International Journal on Recent Technologies in Mechanical and Electrical Engineering (IJRMEE) ISSN: 2349-7947
Volume: 2 Issue: 10 027 - 031

Power Quality Enhancement in a Transmission Line using UPFC based on Fuzzy Logic Controller

Chandana.D
M.Tech student, Dept. of EEE,
SVU College of Engineering, S V University,
Tirupati, A.P., India
e-mail: chandana.dh@gmail.com

Dr.G.V.Marutheswar
Professor, Dept. of EEE,
SVU College of Engineering, S V University,
Tirupati, A.P., India
e-mail:marutheswargv@rediff.com

Abstract—Electrical power companies are concerned about improved, economical and reliable utilization of electrical energy. The operation and control of present power systems can be made feasible using FACTS devices to achieve fast and reliable power system control. Among all the facts devices, UPFC (Unified Power Flow Controller) is one of the most flexible device and can be accomplished for simultaneous control of both active and reactive power flows through injection of voltage in sequence with the line at the same time. In this paper, a standard 5-bus system is analyzed for the impact of power quality on a transmission line, the occurrence of voltage swell and sag conditions are compensated using UPFC, which is designed and compared via PI and FUZZY logic controllers in MATLAB/SIMULINK environment.

Keywords*-Unified Power Flow Controller; Power quality; PI Controller; Fuzzy Logic Controller; Total Harmonic Distortion.*

*****

I. INTRODUCTION

In power industry, from reliability and power quality point of view, the energy supplied to a consumer must be continuous. In the present period, the problems related to power quality issues are given most importance, due to the use of sophisticated devices as loads, which are very sensitive to the quality of power supply. Electronic devices (like PLC – Programmable logic Controllers, ASD – Adjustable Speed Drives, etc) changes the nature of electric loads, as they are non-linear, causes distortions in the voltage waveform. Due to the sensitivity of electronic devices, the tolerance of industrial loads to power quality problems (like voltage swell, sag and harmonic distortions, interruptions, flicker, transients) becomes less.

In a power system, the most important power quality problems are voltage swells/sags, because, their occurrence is more recurrent than other power quality event. Voltage Swell is the raise in RMS voltage, momentarily, at power frequency, from 110% to 180% of nominal value for a period of half cycle to several seconds. Voltage dip or sag is the voltage level drop off to 10% - 90% of nominal value, at power frequency, for a period of half cycle to several seconds.

The power quality problems in transmission, distribution and the end-use devices can be reduced by several procedures[2] like grid adequacy; distributed resources – Energy storage systems like Flywheels, super capacitors etc, Distributed generation; enhanced interface devices like static var compensators, UPFCs etc.

The power control and the utilizable capacity enhancement of present, as well as new and upgraded transmission lines can be made feasible using FACTS technology. The FACTS controllers have the ability to control the interrelated parameters that include impedance, voltage, current, phase angle and oscillation of frequency; to recover system performance by placement and coordination of various FACTS controllers in major emerging power system. Classifying FACTS controllers into different categories, we have series controllers like SSSC (Static Synchronous Series Compensator), TCSC (Thyristor Controlled Series Capacitor), TCPAR (Thyristor controlled Phase Angle Regulator); shunt controllers like SVC (Static Var Compenstor), STATCOM (Static Synchronous Compensator); combined series-shunt controllers like UPFC (Unified Power Flow Controller); combined series-series controllers like IPFC (Interline Power Flow Controller). In theory, for combined series-shunt controllers, the series part injects voltage in series with the line and shunt part injects current into the system. There can be a real power exchange between the series and shunt controllers through a dc link, when these series and shunt controllers are unified.

II. UNIFIED POWER FLOW CONTROLLER

Gyugyi introduced the UPFC concept in the year 1991, which is designed for dynamic compensation and for real time control of ac transmission systems. UPFC is a multi-functional controller with two voltage-sourced converters connected back to back, arranged in the manner, with one converter in series through a series transformer and the other in parallel with the transmission line through shunt transformer. This results in the independent control of both real and reactive power in line and voltage magnitude at the UPFC terminals. Selective and simultaneous control of transmission line parameters like voltage, impedance and phase is the unique capability of UPFC.

