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Analysis and Improvement of Power Quality Parameters by Using UPQC with the Implementation of Fuzzy and PID Controllers

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Abstract : *The advance use of power electronic devices introduces harmonics in the supply system which creates a problem in the quality of power delivered. Good Power Quality is very much important for our day to day use of appliances in both industrial and domestic sectors. Researchers have tried and implemented many useful technologies for removing all the voltage and current related harmonic occurrence problems which in turn improves the quality of power delivered to the power system. The prime focus of this thesis is the implementation of control strategies like SRF theory and instantaneous power (p-q) for the operation of Unified Power Quality Conditioner (UPQC) which is one of the recent technology that includes both series and shunt active power filter operating at the same time and thereby improves all the current and voltage related problem like voltage sag/swell, flicker, etc. at the same time and helps in reduction of Total Harmonic Distortion (THD). In this thesis it is shown via MATLAB simulation how UPQC model can be used to decrease the % THD in source voltage, source current and load voltage waveforms created due to non-linear/ sensitive loads usage.*
Keywords: Power quality, UPQC, THD, sag, swell

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I. Introduction

The introduction of the paper should explain the nature of the problem, previous work, purpose, and the contribution of the paper. The contents of each section may be provided to understand easily about the paper.

For the development of the nation, it is important to adopt economic sources in the form of production. For this production, factories and industries are established and they are operated on heavy loads and need to run the main source for running electricity. Efficiency and accuracy is the main focus of this area. For this, supply of power which is supplied, I should have good quality without any interruption and defect. There is a term for maintaining demand according to the required load “Power Quality” that must be controlled and managed in any case.

The heavy weight of the industry gives a harmonic disorder in the system and which affects the overall parameters of the system to the area of generation. To improve their quality, electrical quality is considered for voltage, current, frequency and harmonics. However, describing the quality of good power is not easy, because for a device like a motor which has the quality of power, it cannot be good for our personal computer and other sensitive loads.

Fig 1 shows the basic structure of power system network and smart utilization of this system respectively.

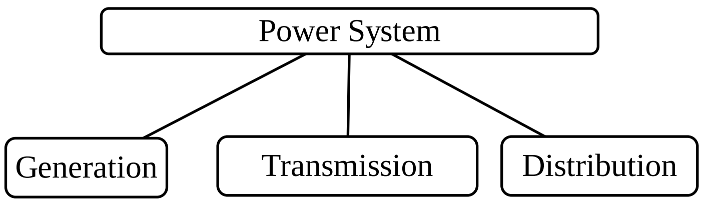

Fig.1 Basic power system network

1. Causes of deficiency in the power quality

Power quality depends on some parameters and to maintain power quality these parameters and effect of these parameters are voltage, current and frequency. Causes and effects due to these parameters are

(a) Irruptions (b) voltage sag (c) voltage swells (d) Transients (e) Harmonics

A. Interruption

When the power system line voltage or current is less of a blockage, at least 10 percent less than 60 seconds is reduced in length. As shown in Fig. 2 Another common power-quality event is "Notching", which can be made by Rectifiers, which is a finite line installation.

Fig.2 Interruption in transmission line voltage waveform

B. Voltage Sag

When the voltage bag / dip is in the electrical system, the RMS line-voltage decreases by 10 to 90 percent of the nominal value of the line-voltage. The standard period of one voltage loosely is 1 minute from 0.5 cycles. Primarily due to the introduction of large induction motors and utility defects. Fig.3. shows the wave form of sag occurs in system.

Fig.3 Sag in transmission line voltage waveform

C. Voltage Swell

When the voltage is swell in the power system, the RMS line-voltage increases by the nominal value of line-voltage from 110 to 180 percent. The standard duration of a voltage swell is 0.5 cycles 1 min. White is primarily due to wrong tape settings in the flaw chamber in line fault and substation

Fig 4. Voltage swell in power system network

Fig 5 Variations in power system

D. Transients and Harmonics

When the power system is transient in line, the voltage and current amplitude vary. The causes for this are switching of inductive load and distribution system. Fig 6 shows impulsive and oscillatory transients in power system and fig. 7 shows reduction in harmonics in system. This type of variation damages the system equipment is as it stays for long time. The power of electronic equipment, such as zener diode or metal oxide varistor, is used for compensating for transient defects.

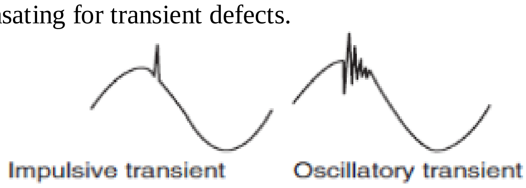

Fig.6 Impulsive and oscillatory transients in power system

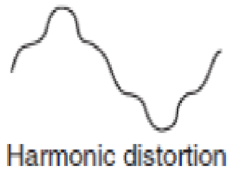

Fig. 7 Harmonic reduction in system

E. Voltage Fluctuation

Fig. 8 shows voltage fluctuation waveforms in power system.due to non-synchronization of line frequency with current parameter, fluctuations in voltage observed. There is small variation due to this fault.

Fig. 8 Voltage fluctuations in power system

A voltage “imbalance” is also results variation in the three-phase voltages; fig.9. shows noise in power system which is due to imbalance in the system.

