POWER FLOW CONTROL OF UPFC IN A POWER SYSTEMS

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ABSTRACT- *The maintenance and reliability of the power system has become a major aspect of study. 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. The solution is the use of FACTS devices especially the use of UPFC. In this paper the study of UPFC with its various modes of operation is understood. Second, the operation of control system used in its converters is also studied. Finally by help of modeling of a power system in MATLAB, and by installing UPFC in transmission link, its use as power flow controller and voltage injection is seen. Conclusion is made on different results to see the benefit of UPFC in power system.*

Keywords– *FACTS, UPFC, Voltage Source Convertor, power flow controller*

I. INTRODUCTION

In AC power systems, for many years to overcome the reactive power problems mechanical switched groups of capacitors and reactors are used. However, to control the switching of power capacitor and reactors has been a major challenge for engineers. Because during transient events such elements cannot provide the necessary compensation because of their slow response times and can really degraded the stability of the system after disturbance influences[1].In power systems it was observed that compensation with the case of the semiconductor switches, the voltage crashes could be prevented and the transient and dynamic stability could be improved FACTS controllers are fast against traditional equipment because of their power electronic based structure and they increase the stability operating limits of the transmission systems when their controllers are properly tuned [3]. UPFC is the most versatile device among FACTS devices. It provides the control of transmission system parameters such as voltage, phase angle and line impedance in power systems [3]. There have been many studies intended for mathematical modeling, impacts on power systems and control system design for UPFC. In [4] authors have been developed mathematical models for steady state, transient stability and eigenvalue studies. In [5] CSI (current Source inverter) topology is used and applied to STATCOM in a power system. In [6], a STATCOM system is applied for compensation of displacement power factor under distorted mains voltage conditions. According to simulation results STATCOM is ensuring the displacement power factor compensation with good transient and steady state performance. Impacts of UPFC, STATCOM and SSSC on voltage stability have been investigated in [6]. It has been shown that these devices are regulate the voltage profile and increased the load ability margin of power systems. Nowadays, control of power systems has a great importance. Especially requirement of energy increases constantly. Maximizing of the usage of available power systems with FACTS and suchlike hardwares is quite an agenda topic because of the fact that construction of new energy power plants is costly. This study presents a simulation program which can be used for investigation of effects of UPFC and other converter based FACTS devices on power system. UPFC system in this program is composed of equations obtained in d-q frame of reference. In simulation studies, control of bus voltage and active power control with UPFC is performed by adding inductive and capacitive loads to the system.

2. UNIFIED POWER FLOW CONTROLLER

A. Characteristics of UPFC

Line outage, congestion, cascading line tripping, power system stability loss are the major issues where capability and utilization of FACTS are noticed. Representative of the last generation of FACTS devices is the Unified Power Flow Controller (UPFC).The UPFC is a device which can control simultaneously all three parameters of line power flow (line impedance, voltage and phase angle). Such "new" FACTS device combines together the features of two "old" FACTS devices: the Static Synchronous Compensator (STATCOM) and the Static Synchronous Series Compensator (SSSC). In practice, these two devices are two Voltage Source Inverters (VSI's) connected respectively in shunt with the transmission line through a shunt transformer and in series with the transmission line through a series transformer, connected to each other by a common dc link including a storage capacitor. The shunt inverter is used for voltage regulation at the point of connection injecting an opportune reactive power flow into the line and to balance the real power flow exchanged between the series inverter and the transmission line. The series inverter can be used to control the real and reactive line power flow inserting an opportune voltage with controllable magnitude and phase in series with the transmission line. Thereby, the UPFC can fulfill functions of reactive shunt compensation, active and reactive series compensation and phase shifting.

Besides, the UPFC allows a secondary but important function such as stability control to suppress power system oscillations improving the transient stability of power system. As the need for Operation of UPFC the basic components of the UPFC are two voltage source inverters (VSIs) sharing a common dc storage capacitor [6], and connected to the power system through coupling transformers. One VSI is connected to in shunt to the transmission system via a shunt transformer, while the other one is connected in series through a series transformer.

A basic UPFC functional scheme is shown in fig.1.flexible and fast power flow controllers, such as the UPFC, is expected to grow in the future due to the changes in the electricity markets, there is a corresponding need for reliable and realistic models of these controllers to investigate the impact of them on the performance of the power system. In this article emphasis is laid to project the use of UPFC in transmission link to increase the power flow and to improve the voltage profile of the system using MATLAB SIMULINK v7.6.