From the two machine system shown in Fig.1, UPFC generates a controllable voltage phasor $\mathbf{V}_{pq}$ with magnitude V_{pq} $(0 \le V_{pq} \le V_{pqmax})$ and angle ρ $(0 \le \rho \le 2\pi)$. Two back-to-back connected voltage-sourced converters representation is shown in Fig.1, where, dc storage capacitor provides a common dc link for both converters. The arrangement is an ideal ac-to-ac power converter, which allows the active power to flow between ac terminals in either direction of converters. The shunt converter draws the demanded active power for series converter from the ac network and supplies to the bus through dc link. Then, the series converter adds up the output voltage to the nodal voltage through series transformer. Both series and shunt converters can independently exchange the reactive power

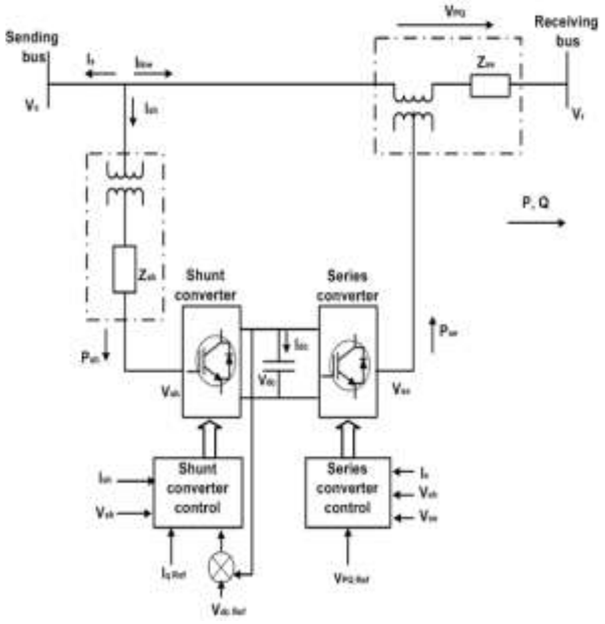

Figure 1. UPFC control scheme.

with the line. Functionally, the control system of UPFC is divided into converter (or internal) control and functional (or external) control. The gating signals required for proper output voltages by the converter valves is issued by the internal control system according to the internal reference valves. The external control operation generates the reference values V_{pqref}, I_{qref} for series and shunt compensation. The operating and contingency requirements can be met by setting these reference values manually by an operator or through an automatic system optimization control.

The shunt converter draws a controlled current I_{sh}, where, its real part is determined by the real power requirement of series converter. The reactive power can be compensated in two different modes, VAR control mode and Automatic voltage control mode.

Series converter injects a voltage V_{pq} in series with the line by controlling its magnitude and angle, influencing the flow of power on the line. The operating modes for series converter for power flow control are direct voltage injection mode, bus voltage regulation and control mode, line impedance compensation mode, phase angle regulation mode, automatic power flow control mode.

III. LITERATURE SURVEY

According to the recent studies, the problems regarding power quality of transmission and distribution systems are of most concern present days due to severe impact on sensitive loads, leading to interruptions and considerable economic loss. For the improvement of power quality using UPFC, various research studies and publications were done regarding this. [1] Presents detailed information about the types and characterization of power quality problems, with the explanation of importance of costs, estimations and solutions related to them. From [2], the issues of PQ are taken in view of economic feasibility and technical problems; and analysis is done for transient studies using custom power devices. [3] N.G Hingorani introduced power electronics based FACTS technology to enhance ac transmission system to be stable and controllable. Controllers like SVC, STATCOM, TCSC, SSSC, TCVR, TCPAR, UPFC and IPFC were discussed in detail by comparing their performances. [4] Presents the implementation of UPFC in the electrical network for PQ improvement. The functional control of series and shunt inverters was done separately by the method of identifying references and controlling inverter gate signals. A decoupled watt-var method was chosen for controlling series and shunt parts using PI controller. [5] Presents the detailed information about usage of fuzzy logic controller applications in power systems. It begins with the basics on fuzzy techniques and methods with simplified examples and methodologies; It includes the advanced concepts like control design, stability analysis and deals with optimization problems in power flow.