Fig. 9. Noise in power system

II. Unified Power Flow Controller (UPFC)

The Unified Power Flow Controller (UPCC) has been developed to connect the power system with a system with the syringes and the STATCOM and SSSC FACTS tools were used separately to isolate the two connections separately.

In UPFC, a common DC link is used to share power. Both converters (Shunt and Series) work independently using this DC link to share active power and absorb reactive power for compensation.

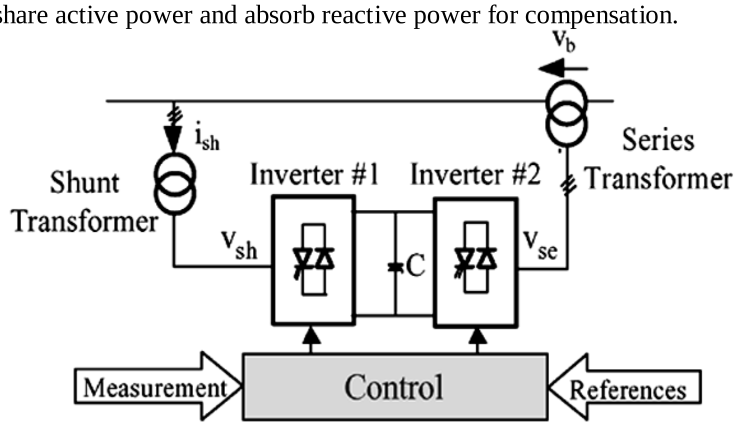

Fig.10 Block Diagram of UPFC

The Distributed Electricity Flow Controller (UPQC) is rebuilt by removing the deficiencies of UPFC because the DC link capacitor ends and the converter used in the series is distributed in different steps as the integrator of the reactive power. As the system reduces by removing the components, it is less expensive and effective efficiency to reduce the reactive power and maintain the active power of the power system. Fig.11 shows the diagram for UPQC.

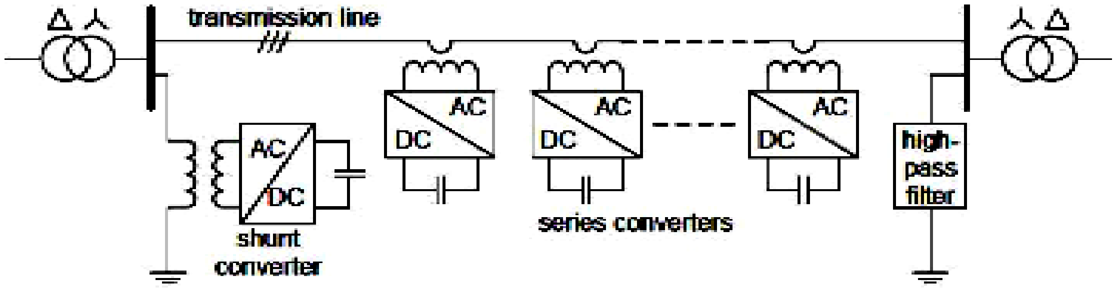

Fig.11. UPQC configuration

SRF controlling method for the operation of UPQC model is very similar to instantaneous reactive power theory method. A major feature this algorithm pursues is that only load current is essential here for the generation of reference current and hence disturbances present in source or distortions present in voltage have will leave no negative impact to the performance of the designed UPQC system. In the given proposed SRF method for UPQC we have optimized the system without using transformer voltage, load, and filter current measurement, this reduces numbers of measurements are and thereby improving system performance.

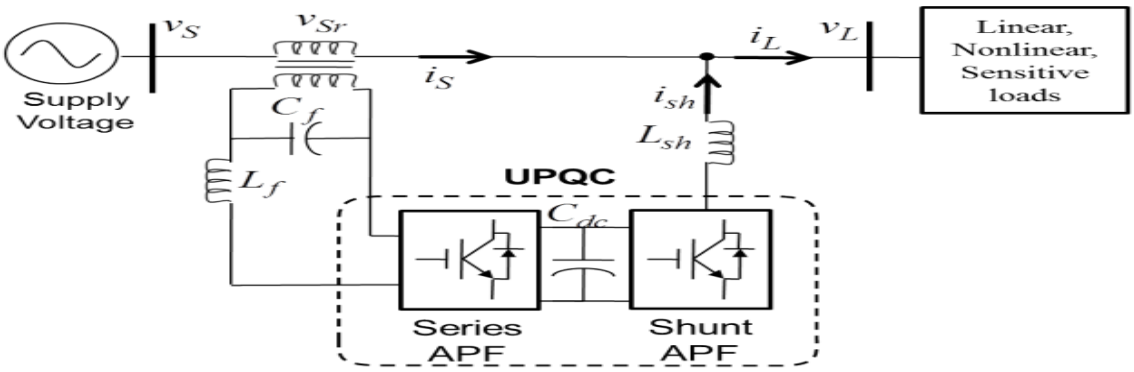

Fig.12 Block Diagram of UPQC

III. Design of the system

The idea used here is to produce harmonic current having components which has 180° phase shift to the components of harmonic current which are generated by the use of nonlinear loads. The concept is totally based on injecting harmonic current in the ac system similar in amplitude but opposite in phase when compared with load current waveform harmonics.

