Power Flow and Voltage Stability Improvement using UPFC

Lohith B A
Department of Electrical and Electronics Engineering
Sri Krishna Institute of Technology
Bangalore, India

Megharaj M, Mohan T, Raghavendra G, Avinash S
Department of Electrical and Electronics Engineering Sri Krishna Institute of Technology
Bangalore, India

***Abstract*- Our Project propose the Real, Reactive Power and voltage control through a transmission line by putting UPFC (Unified Power Flow Controller) at the sending end side Using Computer Simulation Software. The control scheme has the fast dynamic response and hence is satisfactory or acceptable for improving transient behaviour of power system after transient conditions. If there is no UPFC (Unified Power Flow Controller) is installed at Sending end Side Real, Reactive Power through the transmission line can't be controlled. The UPFC (Unified Power Flow Controller) is a Type of FACTS (Flexible AC Transmission Systems) device that is developed to a high degree of Complexity and complex power electronic equipment and has developed for the control and optimization of power flow and also to regulate the voltage in High voltage electrical power transmission system. In this control system, we are using Generalized Pulse Width Modulation(PWM) Technique to generate firing pulses for Shunt and Series converters. Computer Simulation Can be Carried out MAT-LAB/P SCAD software to know and check the performance of UPFC.**

***Keywords*- UPFC, FACTS, SSSC, STATCOM.**

I. INTRODUCTION

The project aim is to design a FACTS device named as UPFC. Its special features(aspects) are to control active and reactive power in a transmission line and to adjust the voltage at the buses. This FACTS device gives great quality power flow 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 thisthe power system simulation models are made in MAT-LAB 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. 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 which generation, transmission and distribution occur separately. The electrical power demand is growing rapidly and due to economic and environmental facts building of newgenerating 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. LITERATURE SURVEY

In general, FACTS controllers can be divided in following categories:

- Series controllers such as Thyristor Controlled Series Capacitor (TCSC), Thyristor Controlled Phase Angle Regulators (TCPAR or TCPST), and Static Synchronous Series Compensator (SSSC)

- Shunt controllers such as Static Var Compensator (SVC), and Static Synchronous Compensator (STATCOM)
- Combined series-series controllers such as Interline Power Flow Controller(IPFC)
- Combined series-shunt controllers such as Unified Power Flow Controller(UPFC)

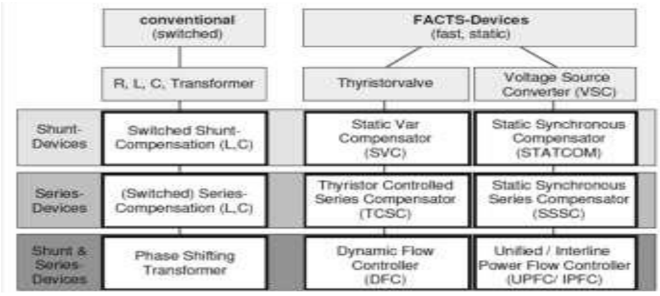


Fig.1. Principals Dis positive of FACTS Systems

UNIFIED POWER FLOW CONTROLLER (UPFC)

The UPFC is the most versatile and powerful FACTS device. UPFC is also known as the most comprehensive multi variable flexible AC transmission system (FACTS) controller. Simultaneous control of multiple power system INTERNATIONAL JOURNAL OF ENERGY, Issue 4, Vol. 6, 2012 115 variables with UPFC posses enormous difficulties. In addition, the complexity of the UPFC control increases due to the fact that the controlled and the variables interact with each other. A combination of static synchronous compensator (STATCOM) and a static synchronous series compensator (SSSC) which are coupled via a common DC link, to allow bidirectional flow of real power between the series output terminals of the SSSC and the shunt output terminals of the STATCOM, and are controlled to provide concurrent real and reactive series line compensation without an external electric energy source. The UPFC, by means of angularly unconstrained series voltage injection, is able to control, concurrently or selectively, the transmission line voltage, impedance, and angle or, alternatively, the real and reactive power flow in the line. The UPFC may also provide independently controllable shunt reactive compensation.