This paper presents the analysis of power quality events like voltage swells/sags in transmission line. Unified Power Flow Controller is used to mitigate this PQ phenomenon by taking a phase fault in one of the lines. The control system for UPFC is designed using PI controller and Fuzzy Logic controller. The results for both the cases were analyzed and compared for THD values.

IV. MODELING AND CONTROL OF UPFC

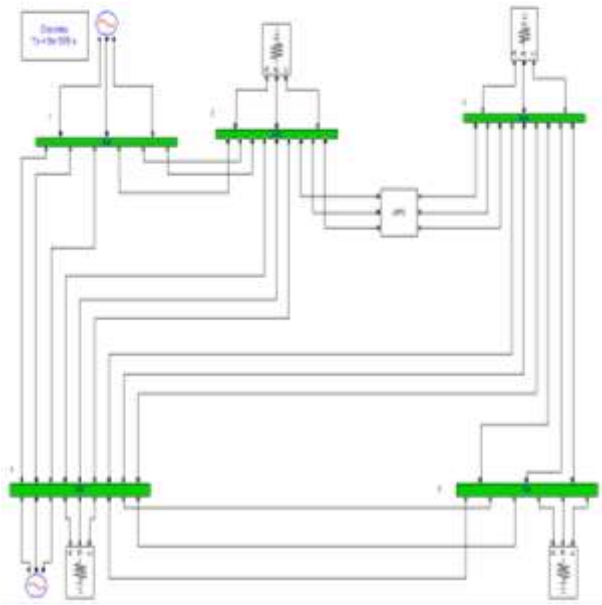

Figure 2. Standard Five bus system

Fig. 2 shows a standard 5-bus system with UPFC connected between buses 2 and 3. The UPFC block is a subsystem in which two voltage source converters are implemented with switching signals generated using subsystem operated with PI controller and Fuzzy Logic controller. The performance of these control strategies were analyzed and compared on the basis of voltage waveforms and THD values. A single phase to ground fault is created with fault resistance of 0.001 ohms for a transition time between 0.1 to 0.2 seconds, analyzed for both the phenomenon of swell and sag.