In normal conditions, the source is assumed as a perfect sinusoidal voltage i.e

$$Vs(t) = Vm \sin(\omega t) \quad (1)$$

Now we apply a non-linear load and as discussed above, the load current will have both fundamental component and also harmonics of higher order. This current we represent as:

$$i_l(t) = \sum_{n=1}^{\infty} I_n \sin(n\omega t + \theta_n) \quad (2)$$

Now, the load power is expressed as:-

$$pl(t) = Vs(t)il(t) = I1Vmsin2(\omega t)cos\theta1 + I1Vm \sin(\omega t) \cos(\omega t)\, sin\theta1 +$$

$$\sum_{n=2}^{\infty} V_m \sin(\omega t)\, I_n \sin(n\omega t + \theta_n) \quad = ps(t) + pc(t) \quad (3)$$

In eqn. (3)the we define $ps(t)$ as real power given by utility source, and $pc(t)$ as the reactive power and the harmonic power, i.e.

$ps(t) = I1Vsmsin2(\omega t)cos\theta1$

$$p_c(t) = I_1\, Vsm \sin(\omega t)\cos(\omega t)\, sin\theta_1 + \sum_{n=2}^{\infty} Vsm \sin(\omega t)\, I_n \sin(n\omega t + \theta_n) \quad (4)$$

By discussion above we know that APF will provide the reactive and harmonic power $pc(t)$, the current supplied by source is given as :-

$$i_s(t) = \frac{p_s(t)}{V_s(t)} = I_1 \cos\theta_1 \sin(\omega t) = I_s \sin(\omega t) \quad (5)$$

The current $is(t)$ is and utility voltage is seen to be in phase and pure sinusoidal. At this time, the APF will provide the following compensation current in the circuit:

$$ic(t) = il(t) - is(t) \quad (6)$$

IV. Proposed power system

Designing and modelling of UPQC is described in this section of thesis. MATLAB/ Simulink (2017a) is used for designing and analysis. Modelling of various sections with system design is elaborated with MATLAB circuits and controllers using Fuzzy logic controller.