B. Operation of UPFC

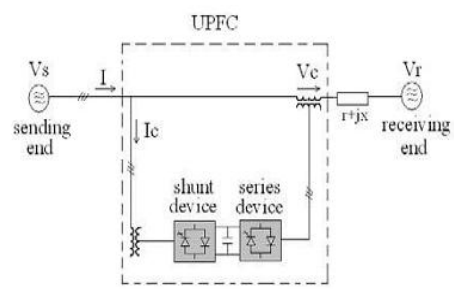


Figure 1: UPFC Link in Transmission Line

The series inverter is controlled to inject a symmetrical three phase voltage system (Vc), of controllable magnitude and phase angle in series with the line to control active and reactive power flows on the transmission line. So, this inverter will exchange active and reactive power with the line. The reactive power is electronically provided by the series inverter, and the active power is transmitted to the dc terminals. The shunt inverter is operated in such a way as to demand this dc terminal power (positive or negative) from the line keeping the voltage across the storage capacitor Vdc constant. So, the net real power absorbed from the line by the UPFC is equal only to the losses of the inverters and their transformers. The remaining capacity of the shunt inverter can be used to exchange reactive power with the line so to provide a voltage regulation at the connection point. The two VSI's can work independently of each other by separating the dc side. So in that case, the shunt inverter is operating as a STATCOM (Static Synchronous Compensators) that generates or absorbs reactive power to regulate the voltage magnitude at the connection point. Instead, the series inverter is operating as SSSC

(Static Synchronous series compensators) that generates or absorbs reactive power to regulate the current flow, and hence the power flows on the transmission line.

3. MODELING OF UPFC ON A TRANSMISSION SYSTEM

Using the concept of the control system a power system is taken to implement the use of UPFC. The two modes i.e. the power flow control and the voltage injection mode are simulated in SIMULINK to see the effect of UPFC on a power system. Study is carried out to verify the utility of FACT device.

The figure 2 below illustrates application study the steady-state and dynamic performance of a unified power flow controller (UPFC) used to relieve power congestion in a transmission system. The load flow analysis and the single line diagram simulation are done on power flow simulator. This software helps to calculate the power flow, the voltage at each bus and the cost effectiveness of the system.

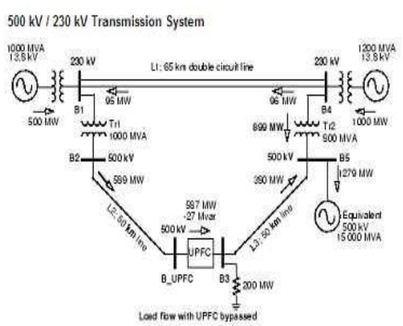


Figure 2: Description of 500kV/230kV Transmission system [2][4]

A UPFC is used to control the power flow in a 500 kV /230 kV transmission systems. The system, connected in a loop configuration, consists essentially of five buses (B1 to B5) interconnected through three transmission lines (L1, L2, L3) and two 500 kV/230 kV transformer banks Tr1 and Tr2. Two power plants located on the 230 kV system generate a total of 1500 MW (illustrated in figure 3) which is transmitted to a 500 kV, 15000 MVA equivalent and to a 200 MW load connected at bus B3. Each plant model includes a speed regulator, an excitation system as well as a power system stabilizer (PSS). In normal operation, most of the 1200 MW generation capacity of power plant #2 is exported to the 500 kV equivalents through two 400 MVA transformers connected between buses B4 and B5. For this illustration we consider a contingency case where only two transformers out of three are available (Tr2= 2*400 MVA = 800 MVA). The load flow shows that most of the power generated by plant #2 is transmitted through the 800 MVA transformer bank (899 MW out of 1000 MW) and that 96 MW is circulating in the loop. Transformer Tr2 is therefore overloaded by 99 MVA. This will now illustrate how a UPFC can relieve this power congestion. The UPFC located at the right end of line L2 is used to control the active and reactive powers at the 500 kV bus B3, as well as the voltage at bus B_UPFC. The UPFC consists of two 100 MVA, IGBT-based, converters (one shunt converter and one series converter interconnected through a DC bus). The series converter can inject a maximum of 10% of nominal line-to-ground voltage (28.87 kV) in series with line L2.

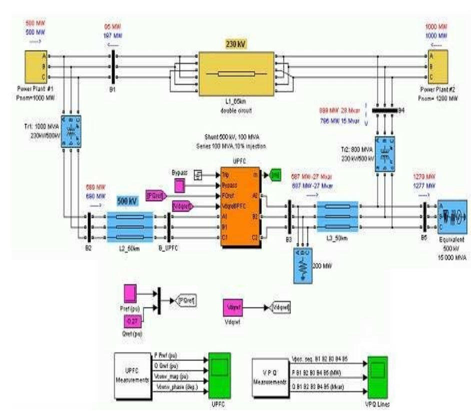


Figure. 3 Model of UPFC

4. SIMULATIONS

Parameters of the UPFC are adjusted as the series converter is rated 100 MVA with a maximum voltage injection of $0.1P_u$. The shunt converter is also rated 100 MVA and is in

Voltage regulation mode and that the series converter is in Power flow control mode.

Initially the Bypass breaker is closed and the resulting natural power flow at bus B3 is 587 MW and -27 Mvar. The Pref block is programmed with an initial active power of 5.87 .corresponding to the natural power flow.

Then, at t=10s, .is increased by 1 . (100 MW), from 5.87 to 6.87 , while Qref is kept constant at -0.27 .

