Improvement of Power Flow and Voltage Stability using Unified Power Flow Controller

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Abstract- *In this paper we are discussing about a FACTs device named as UPFC (unified power flow controller). Its special features are to control active and reactive power course in a transmission line and to adjust the voltage at the bus at which it is situated. This device gives great quality blow on power system stability; these features even more considerable and perceptive that the unified power flow controller can be apply to the transmission line with in their limits and enhancing the power to flow through the preferred path. So this device gives unique control on the power flow and voltage stability.*

In this paper the working of UPFC is in the field of control flow of power in transmission-line .This research regarding the 6-bus power system to control the active and reactive power in the course of transmission line by keeping this controller at the sending end by simulation tools. When there is no FACTs device (UPFC) the active power, reactive power and voltage through the transmission line cannot be controlled. The circuit model for UPFC is developed using rectifier and inverter circuits. In this thesis, the power system simulation models are made on MATLAB version 7.13. By making the power system simulation model, we are getting result without and with using UPFC and after that these results are compared in form of real and reactive power in the transmission line. On the basis of simulation results and to analyse the performance of UPFC, we can conclude that UPFC is ideal controller for performing such parameters.

Keywords- Facts, Upfc, Svc, Real& Reactive Power, Voltage Stability, Power System Simulation, Matlab Version 7.13.

I. INTRODUCTION

A power grid system is a combination of electrical constraints utilized to offer, transfer and utilization of electrical power.We can categorize this into three sub-divisions of power system are generation, transmission and distribution system. All these subsystem are under control of one body in that particular geographical area which supplying power at regulated rates. For economic purpose we deregulate power grid system in whichgeneration, transmission and distribution occur separately. The electrical power demand is growing rapidly and due to economic and environmental facts building of new generating unit and transmission circuit is much complicated. So power utilities are pressured to rely on utilization of existing generating unit and to load existing x-ion line near to their thermal limits. Stability should be maintained at each instant so to operate power system effectively, unchanged system security and good quality of supply.In case of abnormal condition like x-line loss, generating unit loss which happens frequently and it will most possibly happens at higher frequency.

So a latest control method should be implemented. In 1980 a new technology program which is famous as FACTS has introduced by EPRI.The basic behind this program is to increase controllability and optimize the utilization of the existing PS capabilities and optimum utilization of existing PS capacities through replacement of mechanical controller by reliable and high speed electronic device. Solid state synchronous concept devices are now a day used.

The UPFC is the most efficient and powerful are broadly utilized to manage the power flow through the grid system. Here used the FACT type of controller to optimum the power flow in their transmission system.

Static is an analysis at the steady state condition and dynamic is an analysis at the transient condition such as faults occur in transmission system. This chapter described about basic principle of UPFC and the load flow analyses.

II. SCOPE OF WORK

The aim of the project is to model UPFC and its control circuit using SIMULINK and to analyses the control circuit for effective power flow control and system stability in power transmission system using three different control schemes –

1. Real and Reactive power flow control
2. Sending bus voltage magnitude control
3. DC voltage magnitude control.

UPFC is installing in transmission line to controlling the both real and reactive power and also control the output voltage of the system. It is the study of Unified Power Flow

Controller and its role in damping power oscillations to improve system performance.

THE UNIFIED POWER FLOW CONTROLLER

The unified power flow controller (UPFC) is an associate of the cluster of FACTS equipment's that offers synchronous voltage source theory for offering efficient control on the grid system. Within the structure of traditional power transmission concepts, the UPFC is able to control simultaneously or electively all the parameters affecting power now in grid system. This chapter presents operating characteristics and features of the UPFC. The various features have been supported by simulation results.

