IJCTA, 9(9), 2016, pp. 3855-3863

Fuzzy Based Improved IUPQC Controller to Provide Additional Grid-Voltage Regulation as a STATCOM

R. Suguna[1], S. Sri Krishna Kumar[2], Venkata Subbaiah Putta[3], Saravanan S.[4], Sibiraj B.[5] and Kumaran K.[6]

ABSTRACT

This paper presents a Fuzzy based controller for dual topology of the Interline Unified Power Quality Conditioner (iUPQC) for power quality compensation extending its applicability as well as in micro grid applications. Beyond the conventional UPQC power quality features, the iUPQC also provide reactive power support to regulate the load-bus voltage and also the grid-side bus voltage. Here in this paper the iUPQC will work as a shunt active voltage source converter (STATCOM) at the grid-side and it work as a conventional UPQC controller at the load side or micro-grid side. The fuzzy logic controller is used to eliminate harmonics and the values of harmonics with fuzzy and without fuzzy have been compared. Simulation results are provided to verify the enhancement and regulation of voltage of the IUPQC with fuzzy controller and without fuzzy controller. The results are verified using MATLAB simulation.

1. INTRODUCTION

Power-electronics devices have broughtabout great technological improvements. However, theincreasing number of power-electronics-driven loads used generallyin the industry has brought about uncommon power qualityproblems. In contrast, power-electronics-driven loadsgenerally require ideal sinusoidal supply voltage in order tofunction properly, whereas they are the most responsible onesfor abnormal harmonic currents level in the distribution system.

In this scenario, devices that can mitigate these drawbackshave been developed over the years. Some of the solutionsinvolve a flexible compensator, known as the unified powerquality conditioner (UPQC) [1]–[7] and the static synchronouscompensator (STATCOM) [8]–[12]. Nonlinear loads always reduce the power quality at electrical grid and contain a high harmonic which effect thecritical loads. To overcome such problems we are using UPQC is low distortion of harmonic to regulate voltage fromthe loads and undistorted the current from the utility grid.

In UPQC they are two types of filters SAF and PAF, PAF isa current source and SAF is a voltage source both of them are a non-sinusoidal reference and also compensate theharmonic in grid voltage and load current. It is a complex method to solve such problems we are using active filters tocontrol the harmonics and to eliminate harmonics fuzzy controller.Its conditioner consists of two single-phase currentsource inverters where the SAF is controlled by a current loop and the PAF is controlled by a voltage loop both of themare interconnected to fuzzy controller and grid current and load voltage are sinusoidal, and therefore, their referencesare also sinusoidal. This concept is called "dual topology of unified power quality conditioner" (iUPQC), and thecontrol schemes use the p–q theory, for a real time of positive sequence.

[1,2,4,5,6] Department of Electrical and Electronics Engineering, Vel Tech High Tech Dr. Rangarajan Dr. Sakunthala Engineering College, Chennai, Tamil Nadu, *Emails: r_sugan29@yahoo.com, krishnakumar.rvs@gmail.com, sibi.raj868@gmail.com, smartsaran8@gmail.com, kumaran.7617@gmail.com*

[3] Department of Electronics and communication Engineering, Vel Tech, Chennai, Tamil Nadu, India, *Email: venky806@gmail.com*

The aim of this paper is to propose Fuzzybased Interline Unified Power Quality Conditioner for power quality enhancement to eliminate the harmonic fromsource to load.

The performance of the iUPQC and the UPQC were compared when working as unified power quality conditioners. The main difference between these compensators is the sort of source emulated by the series and shunt power converters.

In the UPQC approach, the series converter is controlled as a non-sinusoidal voltage source and the shunt one as a non-sinusoidal current source. Hence, in real time the UPQC controller has to determine and synthesize accurately the harmonic voltage and current to be compensated. On the other hand, in the iUPQC approach the series converter behaves as controlled, sinusoidal, current source and the shunt converter as a controlled, sinusoidal, voltage source. This means that it is not necessary to determine the harmonic voltage and current to be compensated, since the harmonic voltages appear naturally across the series current source and the harmonic currents flow naturally into the shunt voltage source.

2. IUPQC MODEL

In order to clarify the applicability of the improved iUPQC controller, Fig. 1 depicts an electrical system with two buses in spotlight, i.e., bus A and bus B. Bus A is a critical bus of the power system that supplies sensitive loads and serves as point of coupling of a micro grid. Bus B is a bus of the micro grid, where nonlinear loads are connected, which requires premium-quality power supply.

The voltages at buses A and B must be regulated, in order to properly supply the sensitive loads and the nonlinear loads. The effects caused by the harmonic currents drawn by the nonlinear loads should be mitigated, avoiding harmonic voltage propagation to bus A.

The use of a STATCOM to guarantee the voltage regulation at bus A is not enough because the harmonic currents drawn by the nonlinear loads are not mitigated. On the other hand, a UPQC or an iUPQC between bus A and bus B can compensate the harmonic currents of the nonlinear loads and compensate the voltage at bus B, in terms of voltage harmonics, unbalance, and sag/swell. Nevertheless, this is still not enough to guaranteethe voltage regulation at bus A. Hence, to achieve all the desired goals, a STATCOM at bus A and a UPQC (or an iUPQC) between buses A and B should be employed. However, the costs of this solution would be unreasonably high.

