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Comparative Analysis of Power Quality Parameters by Using UPQC with The Implementation of Fuzzy and PID Controllers

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Abstract: ***I****mplementation 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 work 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

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.

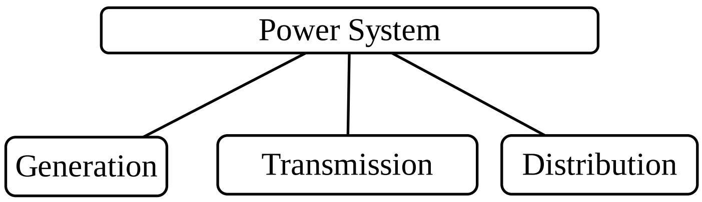

Fig.1 Basic power system network

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. [4-5]

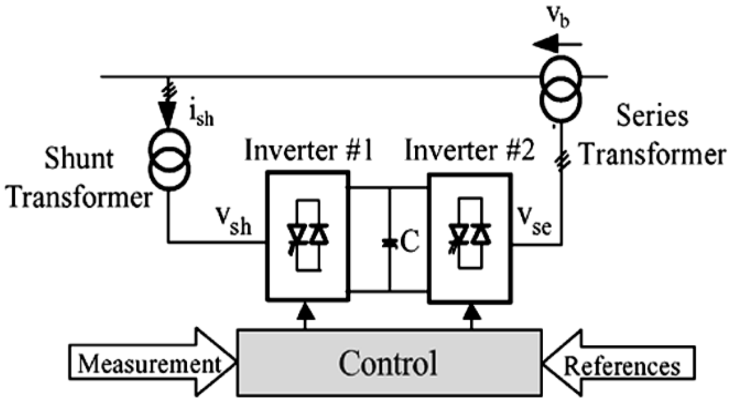

Fig.2 Block Diagram of UPFC

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. 3 shows the diagram for UPQC.

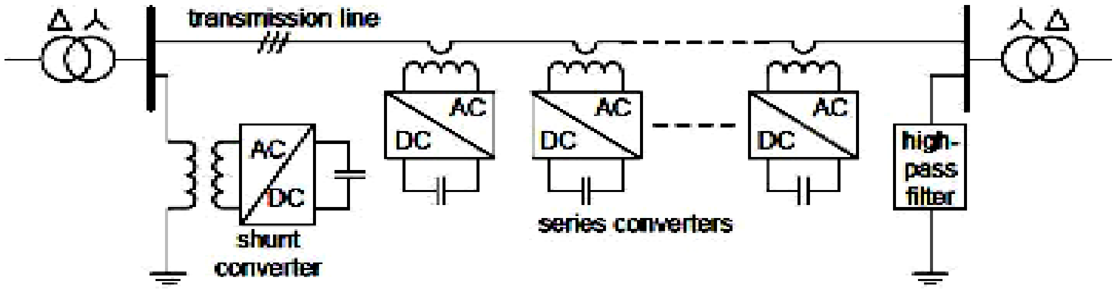

Fig.3 UPQC configuration

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.

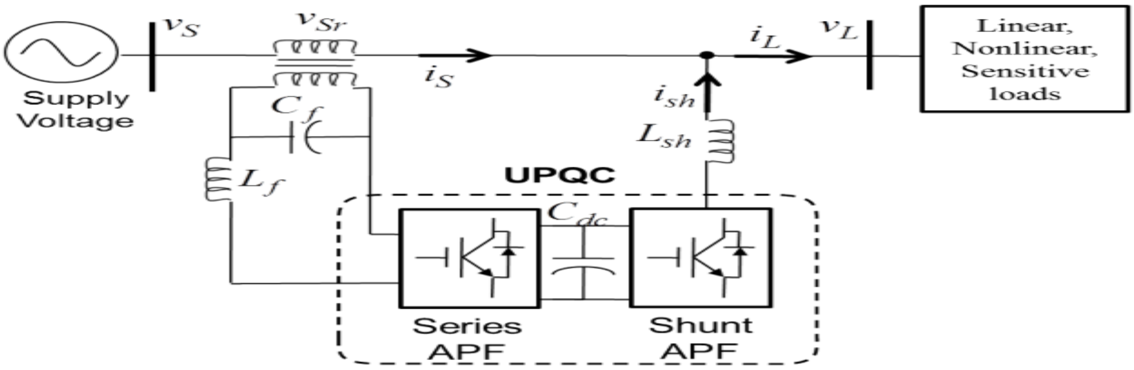

Fig.4 Block Diagram of UPQC

A. Active Power Filters

APF's are the electrical equipment which are connected sometimes as series model or shunt model and sometimes as a combination of both series and shunt filters. UPQC is a model where both series and shunt APF connected via a common dc link capacitor are implemented in one circuit only and they help to solve all voltage and current harmonics problems simultaneously. Series APF are used for solving only voltage harmonics problems like voltage sag, swell, flickering etc. whereas shunt APF is used for solving only current harmonics problems and hence improves power factor by supplying reactive power continuously regulates DC link voltage. Hence service reliability is achieved with the combination of series and shunt filter in the form of UPQC.

