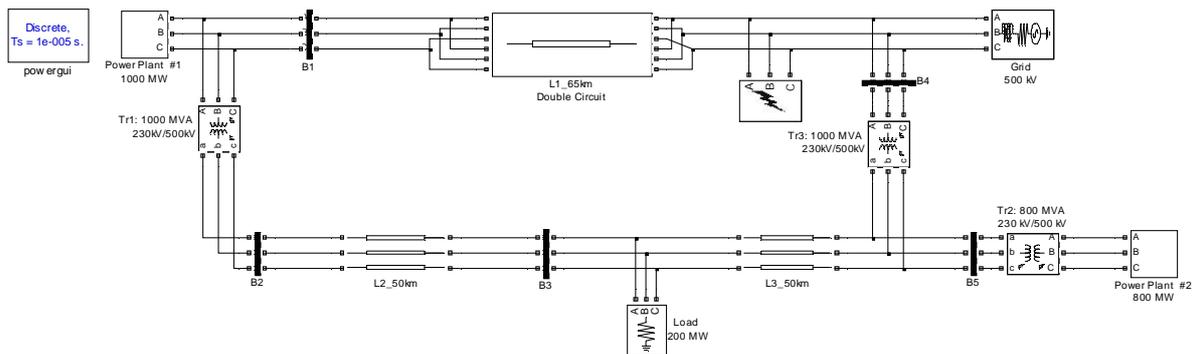


Fig.2.Power system under fault conditions

Using the load flow option of the powergui block, the model is initialized and the voltage, active power and reactive power are monitored by running the model for a period of 0.5 seconds. The plots thus obtained are shown in figure 3.

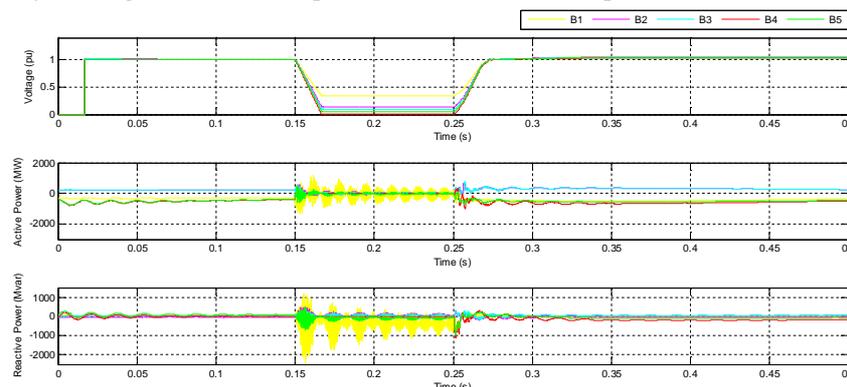


Fig.3.Plots of power system under fault conditions

It is clear from the plots that there is a huge dip in voltage during the fault conditions and wild fluctuations of active and reactive power. This leads to system instability which may cause the machines to loose synchronism..

Now a unified power flow controller (UPFC) is connected between bus B1 and B4 as shown in figure 4. It consists of a two 100 MVA, GTO based converters (one connected in shunt and one connected in series and both interconnected through a DC bus on the DC side and to the AC power system, through coupling reactors and transformers). With the UPFC included in the power system a three phase fault with the parameters same as that of the previous simulation is introduced on line L1.

