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THE UPFC POWER FLOW CONTROLLER FOR POWER FLOW IMPROVEMENT

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Abstract: In this paper the performance of Unified Power Flow Controller (UPFC) is investigated in controlling the flow of power over the transmission line. This research deals with digital simulation of standard IEEE 14-bus power system using UPFC to improve the real and reactive power flow control through a transmission line by placing UPFC at the sending end using computer simulation. When no UPFC is installed, real and reactive power through the transmission line cannot be controlled. The circuit model for UPFC is developed using rectifier and inverter circuits. This paper concentrates on FACT device UPFC which is used for power flow control in the transmission side. With the growing demand of electricity, it is not possible to erect new lines to face the situation. Flexible AC Transmission System (FACTS) makes use of the thruster controlled devices and optimally utilizes the existing transmission network. One of such device is Unified Power Flow Controller (UPFC) on which the emphasis is given in this present work. Real, reactive power, and voltage balance of the unified power-flow control (UPFC) system is analyzed. A novel coordination controller is proposed for the UPFC. The basic control method is such that the shunt converter controls the transmission line reactive power flow and the dc-link voltage. The series converter controls the real power flow in the transmission line and the UPFC bus voltages. Experimental works have been conducted to verify the effectiveness of the UPFC in power flow control in the transmission line. The simulation model was done in MATLAB/SIMULINK platform.

Keywords: - UPFC, FACTS, Power Quality, Transient, Control.

I.INTRODUCTION

The power transmitted over an ac transmission line is a function of the line impedance, the magnitude of sending-end and receiving-end voltages, and the phase angle between these voltages. Traditional techniques of reactive line compensation and step-like voltage adjustment are generally used to alter these parameters to achieve power transmission control. Fixed and mechanically shunt and series reactive compensation are employed to modify the natural impedance characteristics of transmission lines in order to establish the desired effective impedance between the sending and receiving-ends to meet power transmission requirements. Voltage regulating and phase shifting transformers with mechanical tap-changing gears are used to minimize voltage variation and control power flow. These conventional methods provide adequate control under steady-state and slowly changing system conditions, but are largely ineffective in handling dynamic disturbances. The traditional approach to contain dynamic problems is to establish generous stability margins enabling the system to recover from faults, line and generator outages, and equipment failures. This approach, although reliable, generally results in a significant under utilization of the transmission system. As a result of recent environmental legislation, rights-of-way issues, and construction cost increases, and deregulation policies, there is an increasing recognition of the necessity to utilize existing transmission system assets to the maximum extent possible. To this end, electronically controlled, extremely fast reactive compensators and power flow controllers have been developed within the overall framework of the FACTS initiative. These compensators and controllers either use conventional reactive components and tap-changing transformer arrangements with thyristor valves and control electronics or employ switching power converters, as synchronous voltage sources, which can internally generate reactive power for, and also exchange real power with, the ac system.

The unified power flow controller (UPFC) is one of the most widely used FACTs controllers and its main function is to control the voltage, phase angle and impedance of the power system thereby modulating the line reactance and controlling the power flow in the transmission line.

The basic components of the UPFC are two voltage source inverters (VSIs) connected by a common dc storage capacitor which is connected to the power system through a coupling transformers. One (VSIs) is connected in shunt to the transmission system through a shunt transformer, while the other (VSIs) is connected in series to the transmission line through a series transformer. Three phase system voltage of controllable magnitude and phase angle (Vc) are inserted in series with the line to control active and reactive power flows in the transmission line. So, this inverter will exchange active and reactive power with in the line. 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 to the only losses of the inverters and the 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 from each other by separating the dc side. So in that case, the shunt inverter is operating as a (STATCOM) that generates or absorbs reactive power to regulate the voltage magnitude at the connection point. The series inverter is operating as (SSSC) that generates or absorbs reactive power to regulate the current flowing in the transmission line and hence regulate the power flows in the transmission line. The UPFC has many possible operating modes. (1)VAR control mode:-The reference input is a simple var request that is maintained by the control system regardless of bus voltage variation. (2) Automatic voltage control mode:-The shunt inverter reactive current is automatically regulated to maintain the transmission line voltage at the point of connection to a reference value with a defined slope characteristics the slope factor defines the per unit voltage error per unit of inverter reactive current within the current range of the inverter. In Particular, the shunt inverter is operating in such a way to inject a controllable current into the transmission line. The figure 1 shows how the (UPFC) is connected to the transmission line.