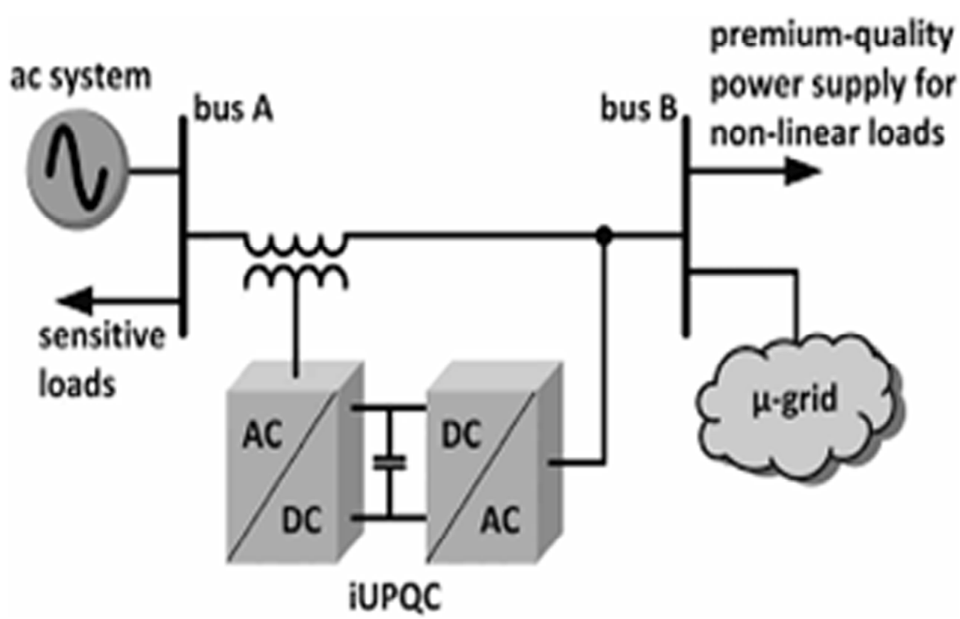

Figure 1: IUPQC Model

BLOCK DIAGRAM OF PROPOSED MODEL

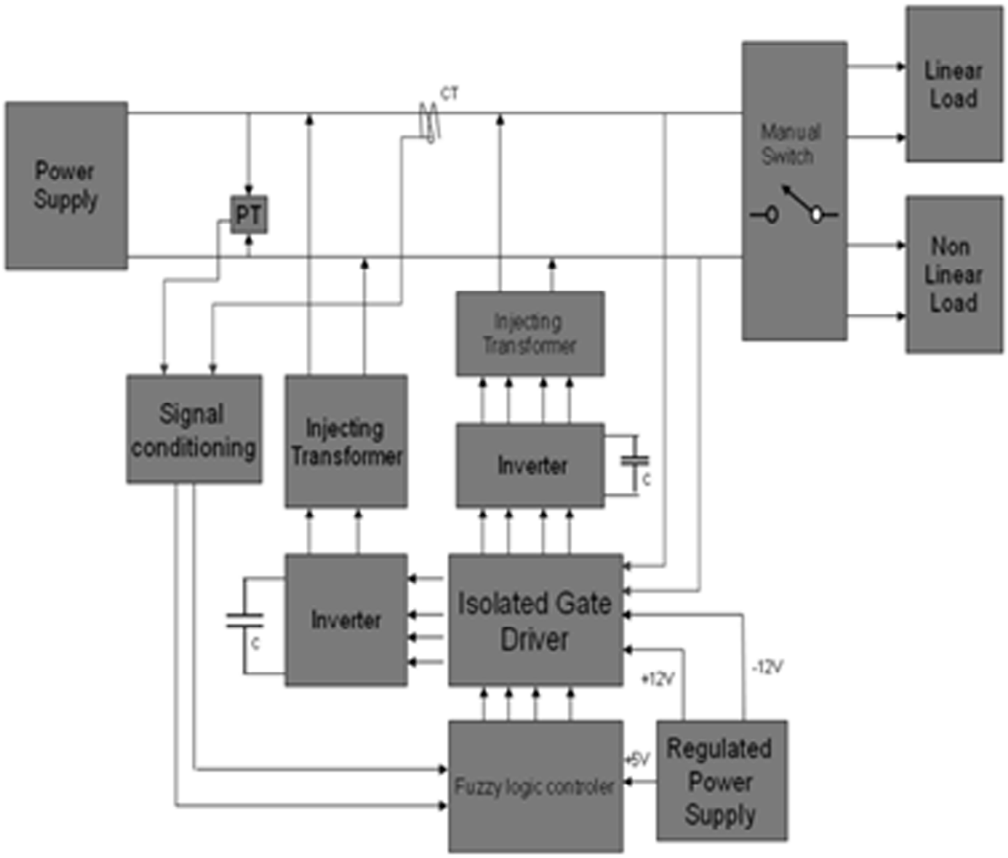

Figure 2: Block Diagram Of Proposed System

In proposed system, the iUPQC having a combination of series and shunt active filter, where the shunt active filter behaves as an ac-voltage source and the series one as an ac-current source, both at the fundamental frequency. It means the iUPQC compensate both voltage and current in input side as well as output side. So the system is more stable when compared to UPQC.IUPQC using series and shunt active filter to compensate the voltage and current by using fuzzy logic control technique in microcontroller. To compensate the line losses occurs due to voltage swell, sag & harmonics and thus increases the efficiency of the distribution lines.In proposed system we use fuzzy logic based controller to overcome the demerits of existing system.Fuzzy logic is a rule based technique.It consists of three blocks namely fuzzification, rule, and defuzzification. All possible ranges of voltage and current values are framed as rules and it gives the required amount of voltage and current. It uses IF-THEN rules approach.Error value and change in error value are the two inputs to the fuzzificationblock.Change in error value is a difference of present and previous error value.

3. FUZZY LOGIC CONTROLLER

3.1. Fuzzification

The first step in the design of a fuzzy logic controller is to define membership functions for the inputs. Seven fuzzy levels or sets are chosen and defined by the following library of fuzzy-set values for the error e and change in error.

They are as follows

- ★ NB negative big
- ★ NM negative medium

- ⋆ NS negative small
- ⋆ ZE zero equal
- ⋆ PS positive small
- ⋆ PM positive medium
- ⋆ PB positive big

- The number of fuzzy levels is not fixed and depends on the input resolution needed in an application. The larger the number of fuzzy levels, the higher is the input resolution.
- The fuzzy controller utilizes triangular membership functions on the controller input. The triangular membership function is chosen due to its simplicity. For a given crisp input, fuzzifier finds the degree of membership in every linguistic variable.
- Since there are only two overlapping memberships in this specific case, all linguistic variables except two will have zero membership.