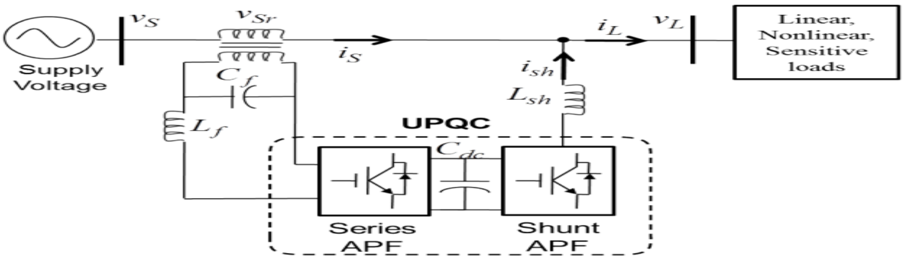

Fig.5 Block diagram of UPQC

In industries and domestic usage, we are having large numbers of single phase loads which employs solid state control which requires the attention to the problem of harmonics occurring due to its usage. These solid state controllers try to convert and also control ac power fed to many loads and thereby increase efficiency of the system and in this process they also introduce harmonic components in the lines which create several problems which need to be solved.

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:-

$$pl(t) = Vs(t)il(t) = I1Vmsin2(\omega t)cos\theta 1 + I1Vm \sin(\omega t)\cos(\omega t)\, sin\theta 1 +$$

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

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.

$$ps(t) = I_1 V_{sm} sin_2(\omega t) cos\theta_1$$

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

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.