The UPFC consists of two voltage source converters series and shunt converter, which are connected to each other with a common DC link. Series converter or Static Synchronous Series Compensator (SSSC) is used to add controlled voltage magnitude and phase angle in series with the line, while 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. Each of the branches consists of a transformer and power electronic converter. These two voltage source converters shared a common DC capacitor.

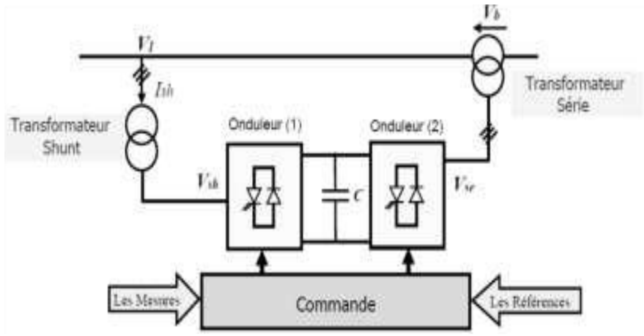


Fig.2. Schematic of three phases connecting between Power network and UPFC

The energy storing capacity of this DC capacitor is generally small. Therefore, active power drawn by theshunt converter should be equal to the active power generated by the series converter. The reactive power in the shunt or series converter can be chosen independently, giving greater flexibility to the power flow control. The coupling transformer is used to connect the device to the system. Shows the schematic diagram of the three phases UPFC connected to the transmission line.

A. Series Controllers

Series controllers inject voltage in series with the line. As long as the voltage is in phasequadrature with the line current, the series controller onlysupplies or consumes variablereactive power. Another phase relationships will involve handling of real power as well.

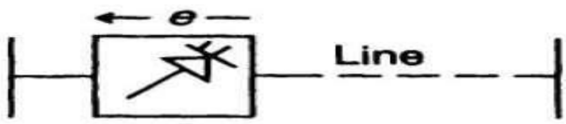


Fig 3. SSSC is One Such Series Controller

B. 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 ofreal power as well.

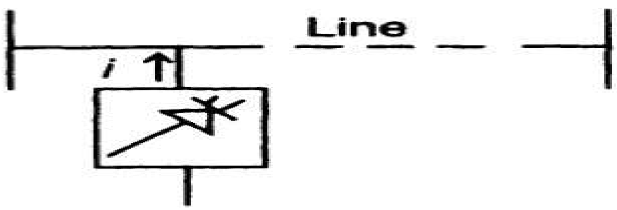


Fig 4. STATCOM is One Such Series Controller

C. Combined Series Series Controllers

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

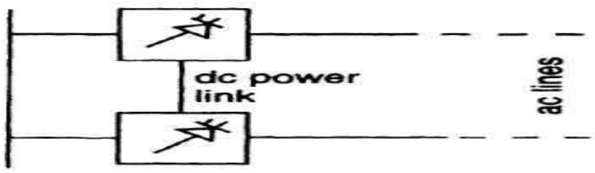


Fig 5. IPFC Comes in this Category

D. Combined Series Shunt Controllers

This could be a combination of separates hunt 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

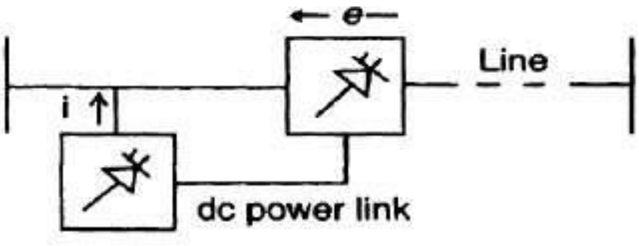


Fig 6. UPFC is One Such Series Controller

III. WORKING PRINCIPLE OF UPFC

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 –

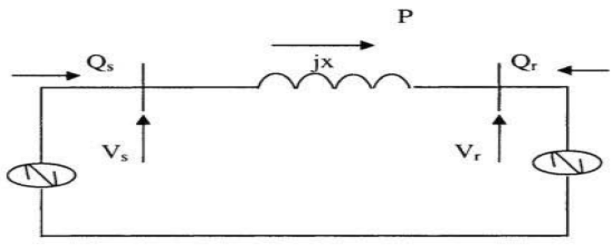
1. Real and Reactive power flow control
2. Sending bus voltage magnitude control
3. DC voltage magnitude control.