REAL AND REACTIVE POWER CONTROL USING UPFC

A simple two machine system with sending-end voltage V_s. receiving-end voltage V_r and line impedance X is shown in Figure 1 (a). Figure 1 (b) shows the system voltages in the form of a phasor diagram with transmission angles δ and

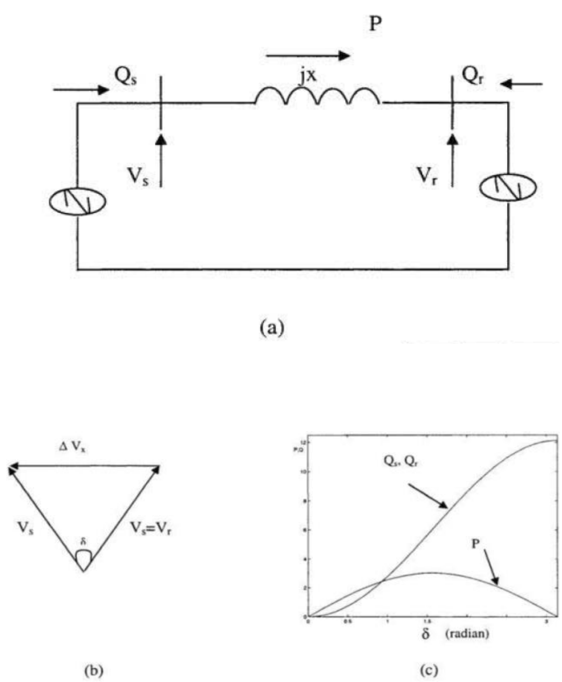

Figure: 1 (a) A basic two machine system (b) Voltage phasor, (c) Real and reactive power to transmission angle.

The elementary system of Figure 1 (a) has been used as a building block to explain the capability of the UPFC to control the real power P and reactive power Q_S and Q_R at the sending-end and the receiving end of line respectively.

Figure 2 shows the power system of Figure 1 (a) included with a UPFC. The UPFC is represented by a controllable voltage source in series with the line which, as explained in the previous section, can generate or absorb reactive power from the sending-end generator. The voltage injected by the UPFC in series with the line is represented by V_{pq}having magnitude V_{pq} ($0V_{pq}V_{pqmax}$) and phase angle. To represent the UPFC properly, the series voltage source is designed to generate only the reactive power Q_{pq} it exchanges with the line.

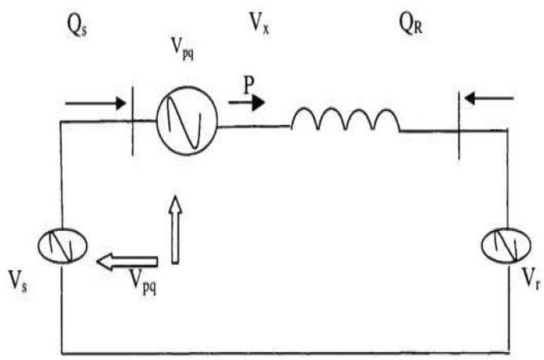

Figure 2: Two machine system with UPFC.

UPFC Injection Model for Load Flow Studies

The UPFC injection model can be easily implemented in load flow programs. If this UPFC is positioned among node i and node j in a power grid system, the Y_{BUS}admittance matrix must be modified to consider the new bus (corresponding to V' in FIG 1) and include the reactance X_s of the UPFC. The Jacobian matrix is modified by the addition of appropriate injection powers.

The model is implemented in a full Newton-Raphson program. Newton Raphson method is found to be more efficient and practical. There are two equations for each load bus and one equation for each voltage controlled bus.

Expanding the power flow equations in Taylor's series results in the following set of mathematical (linear) equations.

$$\begin{bmatrix} \Delta P_2^{(k)} \\ \vdots \\ \Delta P_n^{(k)} \\ \Delta Q_2^{(k)} \\ \vdots \\ \Delta Q_n^{(k)} \end{bmatrix} = \begin{bmatrix} \frac{\partial P_2^{(k)}}{\partial \delta_2} & \frac{\partial P_2^{(k)}}{\partial |V_2|} \\ \frac{\partial P_n^{(k)}}{\partial \delta_n} & \frac{\partial P_n^{(k)}}{\partial |V_n|} \\ \frac{\partial Q_2^{(k)}}{\partial \delta_2} & \frac{\partial Q_2^{(k)}}{\partial |V_2|} \\ \frac{\partial Q_n^{(k)}}{\partial \delta_n} & \frac{\partial Q_n^{(k)}}{\partial |V_n|} \end{bmatrix} \begin{bmatrix} \Delta \delta_2^{(k)} \\ \vdots \\ \Delta \delta_n^{(k)} \\ \Delta |V_2^{(k)}| \\ \vdots \\ \Delta |V_n^{(k)}| \end{bmatrix}$$

In the above equation, bus 1 is assumed to be the slack bus. ΔPn and ΔQn are the difference between the scheduled and calculated values, known as power residuals.