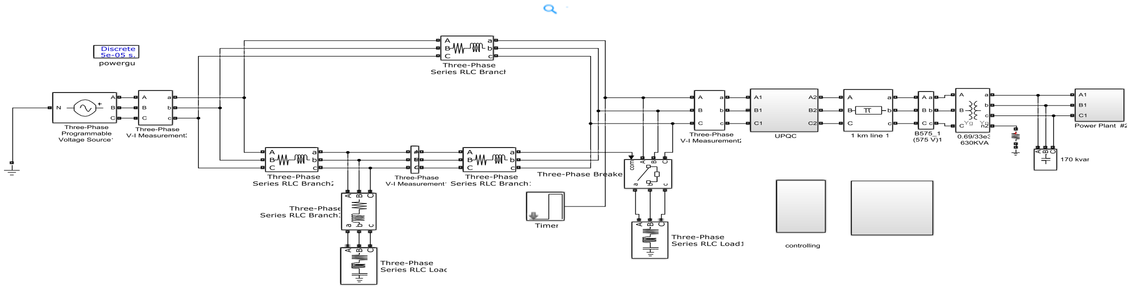

Fig. 6 Proposed MALTAB model for power system with UPQC and controller

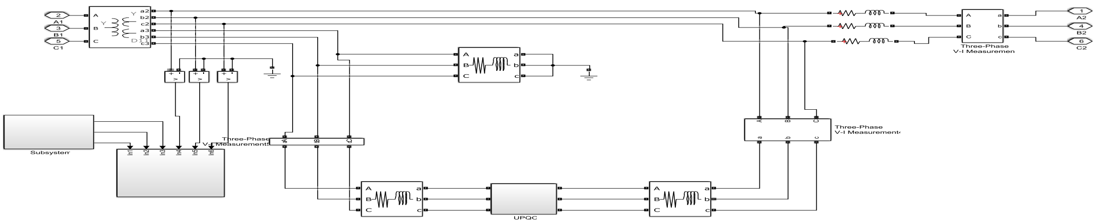

Fig. 7 Proposed MALTAB model for UPQC and controller

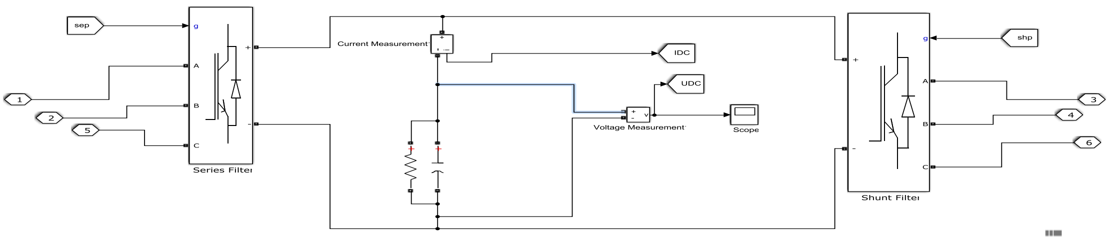

Fig. 8. MALTAB model for UPQC with series and shunt converters

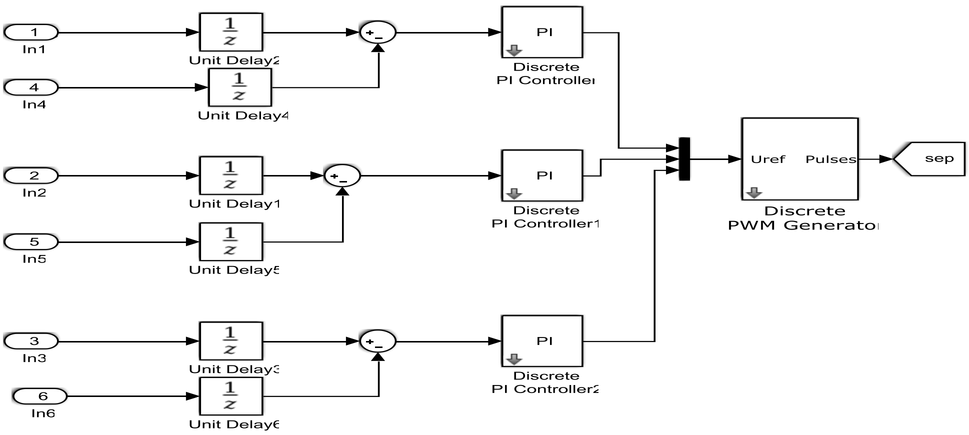

Fig. 9. Shunt controller with PID controller for UPQC

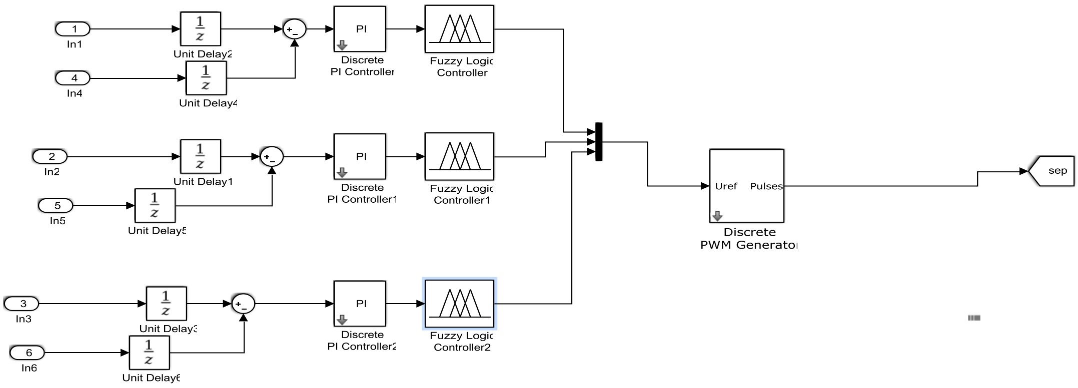

Fig. 10. Shunt controller with fuzzy logic controller for UPQC

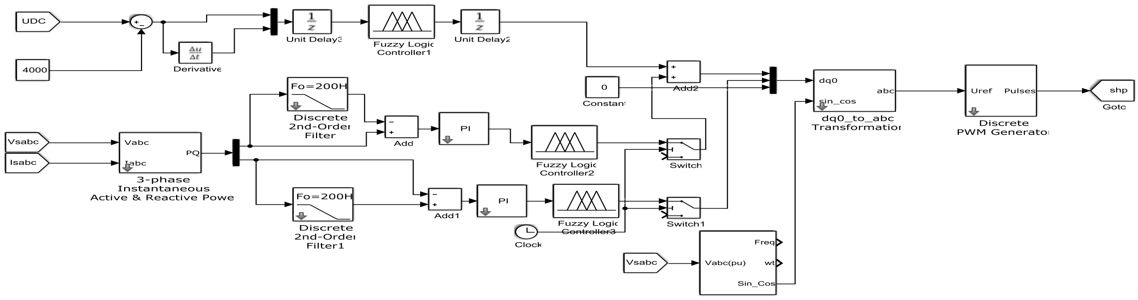

Fig. 11 Series controller with fuzzy logic controller for UPQC

This section of thesis is about the results and analysis of UPQC in proposed power system implementing fuzzy logic controller. Parameter used for analysis are voltage, current and