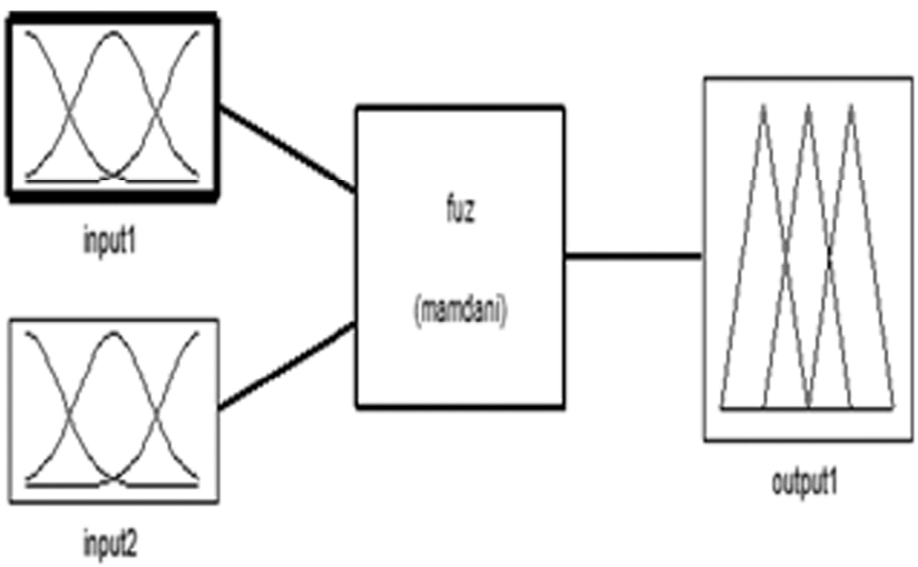

Figure 3: Block Diagram of Fuzzy

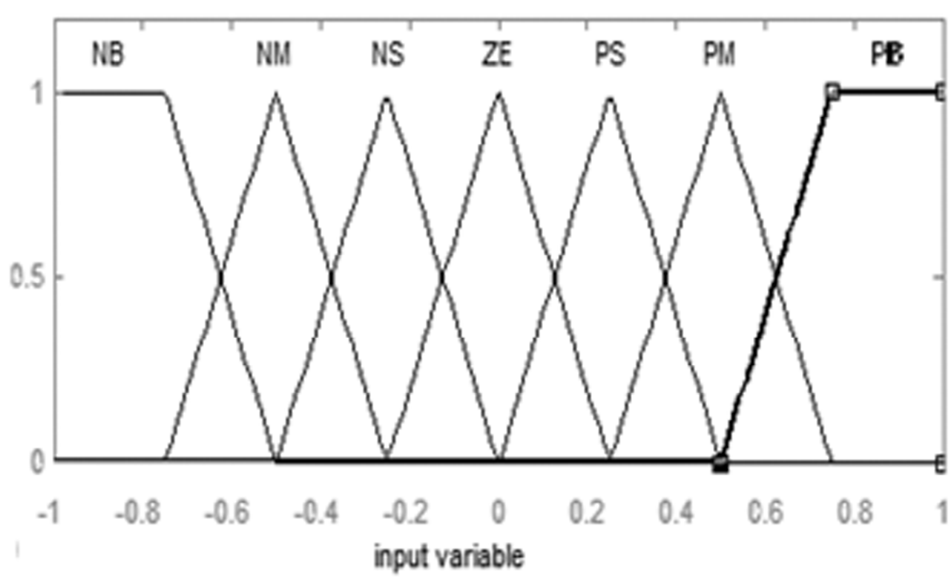

Figure 4: Membership Functions of The Input Linguistic Variables

3.2. Rule Base or Decision-Making

- Fuzzy control rules are obtained from the analysis of the system behaviour. In their formulation it must be considered that using different control laws depending on the operating conditions can greatly improve the converter performances in terms of dynamic response and robustness.
- The control rules that associate the fuzzy output to the fuzzy inputs are derived from general knowledge of the system behaviour[13]. However, some of the control actions in the rule table are also developed using “trial and error” and from an “intuitive” feel of the process being controlled.
- The control rules for the dc–dc converter in Table I resulted from an understanding of converter behaviour. A typical rule can be written as follows. If e is NB and ceis PS then output is ZE Where are the labels of linguistic variables of error (e), change of error (ce) and output respectively. e, ce and output represent degree of membership.
- To obtain the control decision, the max-min inference method is used. It is based on the minimum function to describe the AND operator present in each control rule and the maximum function to describe the OR operator. Control rules are given below.

The derivation of the fuzzy control rules is heuristic in nature and based on the following criteria:

Table 1
Control Rule Table
error(e)

change in error(ce)	NB	NM	NS	ZE	PS	PM	PS
NS	NB	NB	NB	NB	NM	NS	ZE
NM	NB	NB	NB	NM	NS	ZE	PS
NS	NB	NB	NM	NS	ZE	PS	PM
ZE	NB	NM	NS	ZE	PS	PM	PS
PS	NM	NS	ZE	PS	PM	PS	PS
PM	NS	ZE	PS	PM	PS	PS	PS
PS	ZE	PS	PM	PS	PS	PS	PS