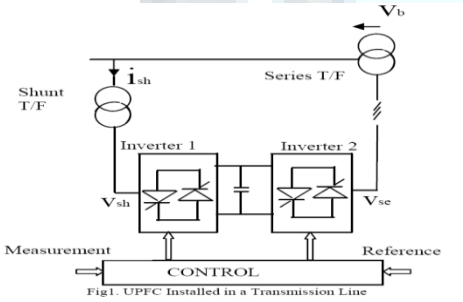

Fig.1shows the UPFC installed in a transmission line

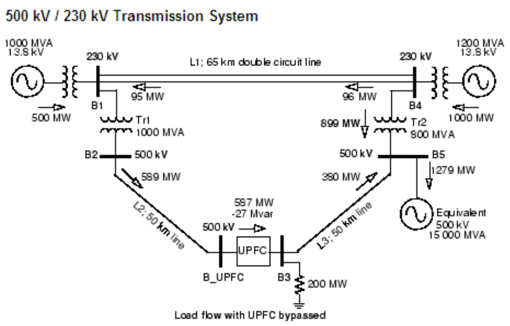

Fig-2 Shows the Single line diagram of a 500kv/230kv transmission system using UPFC.

Description of above single line diagram:

The power flow in a 500 kV /230 kV transmission systems is shown in single line in fig 2. The system is connected in a loop configuration, consists 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 2) 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 generating capacity power plant P1 is exported to the 500 kV equivalents through two 400 MVA transformer connected between buses B4 and B5 .The UPFC is connected at the right end of line L2 is used to control the active and reactive power at the 500kv bus B3 the UPFC used here include two 100 MVA, IGBT based converters (one series converter and one shunt converter) both the converter are interconnected through a DC bus two voltage source inverter connected by a capacitor charged to a DC voltage realize the UPFC the converter number one which is a shunt converter draws real power from the source and exchange it (minus the losses) to the series converter the power balance between the shunt and series converter is maintained to keep the voltage across the DC link capacitor constant. The single line diagram is implemented on MATLAB Simulink.

II. FACTS CONTROLLERS

FACTS controllers are used for the dynamic control of voltage, impedance and phase angle of high voltage AC transmission lines. FACTS controllers can be divided into four categories:

1. Series controllers.
2. Shunt controllers.
3. Combined series-series controllers.
4. Combined series-shunt controllers.

2.1 SERIES CONTROLLERS

Series controllers inject voltage in series with the line. As long as the voltage is in phase quadrature with the line current, the series controller only supplies or consumes variable reactive power. Any other phase relationship will involve handling of real power as well.

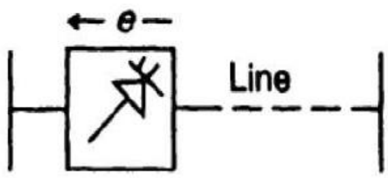

Figure 2.1 Static Synchronous Series Compensator (SSSC) is one such series controller.

2.2 SHUNT CONTROLLERS

All shunt controllers inject current into the system at the point of connection. As long as the injected current is in phase quadrature with the line voltage, the shunt controller only supplies or consumes variable reactive power. Any other phase relationship will involve handling of real power as well.

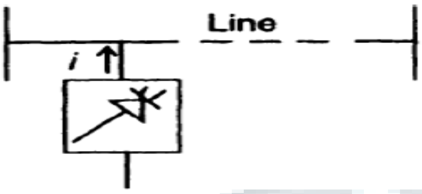

Figure 2.2 Static Synchronous Compensator (STATCOM) is one such controller.

2.3 COMBINED SERIES-SERIES CONTROLLERS

This could be a series combination of separate series controllers, which are controlled in a coordinated manner, in a multilane transmission system. Or it could be a unified controller, in which series controllers provide independent series reactive compensation for each line but also transfer real power among the lines via the power link.

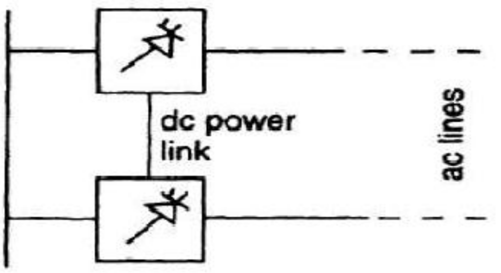

Figure 2.3 Interline Power Flow Controller comes in this category.