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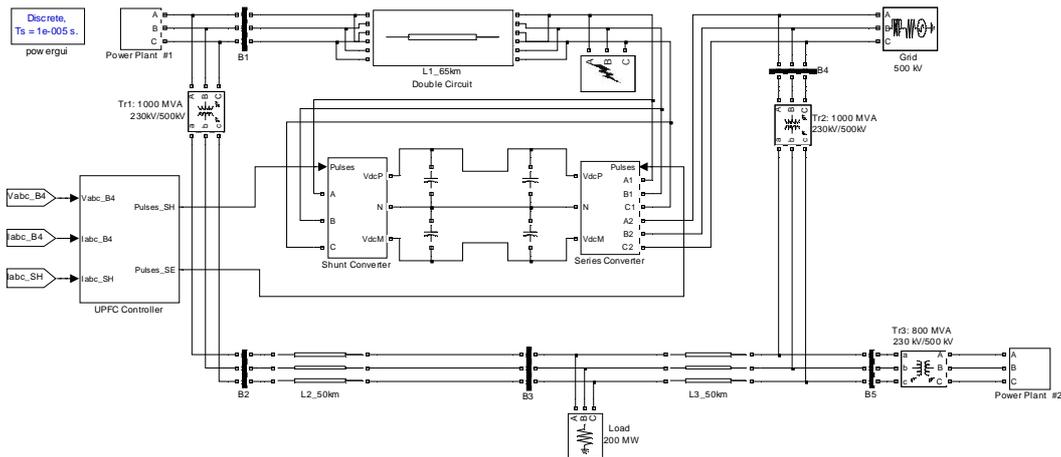


Fig.4. Power system under fault conditions with UPFC

Using the load flow option of the powgui block, the model has been initialized with plants #1 and #2 generating respectively 500 MW and 1000 MW. The plots obtained when the model is run for a period of 0.5 second are shown in figure 5.

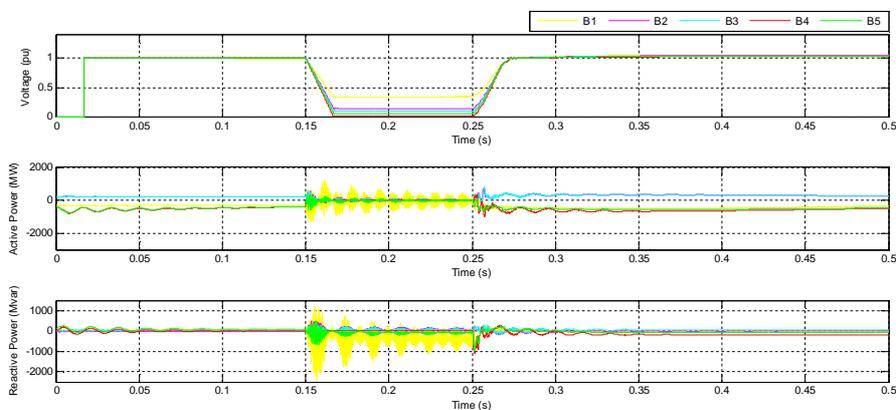


Fig.5. Plots of power system under fault conditions with UPFC

The plots clearly show that the voltage dips as well as fluctuations in real and reactive powers are reduced compared to the previous simulation when the UPFC was not present in the system as shown in table 1. But after clearance of the fault, there are still some oscillations in real and reactive power although for a small amount of time before being significantly damped out.

Simulation	Variation of active power during fault (MW)	Variation of reactive power during fault (Mvar)	Voltage at bus B4 (pu)
Power system under fault conditions	-1300 to 1200	-2400 to 1300	0
Power system with UPFC under fault conditions	-1200 to 500	-1500 to 500	0.3

Table 1. Comparison of the simulations

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From the above table it is clear that the variations of real and reactive powers are the least in case of implementation of UPFC. The voltage at bus B4 where the fault occurs is reduced the least in the case of implementation of UPFC.

VI. CONCLUSION

The system under consideration was modelled using various equations in MATLAB platform with suitable parameters. The simulink models were run and various obtained results were analysed for comparison. The performance of UPFC during fault conditions was observed and it was found that the device helped in maintaining the voltage profile of various buses as well as reduced the extent of wild fluctuations in real and reactive power that were present when the device was not included in the system. Hence the proposed model was successful in improving stability of the power system. However it was realised that instead of using the conventional controllers for UPFC if soft computing technique based controllers are used the performance will further improve due to the adaptive and quick response of these controllers.

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