power of grid and bus at series and shunt controller. Analysis and wave forms for PID and FLC are compared at various parameters and total harmonic distortions at power is calculated.

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. Total Harmonic Distortions (THD)

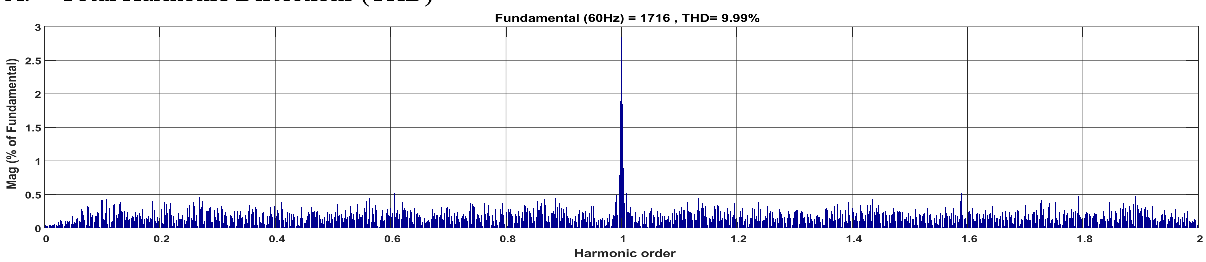

Fig.12. Total Harmonic Distortion of Power Output with PID controller

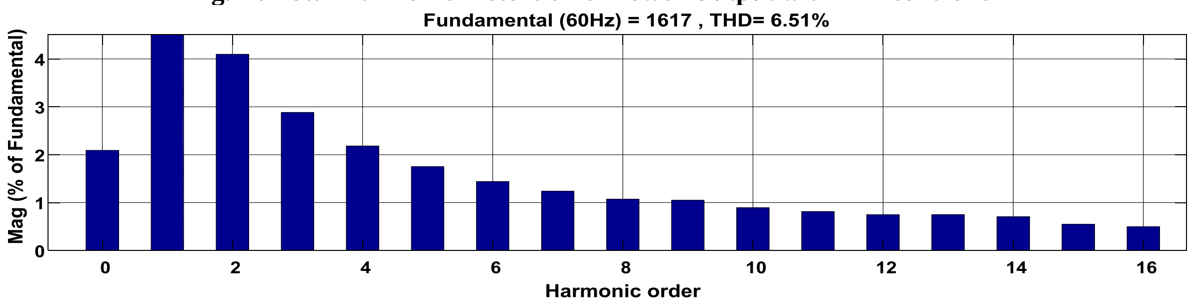

Fig.13 Total Harmonic Distortion of Power Output with FLC controller

Fig. 12 and 13 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.

Comparative Analysis

A. Bus Voltage

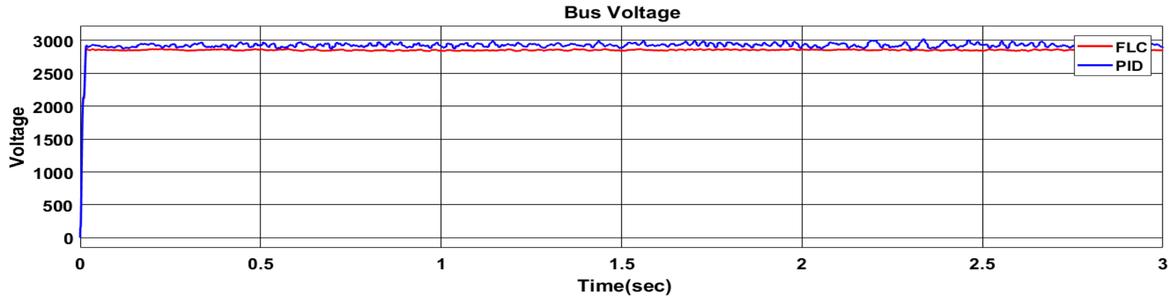

Fig 14. Comparison of bus Voltage of UPQC using FLC and PID controller

Fig. 14 shows 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 2800 voltage.