 ISSN: 2349-7947
027 - 031

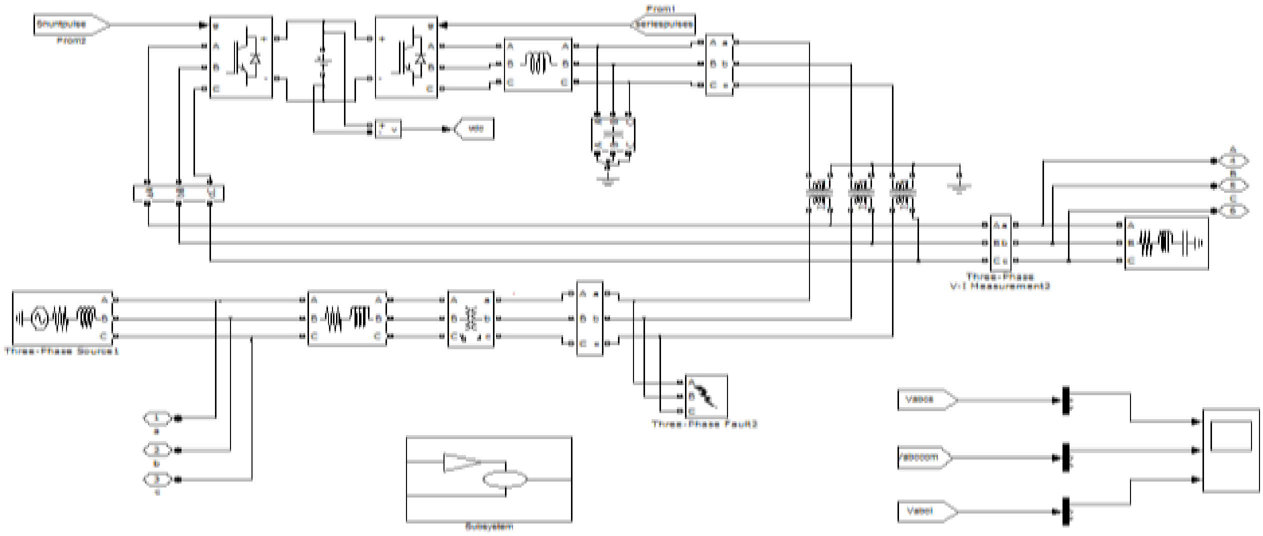

Figure 3. Simulation model of UPFC

A. PI controller based UPFC:

In PI controller, the control action is performed using the weighted sum of error and its integral value. The proportional and integral actions generate the output proportional to the error and the amount of time the error is present. The difference between the actual measured value and set value of the system is given as input to PI controller. The control system for generating pulses for shunt and series parts of UPFC is shown in the block diagrams in Fig. 4 and Fig. 5

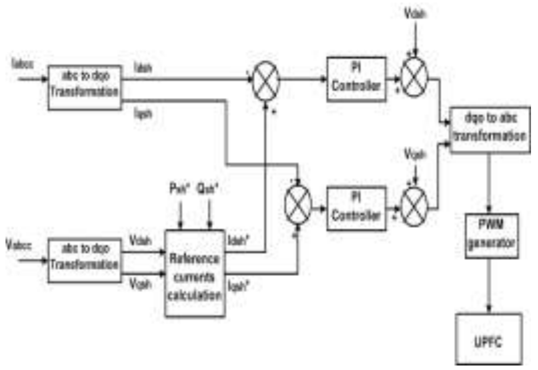

Figure 4. Control method for UPFC series converter

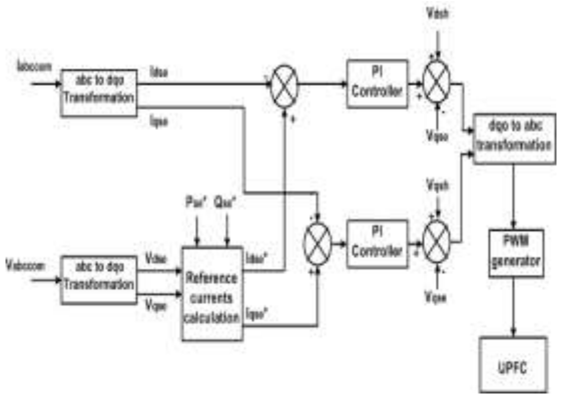

Figure 5. Control method for UPFC shunt converter

The reference currents were calculated by instantaneous power method for both series and shunt parts. The real and reactive series current components, I_{dse}, I_{qse} are compared with the respective reference values I_{dse}*, I_{qse}* and the difference is given to the PI controller. The reference voltage components in dq reference are again converted to phase components by inverse PARK transformation. Then the PMW generator produces pulses to the series part of UPFC. Same happens with the shunt part control scheme. Kp and Ki values are taken as 0.1 and 1 respectively.

B. Fuzzy controller based UPFC:

One of the most successful operations of fuzzy set theory is Fuzzy Logic controller (FLC) which uses linguistic variables rather than numerical variables. This control method depends on human ability to recognize the system performance. The fuzzy controller overcomes the drawbacks of PI controller as it relieves the system from exact and bulky numerical modeling and computations. Fuzzy controller can be well established for enhancements in both transient & steady state analysis. Fuzzy logic controller as shown in the Fig.6, consists of four major functional blocks; Fuzzification, Knowledge base, Inference mechanism, and Defuzzification.