The matrix which contains the partial derivatives is called the Jacobian matrix. Elements of the Jacobian matrix are the partial derivatives of power flow equations evaluated at and. The Jacobian matrix offers the liberalized relationship among small changes in voltage angle Δδn and voltage magnitude. In undersized form, it may be rewritten as

$$\begin{bmatrix}\Delta P\\ \Delta Q\end{bmatrix} = \begin{bmatrix} H & N\\ J & L\end{bmatrix}\begin{bmatrix}\Delta\delta\\ \Delta V/V\end{bmatrix}$$

The state variables related to the UPFC controller are merged by means of the network voltage magnitudes and angles in a single casing of reference for a joined solution through Newton-Raphson method. The UPFC equations are joined with the linearized type of equations corresponding to the respite of the network.

The resulting system equation is represented as

$$[f(X)] = [J]\,[\Delta X]$$

Where, J is the Jacobian matrix and [ΔX] is the mismatch vector,

Equation is included in the power mismatch equations.

The change is reflected in the Δx vector. The original dimensions of the mismatch vector are not altered at all. The Jacobian matrix is personalized by summing of suitable injection powers.

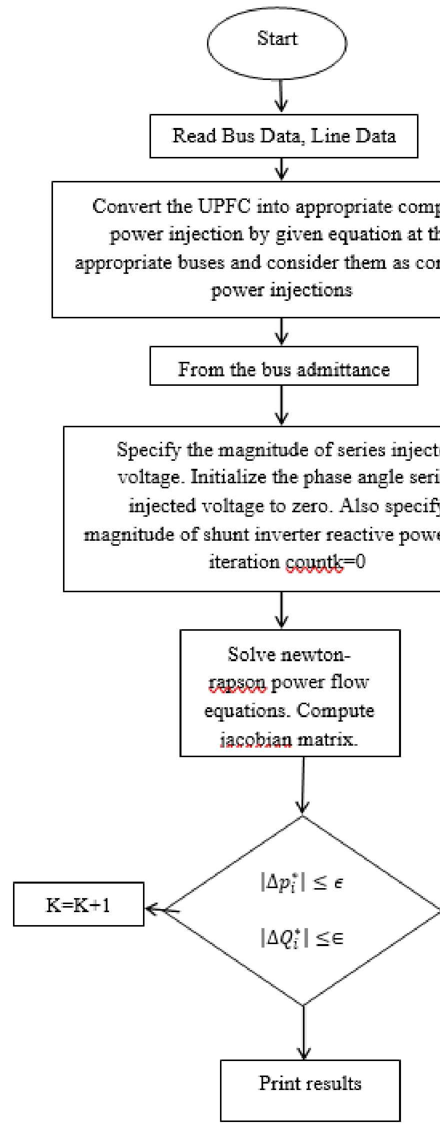

Figure 3 Flow chart for determining load flow solution including the UPFC model

III. SIMULATION AND CASE STUDIES

A UPFC is used to manage the power flow in a 500KV /230 kV transmission systems. The system, associated in a loop arrangement, comprises of five buses (B1, B2, B3, B4, B5) joined by three transmission lines (L1, L2, L3) and two units of 500 kV/230 kV transformers bank named as T1 and T2. Two power plants situated on the 230 kV system produce a total of 1500 MW (Fig. 4) which is spread to a 500 kV, 1500 MVA and to a 500 MW load attached at bus B3. Every plant model comprises a speed regulator, and an excitation system and a Power System Stabilizer (PSS). In usual process, mainly of the 1200 MW generation power of power plant 02 is given to the 500 kV equivalents in the course of two 400 MVA transformers attached among buses B4 and B5. For this design, we think about a special case in which only two transformers out of three units are accessible. The load flow depicts that the majority part of the power developed by plant 02 is spread in the course of the 