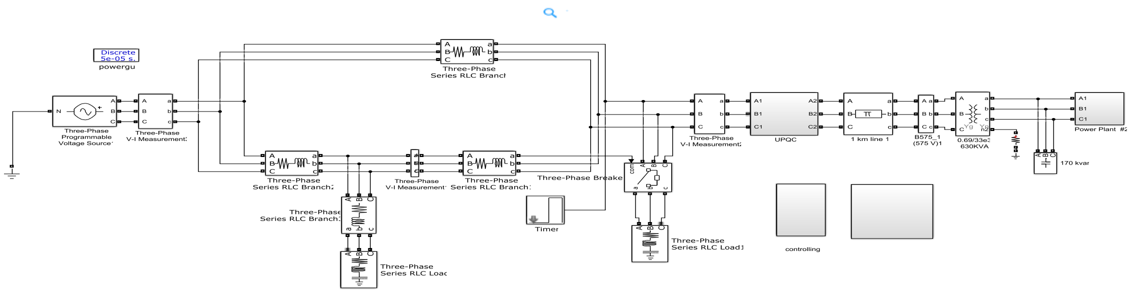

Fig. 13. Proposed MALTAB model for power system with UPQC and controller

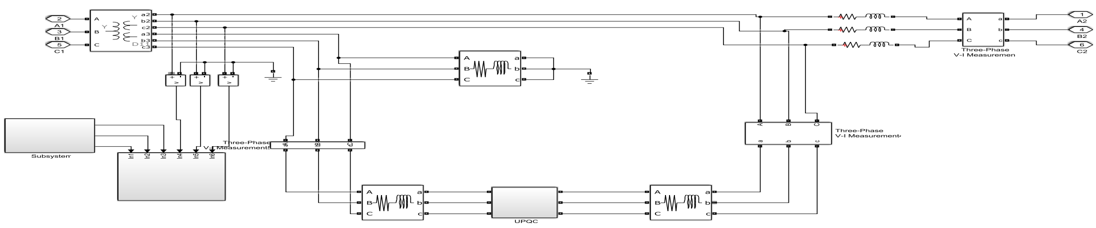

Fig. 14. Proposed MALTAB model for UPQC and controller

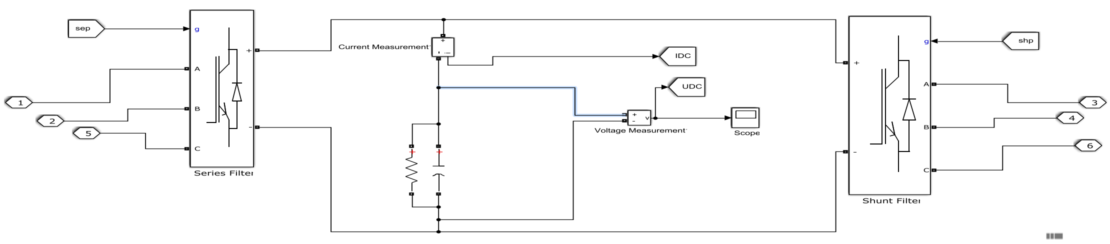

Fig. 15. MALTAB model for UPQC with series and shunt converters

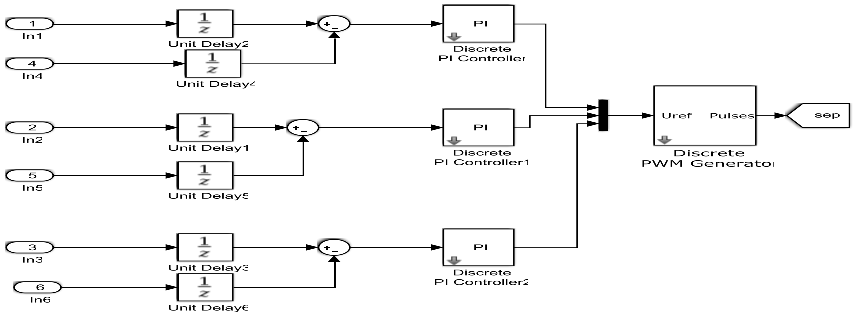

Fig. 16. Shunt controller with PID controller for UPQC

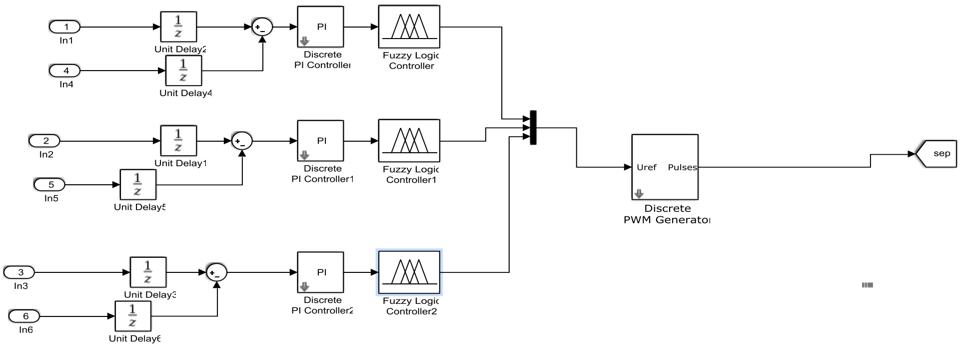

Fig. 17. Shunt controller with fuzzy logic controller for UPQC

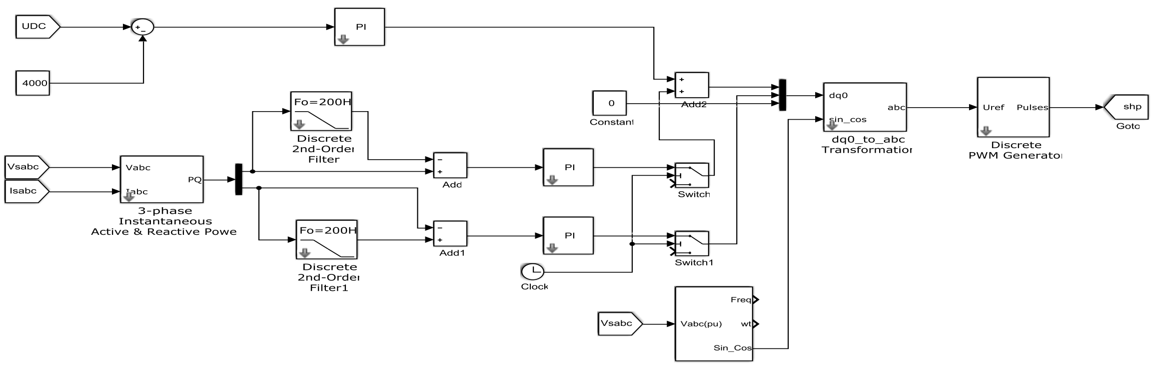

Fig. 18. Series controller with PID controller for UPQC

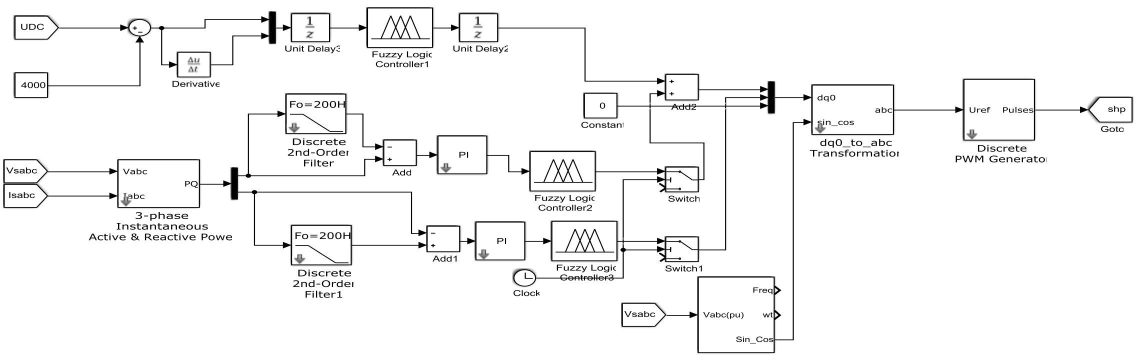

Fig. 19. Series controller with fuzzy logic controller for UPQC

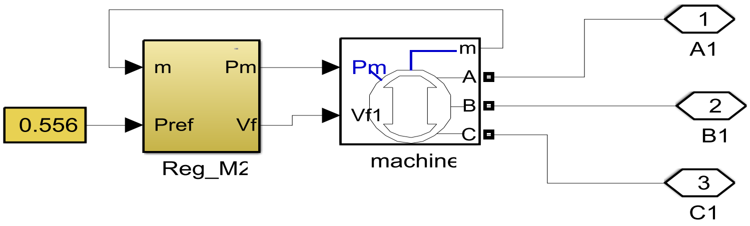

Fig. 20. Power generation source for proposed system

V. Results with PID and Fuzzy Logic Controller

Results in the form of waveforms are presented in this section by taking parameters of shunt, series voltage and current along with grid parameters. In last sections total harmonic distortion and comparison of PID and FLC results are shown.