2.4 COMBINED SERIES-SHUNT CONTROLLERS

This could be a combination of separate shunt and series controllers, which are controlled in a coordinated manner, or a unified power flow controller with series and shunt elements. In principle, combined shunt and series controllers inject current into the system with shunt part of the controller voltage in series in the line with the series part of the controller. However, when the shunt and series controllers are unified, there can be a real power exchange between the series and shunt controllers via the power link.

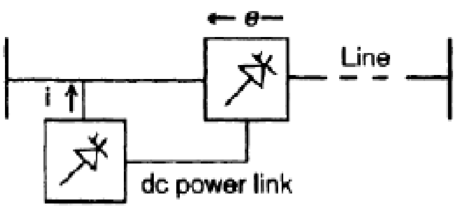

Figure 2.4 Interline Power Flow Controller comes in this category.

2.5 The Unified Power Flow Controller (UPFC)

The basic conception of the UPFC was proposed by Nabavi-Niaki and Iravani in 1996[4].The Unified Power Flow Controller(UPFC) was devised for the real-time control and dynamic compensation of ac transmission systtem, providing multi-functional exibility required to solve many of the problems facing the power delivery industry. The UPFC is made up of two voltage source controllers sharing the same capacitor at their dc voltage controlled side. One voltage source controller is in parallel with one side of a transmission line and the other voltage source controller in the UPFC is in series connect to the other side of the same transmission line. The basic structure of the UPFC is shown in the Figure 1. The UPFC can simultaneously control the active and reactive power flow and voltage magnitude. However it has little effect on voltage angle.

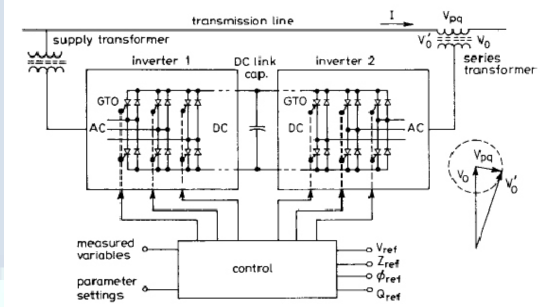

Fig. no: 2.5 Implementation of the UPFC by two back-to-back voltage-sourced converters

AC transmission lines form the backbone of the electricity grid in most countries and continents. The power flow will follow the path of least impedance and is uncontrollable, unless active grid elements are used. To enhance the functionality of the ac transmission grid, flexible ac transmission systems (FACTS) support the transmission grid with power electronics. These devices offer a level of control to the transmission system operator. A unified power-flow controller (UPFC) is the most versatile of these FACTS devices. A transmission line equipped with a UPFC can control the balance of the transmitted power between parallel lines and, as such, can optimize the use of the transmission grid for all parallel power flows. A one-wire schematic of a transmission-line system equipped with a UPFC is given in Fig.2.6

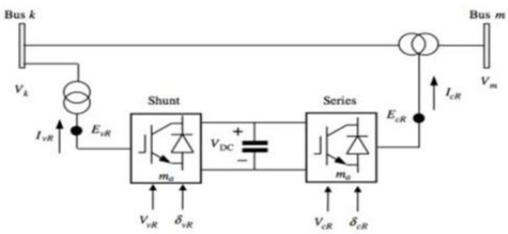

Fig. no:2.6 Basic structure of UPFC

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III. EXPERIMENTS CARRIED OF 22KV TRANSMI SSION LINE SYSTEMWITH UPFC DEVICE

With the development of power systems especially the opening of electric energy markets, it becomes more and more important to control the power flow along the transmission line, thus to meet the need of power transfer. On the other hand the fast development of power electronic technology has made UPFC a promising part for future power system needs. This device is an advance power system device capable of providing simultaneous control of voltage magnitude, active and reactive power flows in an adaptive fashion [10]. The following section is discussing the testing of transmission line with UPFC device with MATLAB / SIMULINK model environment [11-12].

A. Simulink model of 22 kV Transmission Line

The simulation model of Single line transmission system of 22kV Line is shown in Fig .4.1. The model is simulated and Corresponding results of voltage magnitude, real and reactive power flows in line are shown in Fig's 4.2 and 4.3 respectively.