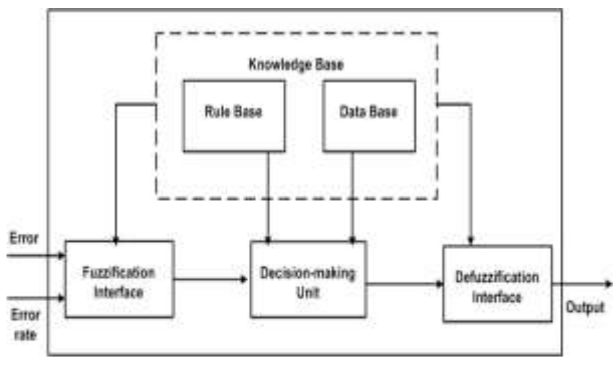

Figure 6. Block diagram of Fuzzy logic controller

FLC is based on simple If- then rules defined from human experience and knowledge about system performance. The correct combination of these rules can improvise the system behavior. From the block diagram, the function of Fuzzification interface is to change input to appropriate linguistic values. Knowledge base consists of data base with necessary linguistic definitions and rule set relating the input variables to desired control actions. The decision-making unit makes use of the set of linguistic rules to change the input condition to fuzzified output. Defuzzification converts the fuzzy outputs to crisp signals.

To improve the performance of UPFC, Fuzzy logic controller is used to mitigate the duration of sag and swell. The block diagram of FLC for UPFC is shown in figure. The error (difference between the reference value and measured system parameters) and the rate of change of error are the inputs for Mamdani fuzzy system. To obtain the fuzzified values from the crisp inputs, triangular membership functions are used which is simplest compared to other membership functions. Centroid method is used for defuzzification and the fuzzy control rules are shown in Table 1. The output from the inference system is given to PWM generator to produce required switching pulses to UPFC.

TABLE I. RULE BASE

Error Rate	Error				
	PB	**PS**	**ZE**	**NS**	**NB**
PB	ZE	ZE	NB	NB	NS
PS	PB	PB	PB	ZE	ZE
ZE	NS	ZE	ZE	ZE	PS
NS	PS	PS	PS	ZE	ZE
NB	ZE	ZE	NS	NS	NS

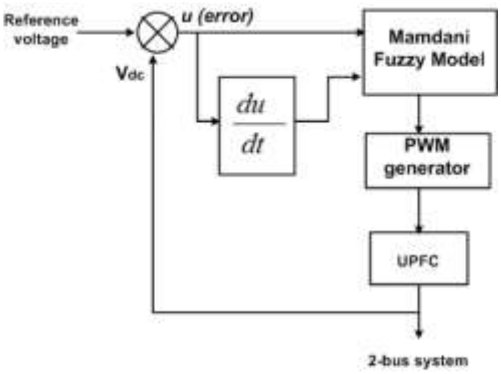

Figure 7. Block diagram of Fuzzy based UPFC

V. SIMULATION AND RESULTS:

The proposed PI based and Fuzzy based UPFC systems for voltage swell and sag compensation in a line is simulated using Matlab/Simulink simulation models. Here a transmission system with a voltage of 345KV and 60Hz is considered. A single phase to ground fault is injected into the system near the load with fault resistance of 0.001ohms. With this, voltage sag and swell are introduced for a period of 0.1 to 0.2 sec. Separate simulink models were taken for sag and swell events. The simulation results shown below are the voltages at source, compensator and at load analyzed along with Total Harmonic Distortion study, for conditions of voltage sag with PI and Fuzzy controllers, and voltage swell with PI and Fuzzy controllers.