A. Grid Voltage and Current

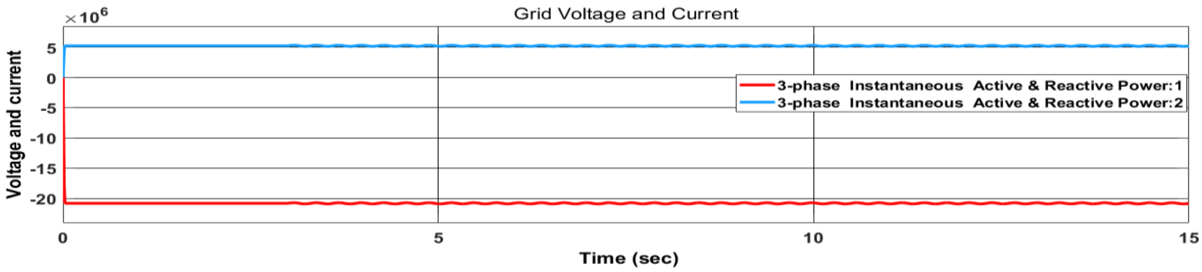

Fig 21. Grid Voltage and current of system using PID controller

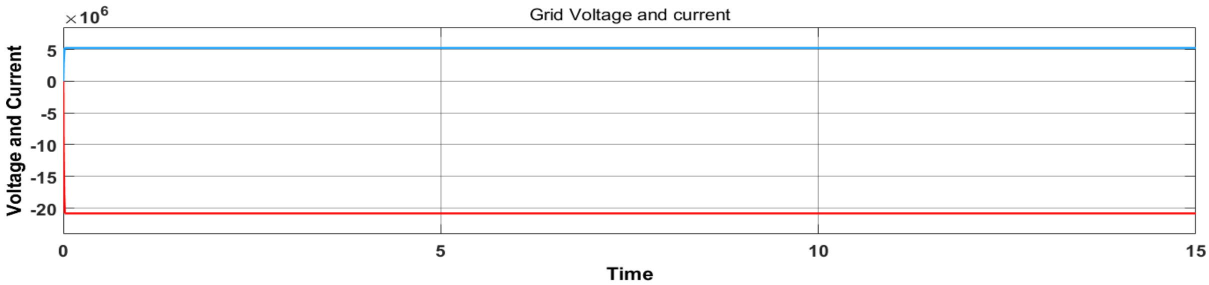

Fig 22. Grid Voltage and current of system using FLC controller

Fig. 21. and 22. shows grid voltage and current of proposed system with UPQC with implementation of PID and FLC respectively. These results shows that while using PID there is distortion in output while with FLC the system output are stable and constant at 5x106 voltage and -20x10^{6} current.