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 (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 orelectively 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.

A. Real and reactive flow control using UPFC

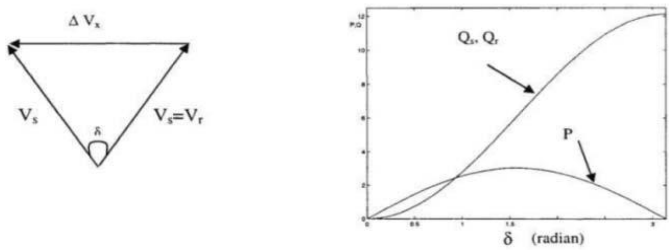
A simple two machine system with sending-end voltage Vs.receiving-end voltage Vr and line impedance X is shown and system voltages in the form of a phasor diagram with transmission angles and



(a)

Fig 7(a). Basic two machine system

The elementary system of has been used as a building block to explain the capability of the UPFC to control the real power P and reactive power QS and QR at the sending-end and the receiving end of line respectively.



(b) (c)

Fig 7(b). Voltage Phasor Fig 7(c). Real and Reactive Power to Transmission angle

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 Vpq having magnitude Vpq (0VpqVpqmax) and phase angle. To represent the UPFC properly, the series voltage source is designed to generate only the reactive power Qpq it exchanges with the line.

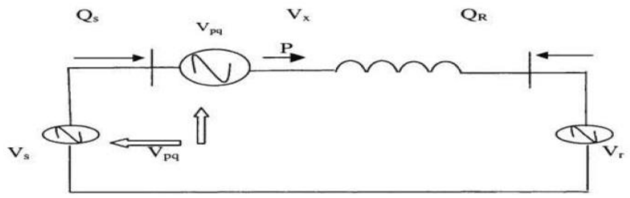


Fig 8. Basic two machine system with UPFC

The Proposed System For Power Quality Using Unified Power Flow Controller (UPFC)

The Operating Principal of UPFC

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. A basic UPFC functional scheme is shown.

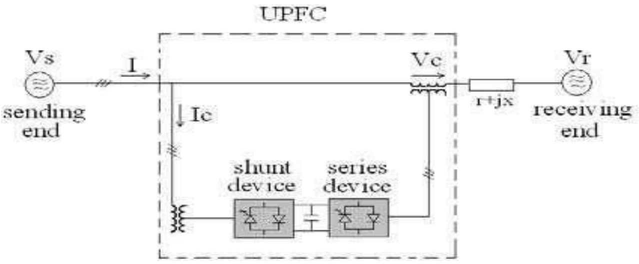


Fig 9. Basic Functional Scheme of UPFC

The series inverter is controlled to inject a symmetrical three phase voltage system (Vse), 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. There active 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 V DC constant. So, the neutral power absorbed from theline 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 lines 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 regulate the current flow, and hence the powers flow on the transmissionline.The UPFC has many possible operating modes. In particular, the shunt inverter is operatingin such a way to inject a controllable current, is to the transmission line. The shunt inverter can be controlled in two different modes:

3.1.1 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 signalrepresenting the DC bus voltage, Vdc, is also required.

3.1.2 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. 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. The actual value of the injected voltage can be obtained in several ways.Direct Voltage Injection Mode: The reference inputs are directly the magnitude and phaseangle of the series voltage.Phase Angle Shifter Emulation mode: The reference input is phase displacement between the sending end voltage and the receiving end voltage.Line Impedance Emulation mode: The reference input is an impedance value to insert inseries with the line impedance.Automatic Power Flow Control Mode: The reference inputs are values of P and Q to maintain on the transmission line despite system changes.

3.2 UPFC CONTRUCTION

The UPFC consists of two voltage source converters; series and shunt converter, which are connected to each other with a common DC link. Series converter or Static Synchronous Series Compensator (SSSC) is used to add controlled voltage magnitude and phase angle in series with the line, while 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. Each of the branches consist of transformer and power electronic converter. These two voltage source converters shared common DC capacitor .The energy storing capacity of this DC capacitor is generally small. Therefore active power drawn by the shunt converter should be equal to the active power generated by the series converter. The reactive power in the shunt or series converter can be chosen in dependently, giving greater flexibility to the power flow control. The coupling transformer is used to connect the device to the system. The schematic diagram of the three phase UPFC connected to the transmission line is in the below Figure.