- When the output of the converter is far from the set point, the change of duty cycle must be large so as to bring the output to the set point quickly.
- When the output of the converter is approaching the set point, a small change of duty cycle is necessary.
- When the output of the converter is near the set point and is approaching it rapidly, the duty cycle must be kept constant so as to prevent overshoot.
- When the set point is reached and the output is still changing, the duty cycle must be changed a little bit to prevent the output from moving away.
- When the set point is reached and the output is steady, the duty cycle remains unchanged.When the output is above the set point, the sign of the change of duty cycle must be negative, and vice versa.

4. SIMULATION MODEL OFEXISTINGSYSTEM (WITHOUT FUZZY)

In existing system simulation model three phase voltage source is connected to three phase VI measurement block from where input voltage and current is measured. We can see the measured values of voltage and current in scope block. In between source and load IUPQC is connected, where the load may be linear or nonlinearload.Then sag and swell is injected into the line through injecting transformer.In our model sag implies sudden turn on of the large loads where as swell implies sudden turn off of the large loads.This will affect the RMS value of line parameters and increase the THD level(4.53%).The RMS value is obtained from the RMS scope block.The THD level is measured from the powergui block.

4.1. Results

The waveform for input and output voltage and currents were shown in the figure. The waveforms are derived without adding fuzzy controller. The total harmonic reduction is 4.53% without fuzzy controller.

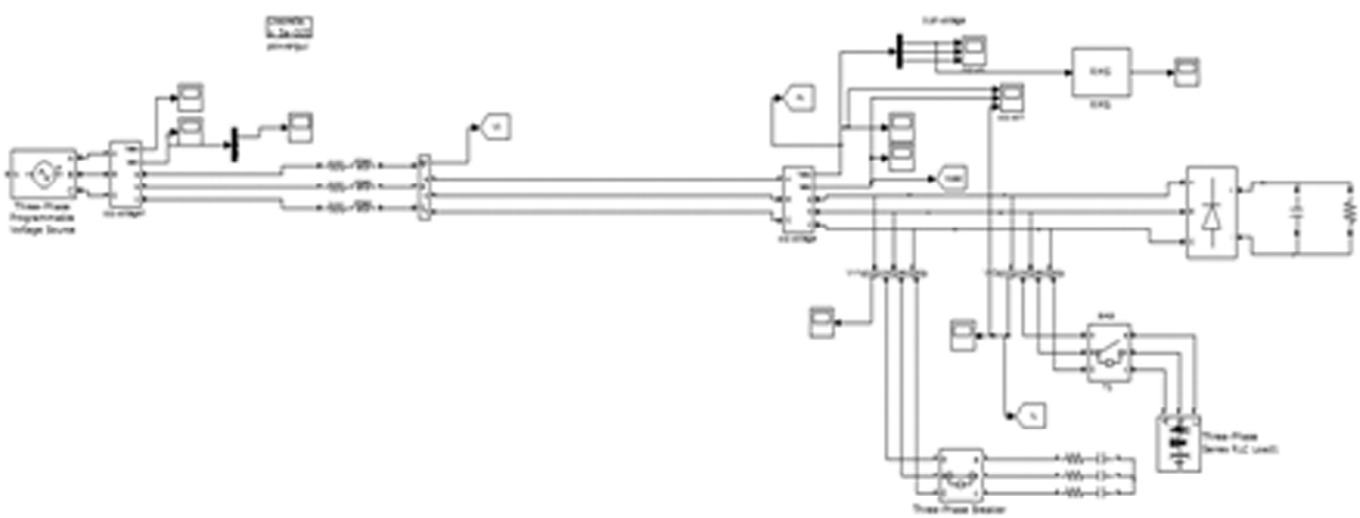

Figure 5: Simulation Model of Existing System (Without Fuzzy)