800 MVA transformer banks and the 96 MW is spreading in the loop pattern. Transformer T2 is then extra loaded to 99 MVA. This would be demonstrating that will a UPFCdevice can mitigate this power blocking.The UPFC placed at the right hand side end of line L2 is utilized to adjust the real and reactive powers to the 500 kV bus B3, and the voltage at bus named B_UPFC. The UPFC device comprises of two 100 MVA, IGBT type, converters (one series converter and one shunt converter coupled by a DC bus). The series converter will gives a maximum of 10% of rated line-to- ground voltage in series attached with line L2.

The single line diagram demonstrated in Fig is implemented on MATLAB SIMULATION in sim-power system to test the existence of the UPFC device. The Model of UPFC device would give two types of outcomes. The measurements system and model of UPFC controller are depicted in Fig. respectively. Initial outcome is regarding the simulations at power flow adjustment module and second outcome is voltage injection Module. The essential keys to message in the block diagram are, elements of the UPFC device are specified in the dialog box. In the Power control elements that the series converter is at nominal 100 MVA with a peak voltage injection of 0.1 Pu. The shunt converter is also at nominal 100 MVA. Also, in the adjustment elements, that the shunt converter is in Voltage adjustment module and that the series converter is in Power flow adjustment module.

The UPFC device has refserence value of real and reactive powers are put in the magenta blocks named Pref (pu) and Qref (pu). At start the Bypass breaker is blocked and the resulting natural power flow at bus B3 is 587 MW and -27 Mvar. The Pref box is programmed with a preliminary active power of 5.87 pu related to the natural power flow. Thus, at t = 10s, Pref is amplified by 1 pu from 5.87 puto 6.87 pu, whereas Qref is held at constant value at -0.27 pu.

The results of Optimal power flow like voltage profile, real and reactive power flow in electrical transmission lines are evaluated and argued. The outcome of occurrence of UPFC and impact of positions of UPFC on buses of power grid system in voltage amplitude and phase angle of voltage and real and reactive of power flow in transmission lines are evaluated and performances are analysed.