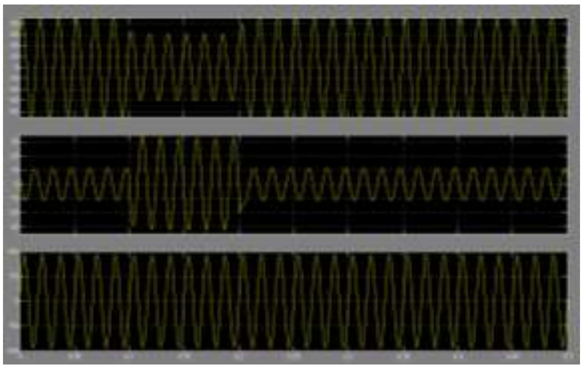

Figure 8. Voltage sag compensation using PI controller

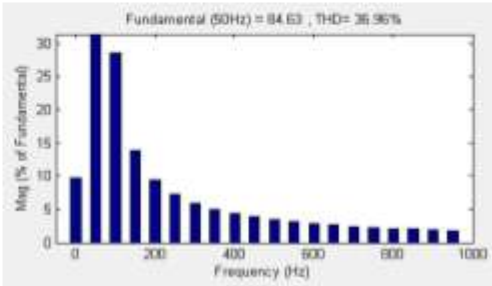

Figure 9. THD after voltage sag compensation using PI controller

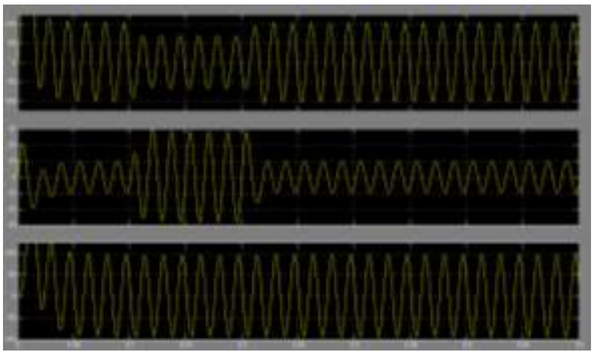

Figure 10. Voltage sag compensation using FL controller

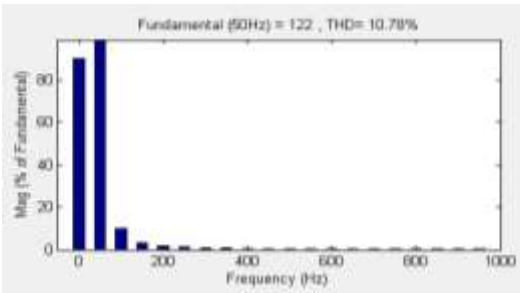

Figure 11. THD after voltage sag compensation using FL controller

The harmonic spectrum of load voltage using both control schemes for voltage sag is analyzed. This shows a reduction in THD values from 36.96% to 10.78% for PI and Fuzzy controllers respectively.