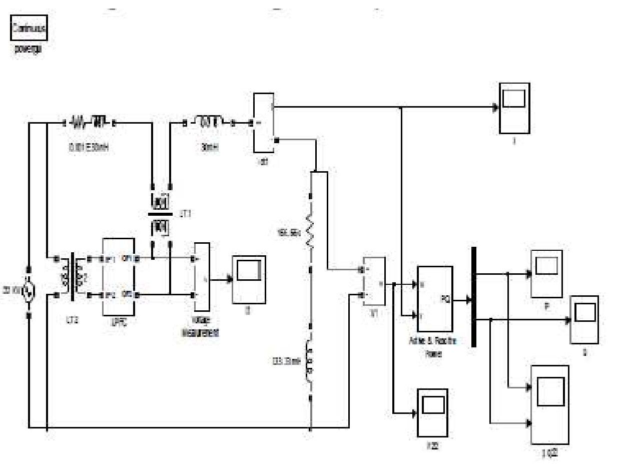

Fig.4.1. Simulink Model of 22 k V Transmission Line.

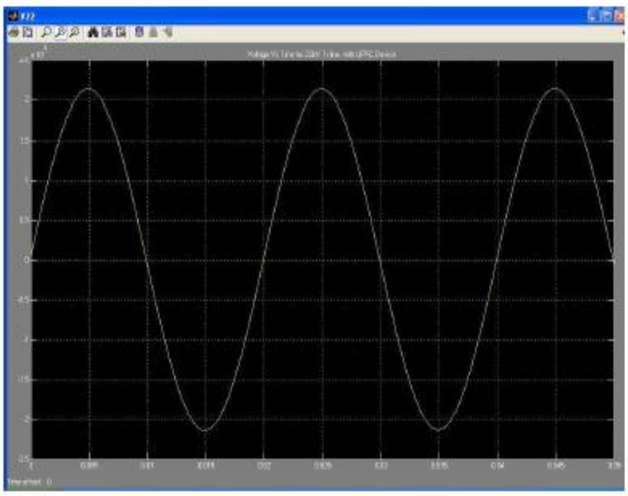

Fig.4.2. Voltage magnitude of 22 kV Transmission Line.

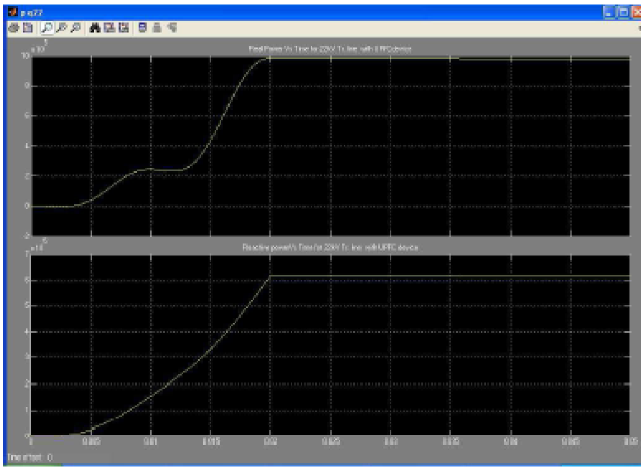

Fig.4.3. Real and Reactive power flows of 22 kV Line.

By observing the above wave forms, at steady state time t = 0.02sec the voltage magnitude is 21.23kV, the real power is 98.15MW and the reactive power is 61.64 MVAr.

IV. CONCLUSIONS

In the simulation study, Matlab Simulink environment is used to simulate the model of UPFC connected to a 3 phase system. The modelling of UPFC and analysis of power systems 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 for installation on a transmission line. Simulation results show the effectiveness of UPFC in controlling real and reactive power through the line. It is necessary to maintain the voltage magnitude, phase angle and line impedance of the transmission system. In this paper the (UPFC) simulation study, matlab simulink is used to simulate the model of UPFC connected to a 3 phase transmission system.

V. FUTURE SCOPE

The UPFC model can be reduce the harmonics and ability to control real and reactive powers. The heating in the transformers is reducing by using multilevel response. This is due to the reduction in the harmonics. So That the simulation results are in line with the predictions .They are used for power quality too.

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