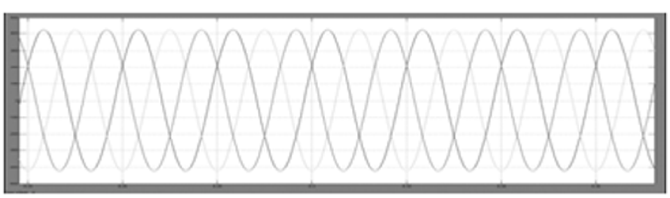

Figure 6: Three Phase Input Voltage (Without Fuzzy)

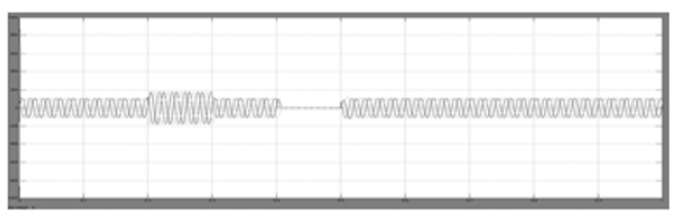

Figure 7: Three Phase Input Current(without fuzzy)

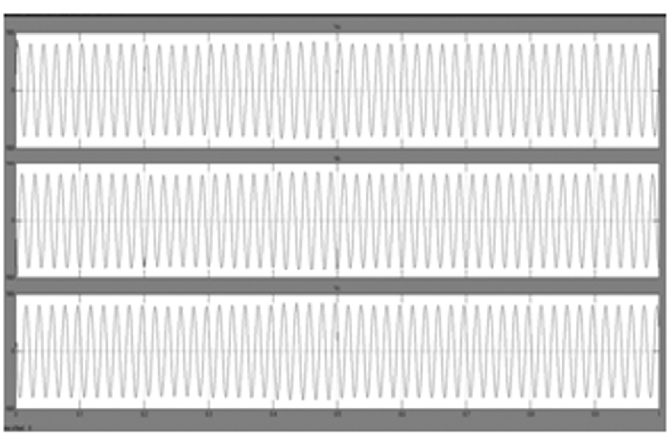

Figure 8: Three Phase Output Voltage(Without Fuzzy)

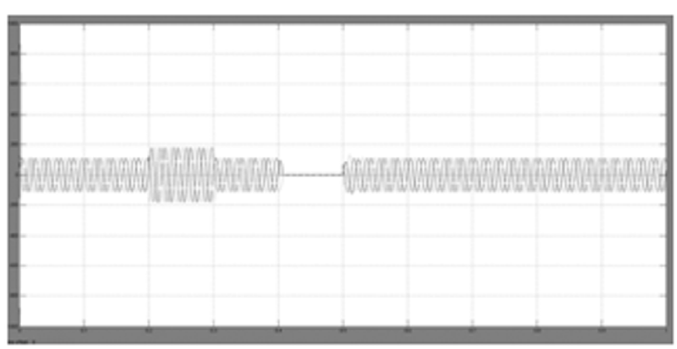

Figure 9: Three Phase Output Current(Without Fuzzy)

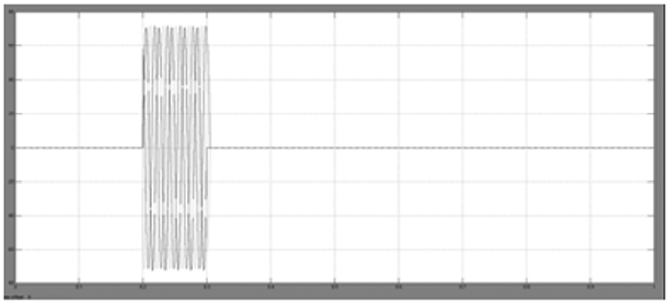

Figure 10: Sag Point (Without Fuzzy)

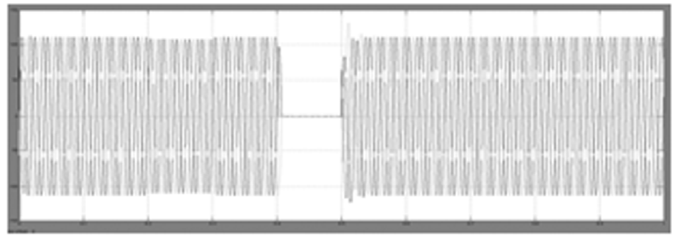

Figure 11: Swell Point (Without Fuzzy)

