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Enhancement of Power System Performance in IEEE 14-Bus by Using UPFC

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***Abstract*: -- Nowadays, the demand for electricity generation is increased tremendously as the utilization of it and other distributed power systems have expanded drastically. With respect to demand of power, at times, it is not possible as well as economical to set up new /transmission lines. The increment in the non-linear loads and the consumption of electrical energy in power systems tend to force the electrical power utilities to provide a large electrical power and this is the cause that this problem becoming more and more significance in power systems. Hence in Electrical Power System for governing, UPFC is the most promising FACTS controller. UPFC is the versatile facts device which can provide full dynamic control of transmission line parameter, bus voltage, line impedance as well as angle, for improvement of system stability and security. In this paper, Unified Power Flow Controller is studied to improve the power flow over a transmission line in a standard IEEE 14 bus system by using MATLAB / SIMULINK. For the selected system, active and reactive power flows are compared with and without UPFC.**

Keywords: - FACTS, IEEE-14 Bus system, UPFC, Power system performance.

I. INTRODUCTION

The technology of power system utilities around the world has rapidly evolved with considerable changes in the technology along with improvements in power system structures and operation. The ongoing expansions and growth in the technology, demand a more optimal and profitable operation of a power system with respect to generation, transmission and distribution systems. [2] Sensitive equipment and non-linear loads are commonplace in both the industrial and the domestic environment; because of this au heightened awareness of power quality is developing. The sources of problems that can disturb the power quality are: load switching, large motor starting, embedded generation, sensitive equipment, storm and environment related damage, network equipment and design. The solution to improve the power quality at the load side is of great important when the production processes get more complicated and require a bigger liability level, which includes aims like to provide energy without interruption, without harmonic distortion and with tension regulation between very narrow margins. In the present scenario, most of the power systems in the developing countries with large interconnected networks share the generation reserves to increase the reliability of the power system. However, the increasing complexities of large interconnected networks had fluctuations in reliability of power supply, which resulted in system instability, difficult to control the power flow and security problems that resulted large number blackouts in different parts of the world. The reasons behind the above fault sequences may be due to the systematic errors in planning and operation, weak interconnection of the power system, lack of maintenance or due to overload of the network. In order to overcome these consequences and to provide the desired power flow along with system stability and reliability, installations of new transmission lines are required. However, installation of new transmission lines with the large interconnected power system are limited to some of the factor like economic cost, environment related issues. These complexities in installing new transmission lines in a power system challenges the power engineers to research on the ways to increase the power flow with the existing transmission line without reduction in system stability and security. [2]

II. INTRODUCTION TO FACTS TECHNOLOGY:-

In the late 1980's the Electric Power Research Institute (EPRI) introduced a concept of technology to improve the power flow, improve the system stability and reliability with the existing power systems. This technology of power electronic devices is termed as Flexible Alternating Current Transmission Systems (FACTS) technology. It provides the ability to increase the controllability and to improve the transmission system operation in terms of power flow, stability limits with advanced control technologies in the existing power systems. FACTS technology is not a single power electronic device but a collection of controllers that are applied individually or in coordination with other devices to control one or more interrelated power system parameters such as series impedance, shunt impedance, current, voltage and damping of oscillations. These controllers were designed based on the concept of FACTS technology known as FACTS Controllers. FACTS controllers are advanced in relation to mechanical control switched systems that are controlled with ease. They have the ability to control the power flow and improve the performance of the power system without

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changing the topology. Unified Power Flow Controller (UPFC) is one among the different FACTS controllers introduced to improve the power flow control with stability and reliability. [1]

2.1 The main objective to introduce FACTS Technology is as follows:-

- To increase the power transfer capability of transmission network in a power system.
- To provide the direct control of power flow over designated transmission routes.
- To provide secure loading of a transmission lines near the thermal limits.