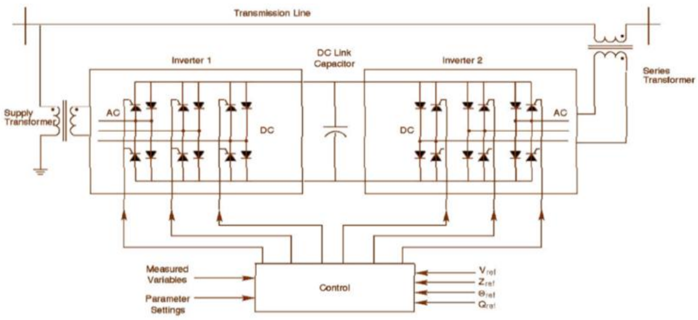


Fig 10. Schematic Diagram of 3P UPFC connected to Transmission Line Control

Control of power flow is achieved by adding the series voltage, VS with a certain amplitude, VS and phase shift ,φ toV1. This will gives a new line voltage V2with different magnitude and phase shift. As the angle φ varies, the phase shift δ between V2 and V3 also varies. Figure shows the single line diagram of the UPFC and phase or diagram of voltage and current.

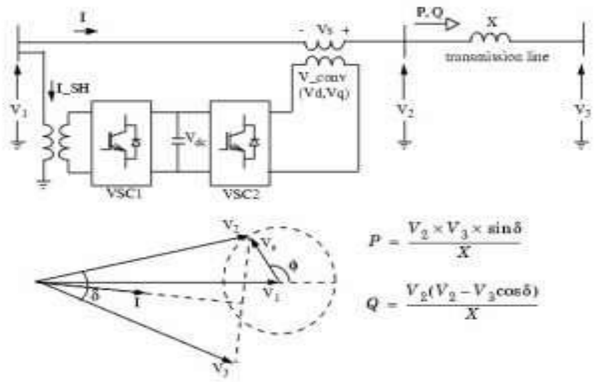


Fig 11. SLD of UPFC and Phase Diagram of Voltage and Control

3.3 Operating diagrams of the UPFC.

We can summarized the principals functions of the UPFC in the following diagrams:

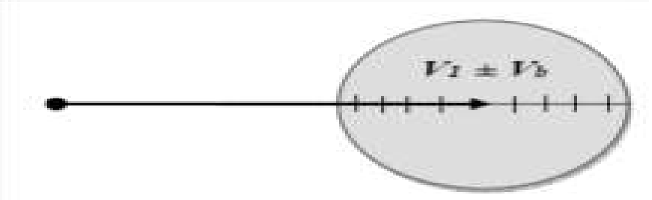


Fig (a). A Pure Voltage Regulator if the Voltage VBE is Inserted in Phase With Voltage V2

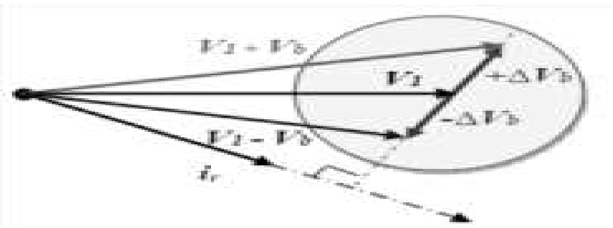


Fig (b). Impedance Controller if the additional voltage Vb is Perpendicular to Line Current Ir

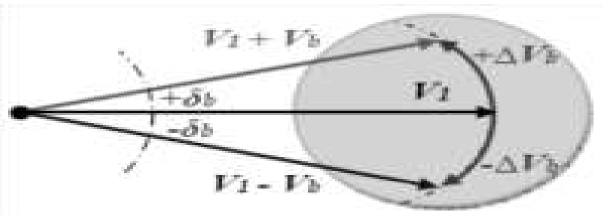


Fig (c). A regulator of the phase angle if the amplitude and phase of the voltage Vb injected are calculated so as to obtain the same module of the voltage before and after the UPFC.