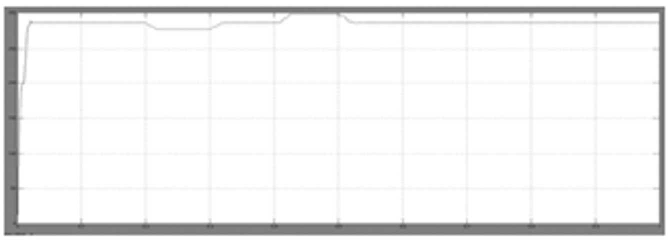

Figure 12: RMS Value (Without Fuzzy)

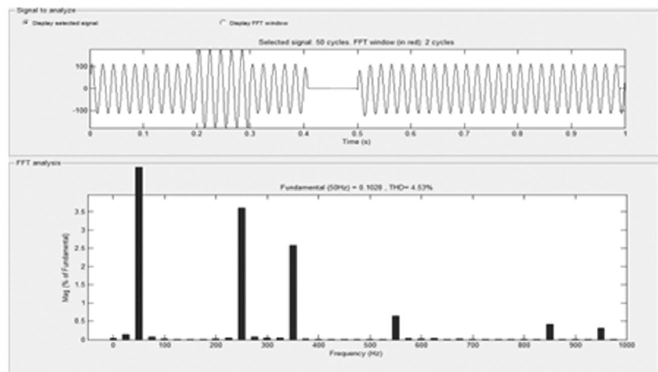

Figure 13: THD Level (Without Fuzzy)

5. SIMULATION MODELOF WITH FUZZY(PROPOSED SYSTEM)

In existing system simulation model three phase voltage source is connected to three phase VI measurement block from where input voltage and current is measured.We can see the measured values of voltage and current in scope block.

In between source and load IUPQC is connected, where the load may be linear or nonlinearload.Then sag and swell is injected into the line through injecting transformer.In our model sag implies sudden turn on of the large loads where as swell implies sudden turn off of the large loads.This will affect the RMS value of line parameters and increase the THD level(4.53%).The RMS value is obtained from the RMS scope block.The THD level is measured from the powergui block.

In our model the logic technique used is fuzzy logic algorithm.For making calculations simple three phase components are converted into two phase components(direct axis and quadrature axis).Here low pass filter is used to eliminate the unwanted noises which are present in the system.After calculating values

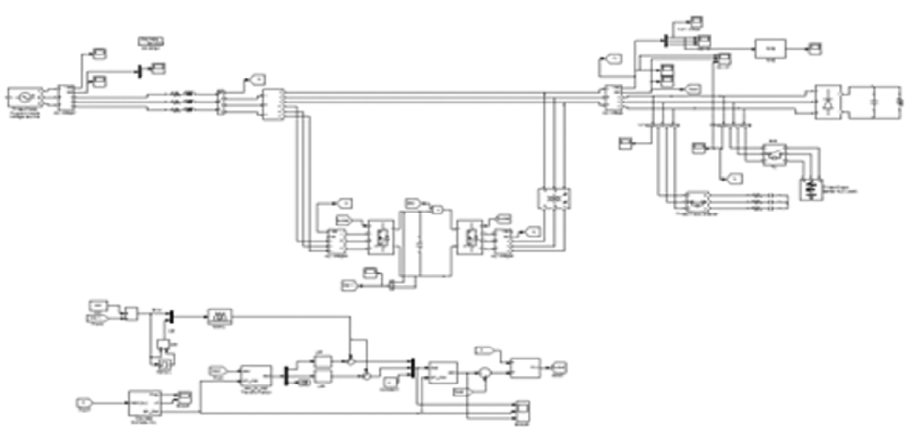

Figure 14: Simulation Model of With Fuzzy (Proposed System)

two phase components are again converted into three phase components.Then the required signal is generated and given to the gate driver for further operation.

5.1. Results With Fuzzy

The waveforms for input voltage and current and output voltage and current with fuzzy controller were shown below. There is a total harmonic reduction of about 0.49%.

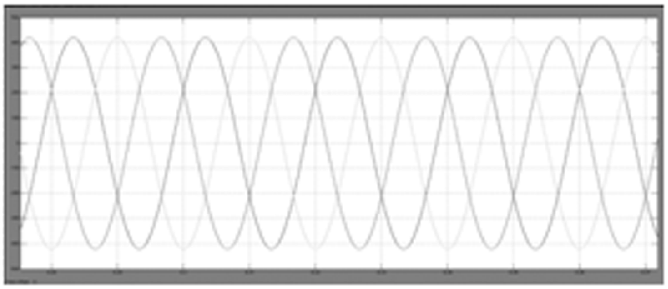

Figure 15: Three Phase Input Voltage (with fuzzy)

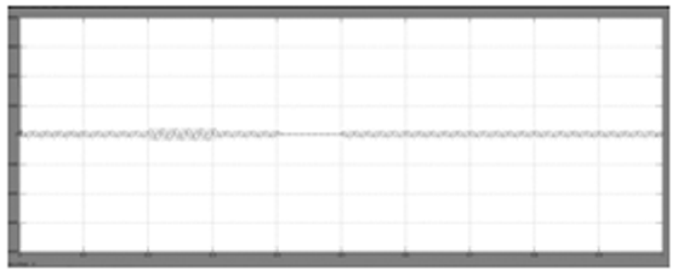

Figure 16: Three Phase Input Current (with fuzzy)