2.2 Benefits of utilizing facts devices:-

The benefits of utilizing FACTS devices in electrical transmission systems can be summarized as follows:

- Better utilization of existing transmission system assets.
- Increased transmission system reliability and availability.
- Increased dynamic and transient grid stability and reduction of loop flows.
- Increased quality of supply for sensitive industries.
- Environmental benefits Better utilization of existing transmission system assets.

III. UNIFIED POWER FLOW CONTROLLER (UPFC) :-

Among all the FACTS devices the most flexible and universal device is unified power flow controller (UPFC). It is a combination of three compensator's characteristics, i.e. impedance, voltage magnitude and phase angle, that are able to produce a more complete compensation. By controlling impedance, voltage magnitude, phase angle Unified power flow controller (UPFC) is used to control the power flow in the transmission systems. This controller brings in new challenges power electronics and power system design. In terms of static and dynamic operation of the power system this controller also offers advantages. The basic structure consists of two Voltage Source Inverter's (VSI's); where one converter is connected in series with transmission line while other converter is connected in parallel to the transmission line. [4]

3.1 Construction of UPFC :-

The UPFC consists of two voltage source converters; series and shunt converter, which are connected to each other with a common dc link. Shunt converter or Static Synchronous Compensator (STATCOM) is used to provide reactive power to the ac system, beside that, it will provide the dc power required for both inverter, while series converter or Static Synchronous Series Compensator (SSSC) is used to add controlled voltage magnitude and phase angle in series with the line. Each of the branches consists of a transformer and power electronic converter. These two voltage source converters shared a common dc capacitor. [4]

3.2 Operating principle of UPFC:-

The UPFC is the most versatile and complex of the FACTS devices, combining the features of the STATCOM and the SSSC. The main reasons behind the wide spreads of UPFC are: its ability to pass the real power flow bi-directionally, maintaining well regulated DC voltage, workability in the wide range of operating conditions etc. The basic components of the UPFC are two voltage source inverters (VSIs) sharing a common dc storage capacitor, 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. The DC terminals of the two VSCs are coupled and this creates a path for active power exchange between the converters. Thus the active supplied to the line by the series converter can be supplied by the shunt converter as shown in figure. Therefore, a different range of control options is available compared to STATCOM or SSSC. The UPFC can be used to control the flow of active and reactive power through the transmission line and to control the amount of reactive power supplied to the transmission line at the point of installation. The series inverter is controlled to inject a symmetrical three phase voltage system 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 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 that generates or absorbs reactive power to regulate the voltage magnitude at the connection point. Instead, the series inverter is operating as SSSC that generates or absorbs reactive power to regulate the current flow, and hence the power flows on the transmission line. The UPFC can also provide simultaneous control of all basic power system parameters, viz., transmission voltage, impedance and phase angle. The UPFC has many possible operating modes: Var control mode, automatic voltage control mode, direct voltage injection mode, phase angle shifter emulation mode, line impedance emulation mode and automatic power flow control mode. [1]

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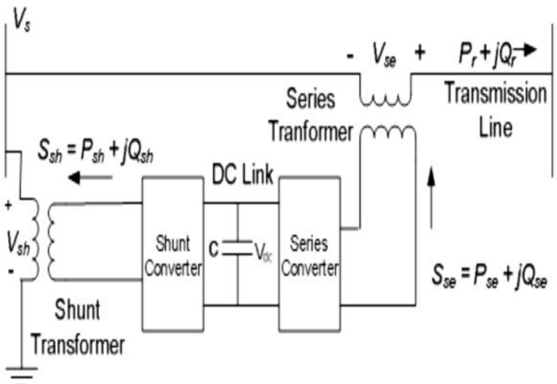