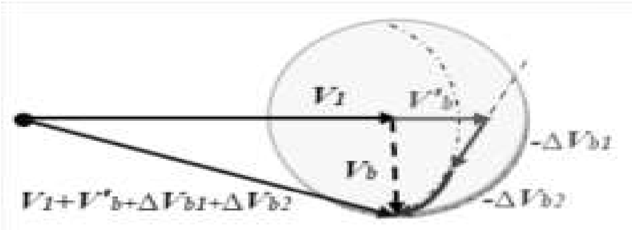


Fig (d). The UPFC is able to combine the different compensations of earlier and switch from one mode to another perpendicular to the line current Ir.

Fig 12 Principals functions of the UPFC (a),(b),(c) and (d)

IV. 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 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 UPFC device 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% o rated line-to- ground voltage in series attached with line L2.

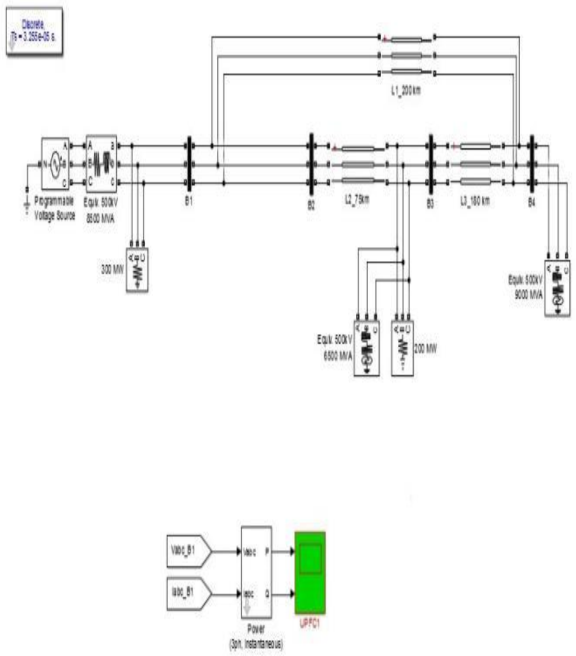


Fig.13. Simulink model of test power system without UPFC

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 dialogue 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.

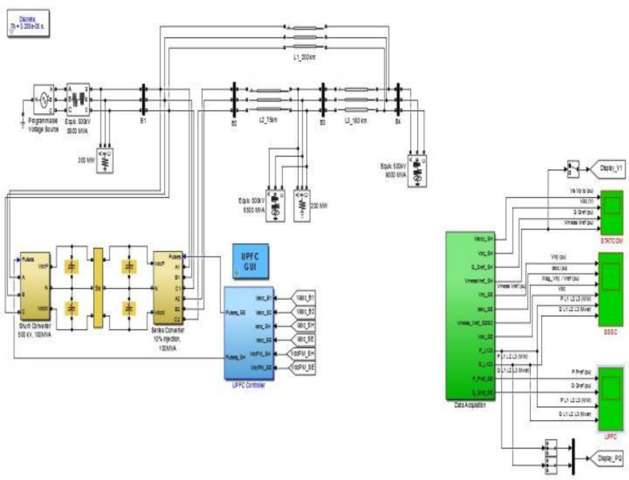


Fig.14 Simulink model of test power system with UPFC

The UPFC device has reference 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 pu to 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