At t=5 s, when the Bypass breaker is opened, the natural power is diverted from the Bypass breaker to the UPFC series branch without noticeable transient. At t=10 s, the power increases at a rate of 1 pu/s. It takes one second for the power to increase to 687 MW. This 100 MW increase of active power at bus B3 is achieved by injecting a series voltage of 0.089 . with an angle of 94 degrees.

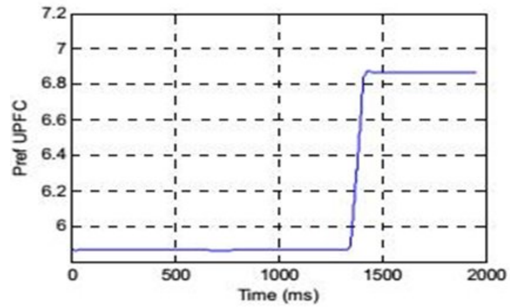
This results in an approximate 100 MW decrease in the active power flowing through Tr2 (from 899 MW to 796 MW), which now carries an acceptable load.

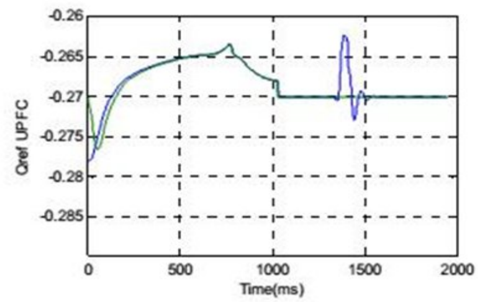
UPFC scope show P and Q measured at bus B3 follow the reference values. Waveforms are reproduced as in the graphs shown below.

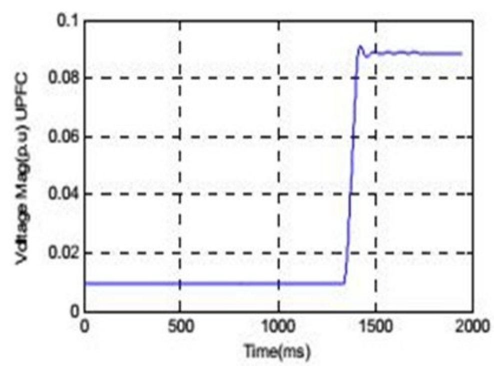
UPFC P-Q Controllable Region

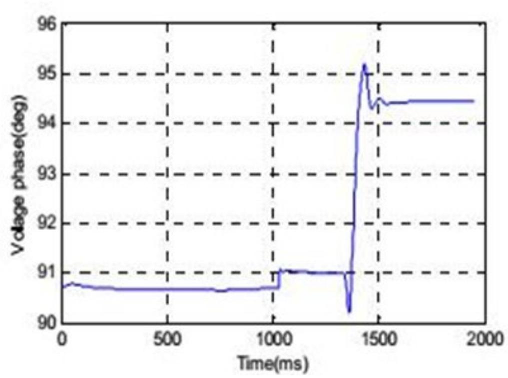
Select Mode of operation = Manual Voltage injection. In this control mode the voltage generated by the series inverter is controlled by two external signals , multiplexed at the input and generated in the magenta block.

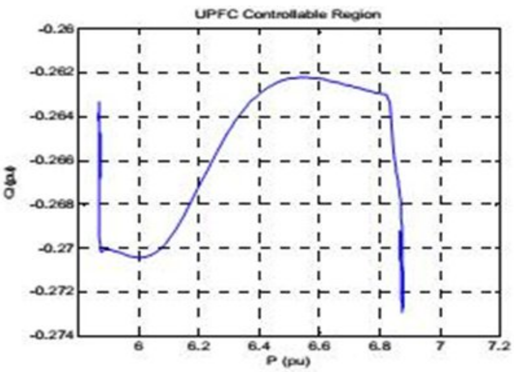
For the first five seconds the Bypass breaker stays closed, so that the PQ trajectory stays at the (-27Mvar, 587 MW) point. Then when the breaker opens, the magnitude of the injected series voltage is ramped, from 0.0094 to 0.1 . At 10 s, the angle of the injected voltage starts varying at a rate of 45 deg/s.











5. RESULTS

The results are in compliance with the UPFC characteristics. The net reference real power output of the UPFC increased by 100 MW when the breaker opened. The increase in the real power led to decrease in congestion on bus 5. This can be seen by the power variation at every bus in the graphs given above. Relating to the reactive power, when the breaker opened the oscillations of reactive power was finished and reactive power was then constant at - 27MVAr. The main concern lies at the UPFC controllable region. The region defined in the graph is such that the UPFC can only act under these conditions; else the UPFC behaves like open to transmission link. The voltage levels were also increase so **to** meet the real power demand.

6. CONCLUSION

In power system transmission, it is desirable to maintain the voltage magnitude, phase angle and line impedance. Therefore, to control the power from one end to another end, this concept of power flow control and voltage injection is applied. Modeling the system and studying the results have given an indication that UPFC are very useful when it comes to organize and maintain power system. Following conclusions are made-

1. Power flow control is achieved and congestion is less.

2. Transient stability is improved.

3. Faster Steady State achievement.

4. Improved Voltage Profile

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