Fig.1 Basic circuit arrangement of UPFC

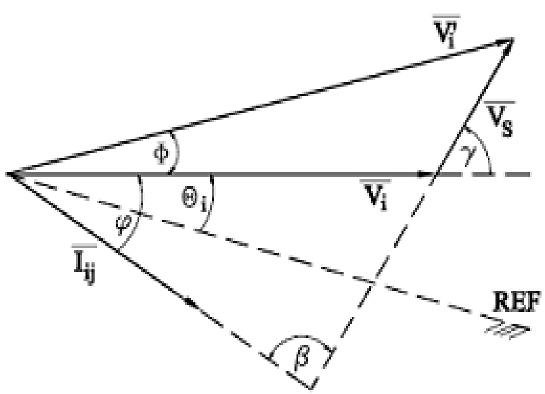

Fig.2 Phasor Diagram of UPFC

3.3 Mathematical modelling of UPFC:-

In this model, we have considered the UPFC is placed at the centre of a 300km transmission line. This model was derived with to study the relationship between electrical transmission system and UPFC in steady state conditions. The basic scheme is shown in fig.3 [26]. A UPFC can be represented by two voltage sources representing fundamental components of output voltage waveforms of the two converters and impedances being leakage reactance of the two coupling transformers. Based on the basic principle of UPFC and network theory, the active and reactive power flows in the line, from bus-i to bus-j, having UPFC can be written as-

$$P_i = P_{Gi} - P_{Di}^0(1+\lambda) = \sum_{j\in N_b} P_{ij} \cdot\cdot$$

$$Q_i = Q_{Gi} - Q_{Di}^0(1+\lambda) = \sum_{j\in N_b} Q_{ij}$$

3.4 Operating modes of UPFC:-

The UPFC has many possible operating modes. In particular, the shunt inverter is operating in such a way to inject a controllable current, into the transmission line. This current consists of two components with respect to the line voltage: the real or direct component, which is in phase or in opposite phase with the line voltage, and the reactive or quadrature component, which is in quadrature. The direct component is automatically determined by the requirement to balance the real power of the series inverter. The quadrature component, instead, can be independently set to any desired reference level (inductive or capacitive) within the capability of the inverter, to absorb or generate respectively reactive power from the line. The shunt inverter can be controlled in two different modes:-

- **VAR Control Mode:-**

The reference input is an inductive or capacitive VAR request. The shunt inverter control translates the VAR reference into a corresponding shunt current request and adjusts gating of the inverter to establish the desired current. For this mode of control a feedback signal representing the dc bus voltage, Vdc, is also required.

- **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. For this mode of control, voltage feedback signals are obtained from the sending end bus feeding the shunt coupling transformer. The series inverter controlS the magnitude and angle of the voltage injected in series with the line to influence the power flow on the line.

- **Direct Voltage Injection Mode:-**

The reference inputs are directly the magnitude and phase angle of the series
voltage. [2]

IV. IEEE 14 BUS TEST SYSTEM

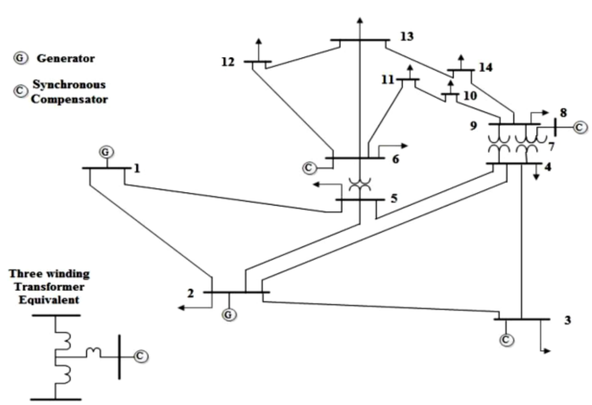

Fig.3: IEEE 14 bus test system.

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It consist of 2 generators, 2 transformers, 3 synchronous compensators, 14 buses and loads.

V. CONCLUSION

As from the literature studies and comparison of the facts controller and other technologies of improvement of system performance, UPFC is the best facts device among all the facts controller and other technologies for the improvement of system performance. Thus UPFC is introduced in IEEE 14 bus system after finding proper location of weak bus by load flow analysis and further result will be analyse.

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