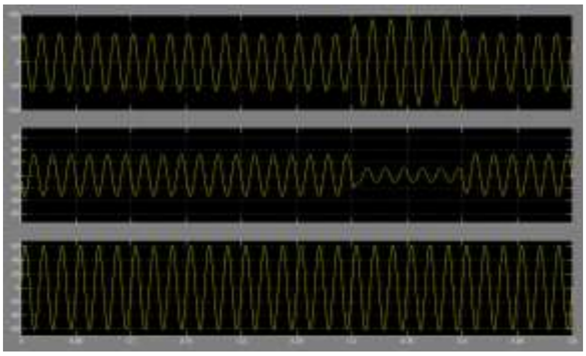

Figure 12. Voltage swell compensation using PI controller

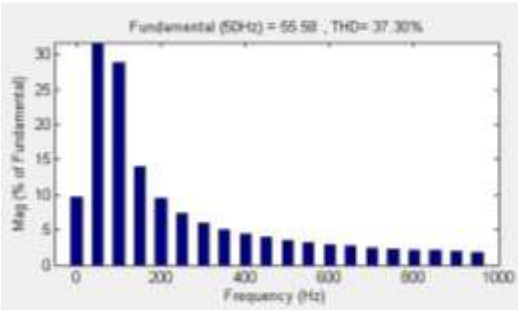

Figure 13. THD after voltage swell compensation using PI controller

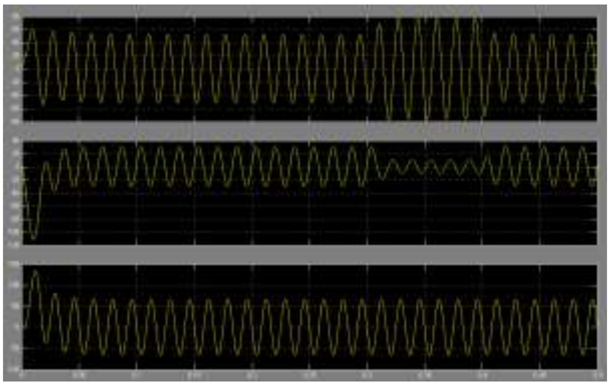

Figure 14. Voltage swell compensation using FL controller

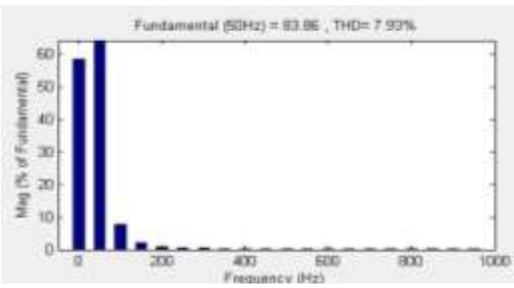

Figure 15. THD after voltage swell compensation using FL controller

The harmonic spectrum of load voltage using both control schemes for voltage swell is analyzed. This shows a reduction in THD values from 37.30% to 7.93% for PI and Fuzzy controllers respectively.

VI. CONCLUSION

In this paper, the performance of UPFC on balancing the voltage sag and swell power quality events in the line is studied with two control methods, i.e. with PI and Fuzzy logic controllers with an L-G fault applied to the system. From the simulation results, it is clear that, UPFC with Fuzzy control is simple and gives better sag/swell compensation and better THD values than UPFC with PI controller.

REFERENCES

[1] A.de Almeida, L.Moreira. J. Delgado, “Power quality problems and new solutions”, ISR University of coimbra (Portugal)

[2] Mahesh Singh (SSCET), Vaibhav Tiwari (CSIT), “Modeling analysis and solution of power quality problems”, Bhilai, India, Unpublished.

[3] N.G. Hingorani, L. Gyugyi,” Understanding FACTS: Concepts and technology of flexible AC transmisson systems” IEEE, Wiley- Interscience.

[4] DIB Djalei, Z. Abada, Rezaiguia, ”Improving electric power quality by UPFC systems in electrical networks” Published in ‘International journal of energy, issue 4, vol. 6, 2012.

[5] O.P. Malik. D. Niebur, T. Hiyama, “Tutorial on Fuzzy Logic Applications in Power Systems” Prepared for the IEEE-PES Winter Meeting in Singapore January, 2000

[6] Enrique Acha, Claudio R.Fuerte-Esquivel, Hugo Amnriz- Perez, Cesar Angeles-Camacho, “FACTS, Modelling and Simulation in power networks”, John Wiley & Sons, LTD.

[7] Math H.J. Bollen, “Understanding power quality problems: voltage sags and interruptions”, A volume in the IEEE press series on power engineering.

[8] Hakim Elahi Tooraji and Nekoubin Abdolamir, “Improving power quality parameters in AC transmission systems using unified power flow controller”, Published in Research Journal of Recent Sciences, April 2013.

[9] M.R.Mohanraj, V.P.Suresh, G.Syed Zabiyullah,” Protection from voltage sags and swells using facts controllers” punlished in International Journal of Innovative Research in Science, Engineering and Technology, february, 2015.