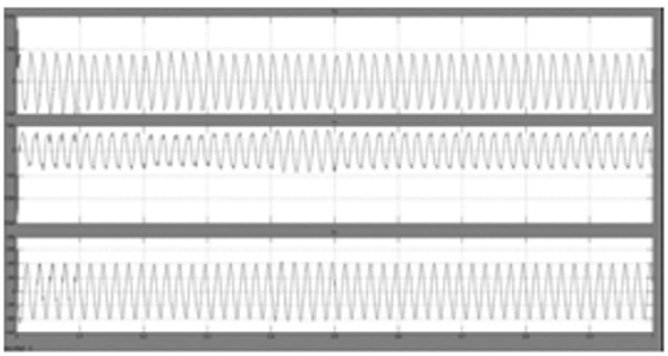

Figure 17: Three Phase Output Voltage (with fuzzy)

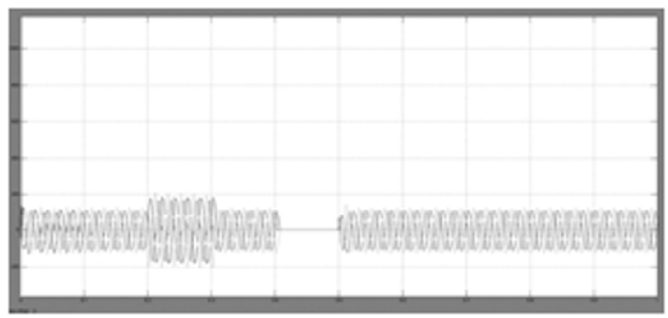

Figure 18: Three Phase Output Current (with fuzzy)

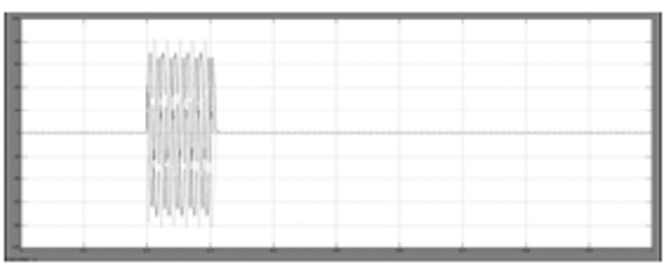

Figure 19: Sag Point (with fuzzy)

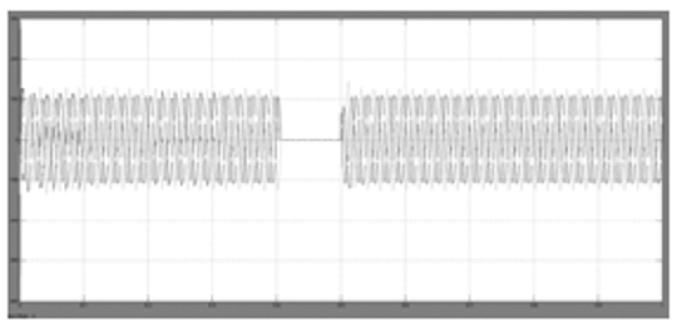

Figure 20: Swell Point (with fuzzy)

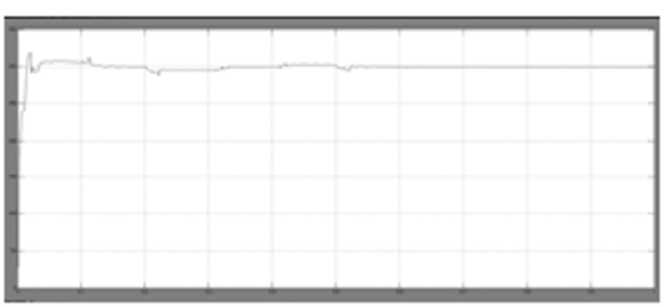

Figure 21: RMS Voltage (with fuzzy)

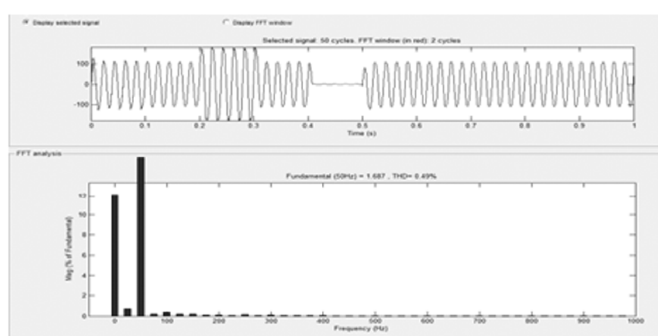

Figure 22: THD Level (with fuzzy)