B. Shunt controller Bus voltage

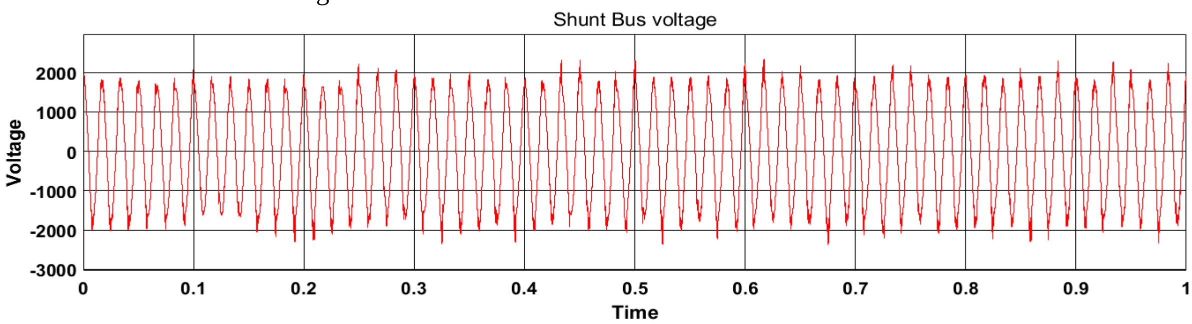

Fig 23. Shunt bus Voltage of UPQC using PID controller

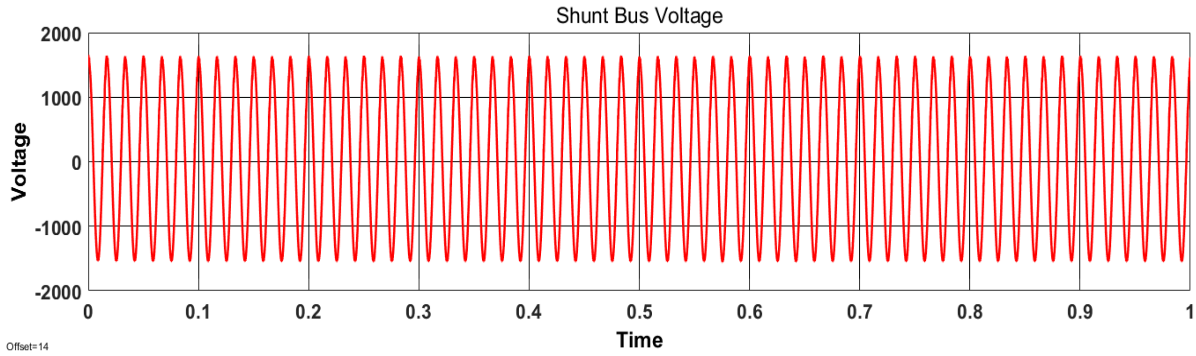

Fig 24. Shunt bus Voltage of UPQC using FLC controller

Fig. 23. and 24. shows shunt controller bus voltage of proposed system with UPQC with implementation of PID and FLC respectively. These results shows that while using PID there is distortion in output while with FLC the system output is stable and constant at 1800 voltage.

C. Bus bar Voltage at Shunt Converter

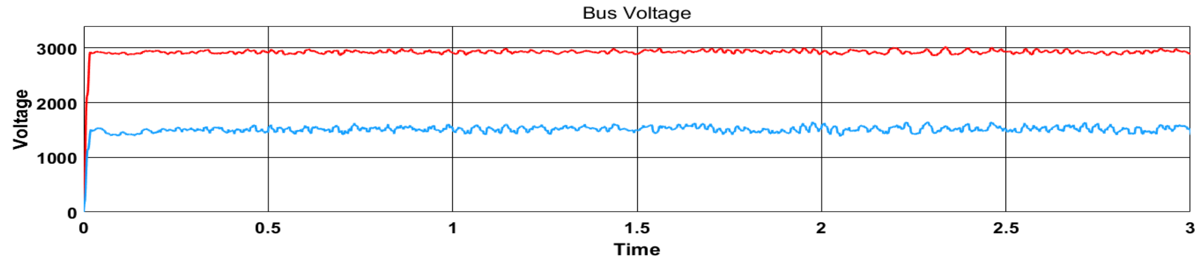

Fig 25. Bus Voltage of UPQC at shunt controller using PID controller

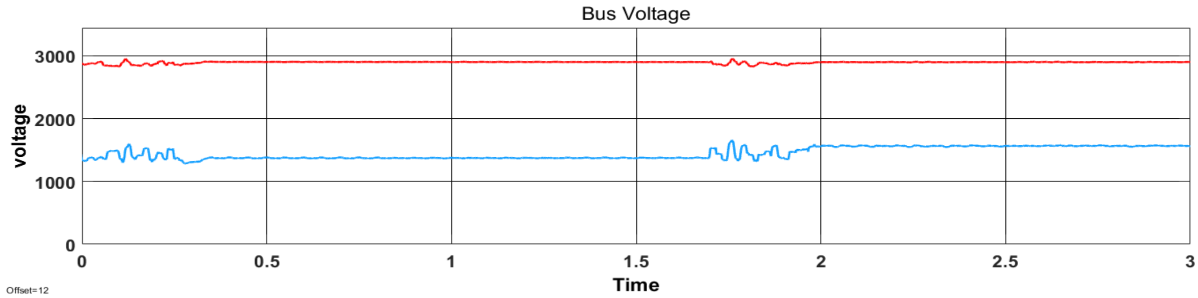

Fig 26. Bus Voltage of UPQC at shunt controller using FLC controller

Fig. 25. and 26. shows bus bar voltage near to shunt controller of proposed system with UPQC with implementation of PID and FLC respectively. These results shows that while using PID there is distortion in output while with FLC the system output is stable and constant at 2800 voltage.

D. Unified DC link Voltage

E.