B. Bus Current

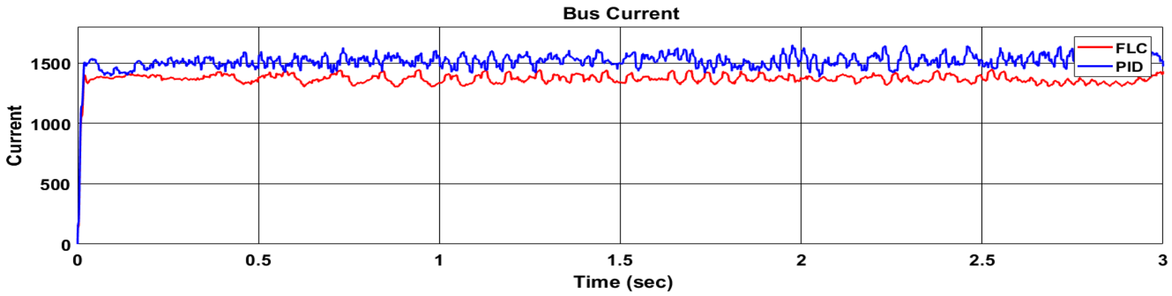

Fig 15. Comparison of bus Current of UPQC using FLC and PID controller

Fig. 15 shows bus 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 is stable and constant at 1500 A.

C. Shunt Bus Voltage

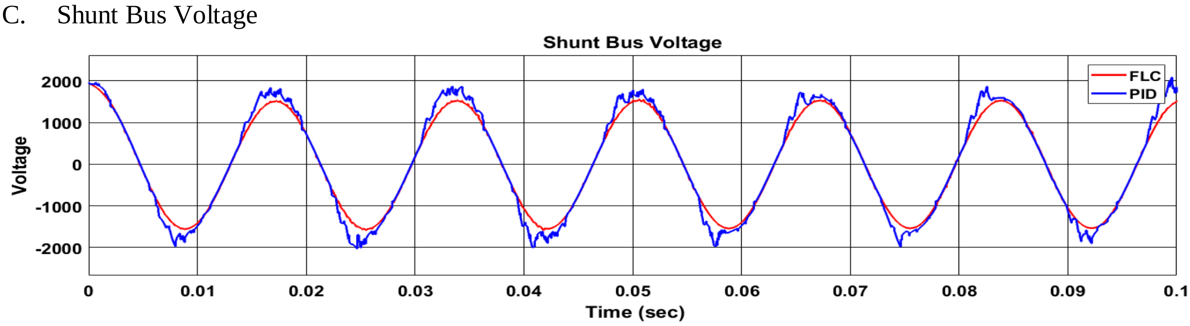

Fig 16 Comparison of Shunt Bus Voltage of UPQC using FLC and PID controller

Fig. 16 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.

D. Shunt Bus DC voltage

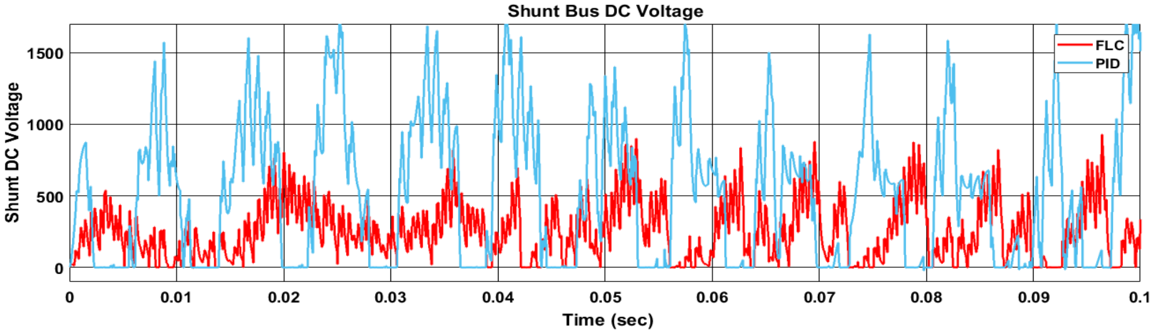

Fig 17 Comparison of Shunt bus DC Voltage of UPQC using FLC and PID controller

Fig. 17 shows shunt 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 has less distortions.

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 Quality Controller (UPQC) 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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