6. CONCLUSION

In the improved iUPQC controller using fuzzy logic, the currents synthesized by the series converter are determined by the average active power of the load and the active power to provide the dc link voltage regulation, together with an average reactive power to regulate the grid-bus voltage. In this manner, besides all the power-quality compensation features of a conventional UPQC or an iUPQC, this improved controller also mimics a STATCOM to the grid bus.Applicability of the iUPQC provides new solution in the future scenario involving smart grids and micro grids including distributed generation and energy storage systems to better deal with the inherent variability of renewable resources such as solar and wind power. Moreover, the improved iUPQC controller may justify the costs and promotes the iUPQC applicability in power quality issues of critical systems, where it is necessary not only an iUPQC or a STATCOM, but both, simultaneously. A fuzzy code designed to control something, which may be software or hardware is used from small circuits to large mainframes.Despite the addition of one more power-quality compensation feature, the grid-voltage regulation reduces the inner-loop circulating power inside the iUPQC, which would allow lower power rating for the series converter. The experimental results verified the improved iUPQC goals. The grid voltage regulation was achieved with no load, as well as when supplying a three-phase non-linear load. These results have demonstrated a suitable performance of voltage regulation at both sides of the iUPQC, even while compensating harmonic current and voltage imbalances. By using fuzzy logic with iUPQC manual calculations are minimised and it gives fast response compare to the other logic techniques.Voltage, current are regulated and total harmonic distortion is reduced from 4.53% to 0.49%.

REFERENCES

[1] A Simplified Control Technique for a Dual Unified Power Quality Conditioner, R. J. Millnitz dos Santos; J. C. da Cunha; M. Mezaroba, IEEE Transactions on Industrial Electronics, Year: 2014, Volume: 61, Issue: 11 pp. 5851-5860, DOI: 10.1109/ TIE.2014.2314055.

[2] K. Karanki, G. Geddada, M.K. Mishra, and B.K. Kumar, "A ModifiedThree-Phase Four-Wire UPQC Topology With Reduced DC-Link Voltage Rating," IEEE Trans. Ind. Electron., vol. 60, no. 9, pp. 3555-3566, Sep. 2013.

[3] Kian Hoong Kwan, Ping Lam So, and Yun Chung Chu, "An Output Regulation-Based Unified Power Quality Conditioner With Kalman Filters," IEEE Trans. Ind. Electron., vol. 59, no. 11, pp. 4248-4262, Nov. 2012.

[4] J.A. Munoz et al., "Design of a Discrete-Time Linear Control Strategy for a Multi-cell UPQC," IEEE Trans. Ind. Electron., vol. 59, no. 10, pp. 3797-3807, Oct. 2012.

[5] V. Khadkikar, "Enhancing Electric Power Quality Using UPQC: A Comprehensive Overview," IEEE Trans. Power Electron., vol. 27, no. 5, pp. 2284-2297, 2012.

[6] Convertible unified power quality conditioner to mitigate voltage and current imperfections, S. M. B. Eldin; K. S. R. Rao; R. Ibrahim; N. Perumal, Intelligent and Advanced Systems (ICIAS), 2012 4th International Conference on, Year: 2012, Volume: 1, Pages: 473 - 478, DOI: 10.1109/ICIAS.2012.6306240.

[7] V. Khadkikarand A. Chandra, "UPQC-S: A Novel Concept of Simultaneous Voltage Sag/Swell and Load Reactive Power Compensations Utilizing Series Inverter of UPQC," IEEE Trans. Power Electron., vol. 26, no. 9, pp. 2414-2425, 2011.

[8] A. Mokhtatpour and H.A. Shayanfar, "Power Quality Compensation as Well as Power Flow Control Using of Unified Power Quality Conditioner," in Power and Energy Engineering Conference (APPEEC), 2011 Asia-Pacific, 2011, pp. 1-4.

[9] R.J. Millnitz dos Santos, M. Mezaroba, and J.C. da Cunha, "A dual unified power quality conditioner using a simplified control technique," in Power Electronics Conference (COBEP), 2011 Brazilian, 2011, pp. 486-493.

[10] "An Improved iUPQC Controller to Provide Additional Grid-Voltage Regulation as a STATCOM", IEEE Transactions on Industrial Electronics (Volume:62, Issue: 3), Page(s):1345-1352ISSN :0278-0046.

[11] M. Aredes and R.M. Fernandes, "A dual topology of Unified Power Quality Conditioner: The iUPQC," in Power Electronics andApplications, 2009. EPE '09. 13th European Conference on, 2009, pp. 1-10.

[12] R. Suguna, S. Jalaja, M. Pradeep, R. Senthil Kumar, S. SrikrishnaKumar and K. R. Sugavanam "Transient Stability Improvement using Shunt and Series Compensators" Indian Journal of Science and Technology, Vol 9(11), DOI: 10.17485/ ijst/2016/v9i11/89402, March 2016, ISSN: 0974-5645.

[13] K. MohanaSundaram, R. Senthil Kumar, C. Krishnakumar, K. R. Sugavanam "Fuzzy Logic and Firefly Algorithm based Hybrid System for Energy Efficient Operation of Three Phase Induction Motor Drives" Indian Journal of Science and Technology, Vol . 9, No. 1, DOI: 10.17485/ijst/2016/v9i1/85762, January 2016. ISSN: 0974-5645.