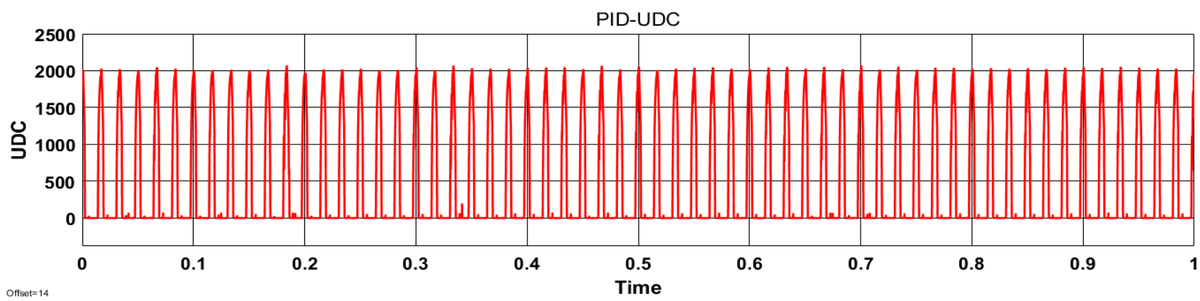

Fig 27. UDC of UPQC using PID controller

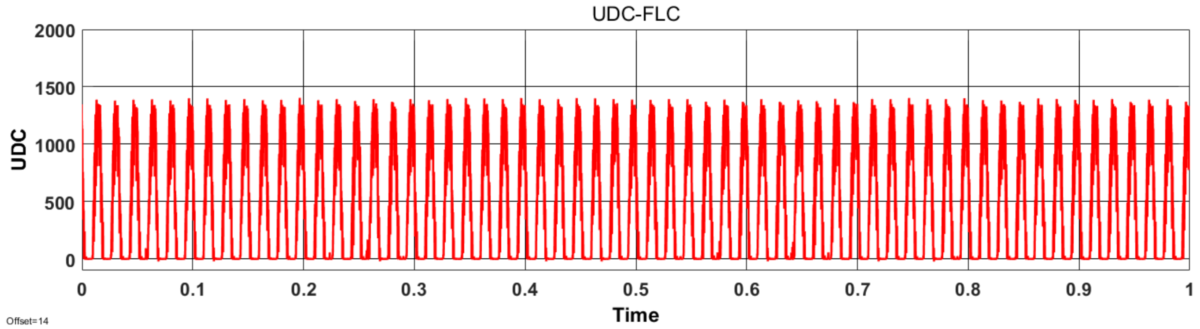

Fig 28. UDC of UPQC using FLC controller

Fig. 27. and 28. shows Unified DC link Voltage connected in between shunt and series controllers of proposed system with UPQC with implementation of PID and FLC respectively. These results shows that while using PID there is higher variation in amplitude that is not good but with FLC these fluctuations are lower.

F. Unified DC link current

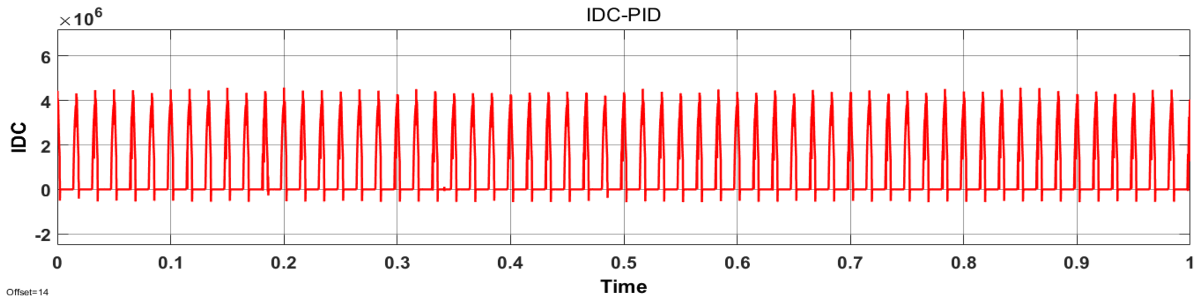

Fig 29. IDC of UPQC using PID controller

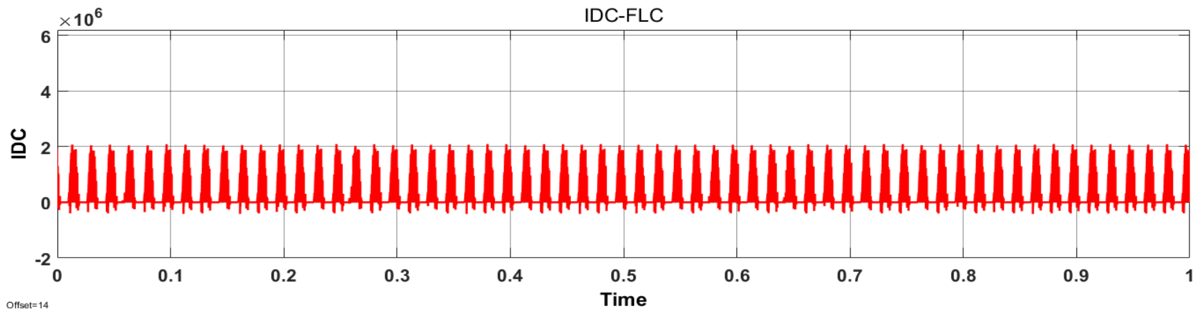

Fig 30. IDC of UPQC using FLC controller

Fig. 29. and 30. shows Unified DC link current connected in between shunt and series controllers of proposed system with UPQC with implementation of PID and FLC respectively. These results shows that while using PID there is higher variation in amplitude that is not good but with FLC these fluctuations are lower.