V. RESULTS AND TABULATION

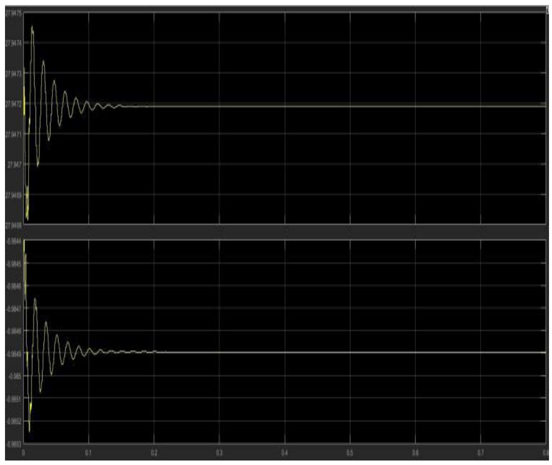


Fig. 15.VPQ Wave form for Without UPFC Circuit

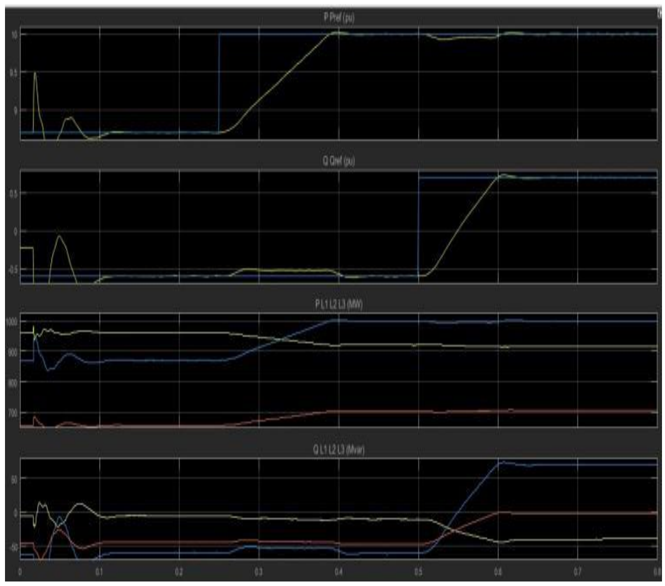


Fig.16.VPQ Wave form for With UPFC Circuit

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. e the author and affiliation lines for the second affiliation.

Table 1. Magnitude of Voltage

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

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 2. Active Powers

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

Table 3 depicts 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.

Table 3.Reactive Powers

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

VI. CONCUSION

The 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. 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.

REFRENCES

[1] M. Noroozian, L. Angquist, M. Ghandhari, and G. Anderson, "Use of UPFC for optimal power flow control," IEEE Trans. on Power Delivery, For a book citation:

[2] Zhang. Rehtanz. Pal ''Flexible AC Transmission Systems: Modelling and Control', Springer-Verlag Berlin Heidelberg 2006.

[3] L-Gyugyi, ''Unified power-flow concept for flexible ac transmission systems'', IEEE Proceedings-C, Vol.139, No.4, July 1992, pp. 323-33 10.

[4] Le DU A., "Pour un réseau électrique plus performant: l e projet FACTS" RGE n°6/92,June 1992, pp.105- 117.

[5] Belcheheb K., Saadate S., "utilization of the UPFC for optimal exploitation of costly centrals in the electrical systems", PEMC'98, Prague Czech Republic, September 98.

[6] L. Gyugyi, "Unified power flow control concept for flexible AC transmission systemsgeneration," in proc. Transmission distribution conf. vol 139, July 2003, pp.323-331.

[7] Douglas J., Heydt G.T., " Power flow control and power flow studies for systems with FACTS devices, in IEEE transactions on power systems,vol.13,n°1,February 1998, pp. .

[8] J. F. Keri, "Unified Power Flow Controller (UPFC): Modelling and analysis." IEEE . Trans. Power Delivery, vol. 14. pp.648-654, Apr. 1990.

[9] L. Gyugi, \A Uni¯Ed Power Flow Control Concept for Flexible AC Transmission Systems," IEEE Proceedings, Vol.139, No.4, pp. 323-331, July 1992.

[10] L. Gyugyi, C.D. Schauder, et al, \The Unified Power Flow Controller: A New Approach to Power Transmission Control," IEEE Transactions on Power Delivery, Vol. 10, No. 2, pp.1085-1093, April 1995.

[11] H. Fujita, Y. Watanabe, H. Akagi, \Control and Analysis of a Unified Power Flow Controller," IEEE Transactions on Power Electronics, Vol.14, No.6, pp. 1021-1027, November 1999.

[12] S.H. Hosseini, A. Ajami, \Dynamic Compensation of Power Systems Using a Multilevel Static Synchronous Series Compensator," the 8th International Iranian Conference on Electrical Engineering, May 2000.

[13] Mausam Yadav, Ankur Soni, Improvement of power flow and voltage stabilityusing unified power flow controller, International Conference on Electrical, Electronics, and Optimization Techniques (ICEEOT) - 2016