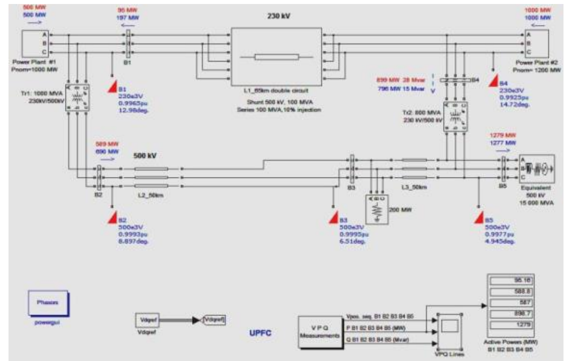

Figure 4: Simulink model of test power system without UPFC

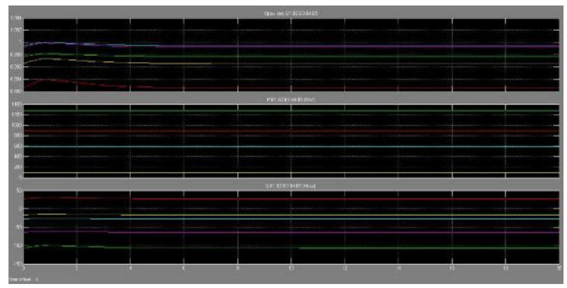

Figure 5: VPQ waveforms without UPFC

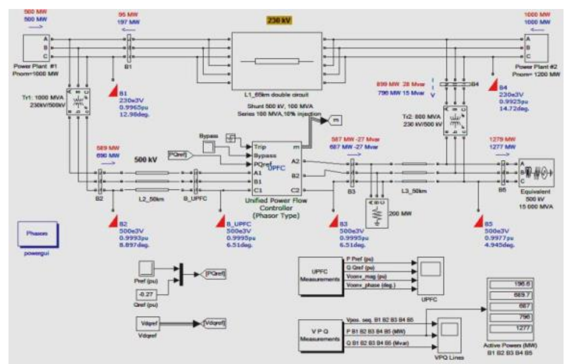

Figure 5: Simulink model of test power system with UPFC

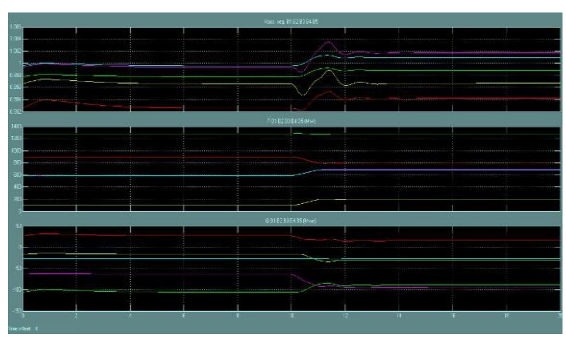

Figure 6: VPQ waveforms

Table 1 depicts the amplitude of voltage at buses of electrical power grid system. Amplitude of voltage at buses of power system for six case studies at buses 1, 2,3,4,5 of power system has been demonstrated.

Table 2 depicts the real power flow in electrical transmission lines of power system. Performances of simulation for Real power flow B1, B2, B3, B4 and B5 of power system have been demonstrated. To facilitate best realize the impact of positions of implementing the UPFC device.

Table 3depicts the reactive power flow in transmission lines of power system. Performances of simulation for reactive power flow at buses B1, B2, B3, B4 and B5 of electrical power system have been demonstrated.

SIMULATION RESULTS FOR POWER TRANSFER CAPABILITY:

Table 1 Magnitude of voltage

Bus	Without UPFC	With UPFC
B1	0.9965	0.9968
B2	0.9993	1.0017
B3	0.9995	1.001
B4	0.9925	0.9942
B5	0.9977	0.9987

Table 2 Active Power

Bus	Without UPFC	With UPFC
B1	95.2	196.6
B2	588.7	689.7
B3	586.997	687
B4	898.76	796
B5	1279.2	1277.2

Table 3 Reactive Power

Bus	Without UPFC	With UPFC
B1	-16.35	-30.1
B2	-63.3	-94.2
B3	-27.79	-27
B4	26.62	15.50
B5	-106.45	-90.01

IV. CONCLUSION

In this paper conclude that to facilitate the results of Unified Power Flow Controller (UPFC) technique to maintaining the course of power in the electrical transmission line. In power grid system transmission, it is enviable to control the voltage amplitude, phase angle and line parameters. So, to manage the power from one place to other place, this theory of power flow adjustment and voltage injection is applicable. Analysing the electrical system and on taking the results have specified a hint that UPFC are extremely valuable when it brings to arrange and control power system. In this revision the impacts of UPFC positions are examined on voltage profile and electrical transmission lines power course as active and reactive power are examined. This research deals with simulation of 5-bus power system utilizing UPFC to enhance the power transfer ability and system stability by an electrical transmission line by introduction of UPFC at the supplying terminal using modern simulation.

When no UPFC is installed, power transfer capability and system stability through the transmission line cannot be improved. The network model of UPFC is made utilizing rectifier and inverter network. The technical software MATLAB simulation performances are represented to authorize the model. The performance of network with utilized and without utilized UPFC are evaluated by means of real and reactive power flows in the electrical transmission line and real and reactive power flows to the bus(particular position) to examine the results of UPFC and got better result with UPFC model as compared to without UPFC model. In this thesis, the ability of controlling power flow to a multi-machine Infinite bus system utilizing UPFC device has been examined. The procedure of the three adjustment techniques comprises of, in-phase voltage adjustment, quadrature voltage adjustment and shunt compensation was also evaluated in enhancing the transient and dynamic stability of the electrical power grid system

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