G. Series controller Bus Voltage

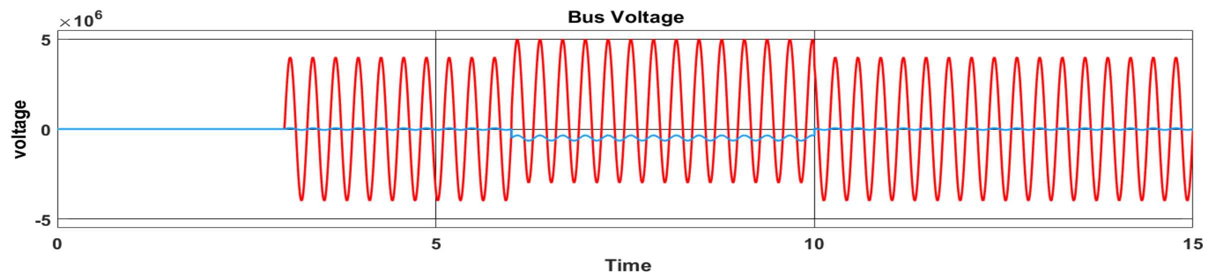

Fig 31. Series bus Voltage of UPQC using PID controller

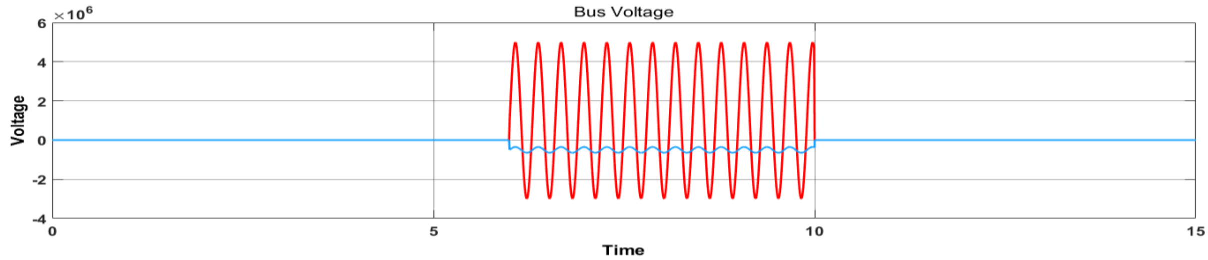

Fig 32. Series bus Voltage of UPQC using FLC controller

Fig. 31. and 32. shows series controller bus voltage of proposed system with UPQC with implementation of PID and FLC respectively. These results shows that while using PID there is distortion in output while with FLC the system output is stable and constant.

H. Total Harmonic Distortions (THD)

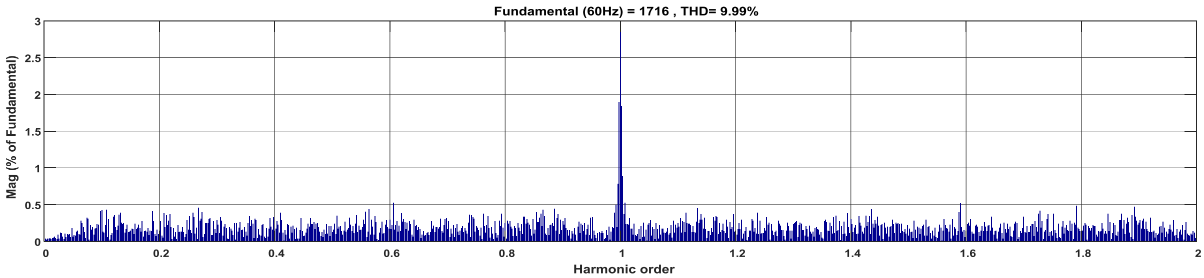

Fig.33. Total Harmonic Distortion of Power Output with PID controller

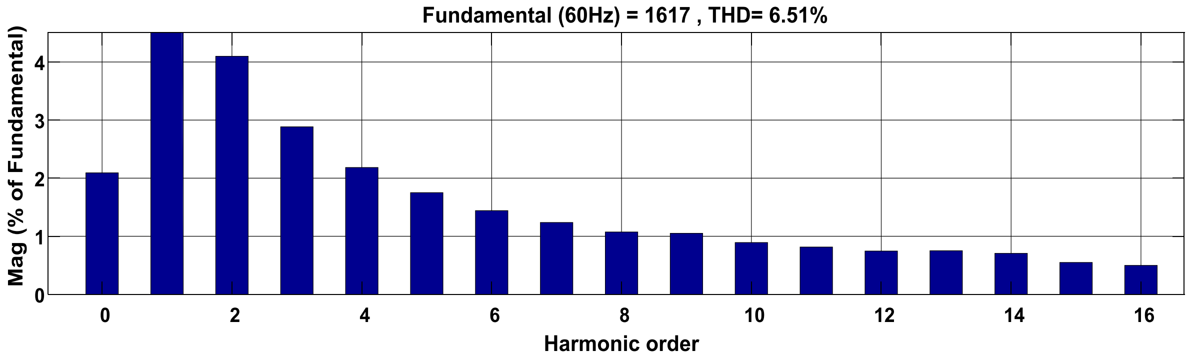

Fig.34. Total Harmonic Distortion of Power Output with FLC controller

Fig. 33. and 34. shows Total Harmonic Distortion of output voltage of proposed system with UPQC with implementation of PID and FLC respectively. These results shows that while using PID there is distortion of 9.99 % in output while with FLC the system output has 6.51% THD.

VI. Conclusion

As the requirement of power system transmission is increasing, the requirement of stable system is more required for shunt and series system for voltage and current controlling. In this aspect many FACT devices are being used for reactive power control and for stability. In this work Unified Power Flow Controller (UPFC) is used. This controller used in series as well as shunt controlling. PID and Fuzzy Logic Controller is used for triggering control and compared for analysis.

Voltage and current are primary parameter for analysis and Total Harmonic Distortion (THD) is calculated. While analysis it is seen that using FLC is more stable and less distortions are generated as compared to PID. THD with PID is 9.99 % whereas with FLC its only 6.51 %.

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