International Journal of ChemTech Research
CODEN (USA): IJCRGG, ISSN: 0974-4290, ISSN(Online):2455-9555
Vol.11 No.04, pp 92-100, 2018

Performance Comparison of L-UPQC and R-UPQC with FUZZY logic Controller for Power Quality Improvement

Ananthan Nagarajan[1]*, P.Sivachandran[2], M.V.Suganyadevi[3]

[1]Ph.D Scholar, Anna University, Guindy, Chennai,India
[2]Professor, Department of EEE, Vel Tech Multi Tech Dr. Rangarajan Dr. Sakunthala Engineering College, Chennai,India
[3] Associate Professor, Department of EEE, Saranathan College of Engineering, Trichy, India

Abstract : In the modern power system, the usage of power electronic loads was statically high and it behaves as non-liner load. This load causes the serious voltage distortion and power quality issues on the transmission and distribution system by injecting the harmonics. Usually active power filters are used to regulate this problem. Unified power quality conditioner is the combination of series and shunt active power filters. It not only eliminates the harmonics, also it treats all type of voltage and current fluxuations and compensate the reactive power in distribution system. In this paper new topology of unified power quality conditioner with different control strategy was introduced to rectify the power quality issues and increase the strength of power quality. UPQC concern feedback system with FUZZY logic controllers was used to improve the performance of UPQC and compare the results using MAT LAB/SIMULINK.

Index Terms : L-UPQC, R-UPQC, Active Power Filters, Power Quality.

I. Introduction

An electric power system is a network of electrical components deployed to supply, transfer, store, and use electric power. An example of an electric power system is the grid that provides power to an extended area. An electrical grid power system can be broadly divided into the generators that supply the power, the transmission system that carries the power from the generating centres to the load centres, and the distribution system that feeds the power to nearby homes and industries[1]. Compared to generation and transmission we have huge power quality issues on distribution system. The impacts of power quality problems are voltage surges/spikes, voltage dips, under voltage, high-voltage spikes, frequency variation, power sag, electrical line noise, brownouts, blackouts, very short interruptions, long interruptions, voltage swell, and harmonic distortion.[2].

Now a day we frequently using variety of sensitive loads such as computer, led television, home automation, etc. Due to poor power quality such equipment may failure or less life span. To diagnose this

Ananthan Nagarajan *et al* /International Journal of ChemTech Research, 2018,11(04): 92-100.

DOI : http://dx.doi.org/10.20902/IJCTR.2018.110410

problem and also to improve the power quality we have only solution, called Active Power Filters. The Active Power Filters (APF) are the most promising solution to reduce the power quality issues and made it possible to mitigate the PQ problems effectively. The APF is split into series active power filter (se-APF) and shunt active power filter (sh-APF). The series active power filter is operated to diagnose the source side problems. Likewise, shunt active power filter is operated to diagnose the load side problems[3].

UPQC is one of APF families which consists of both series and shunt active power filters to achieve the extreme compensation for rapid PQ problems. The UPQC is a hybrid compensation device which tolerates both voltage and current related problems. The source side problems are referred as voltage related problems and it is compensated by series active filter. Typically, the load side problems are current related problems and it is compensated by shunt active power filter. The both series active power filter and shunt active power filter are coupled with dc capacitor for dc link.[3] The series APF is connected via an injection transformer with the ac line. The isolation of voltage based distortion is done by the series APF and the isolation of current based problems is done by the shunt APF

II. Problem Formation

The mathematical formulation of two voltage sag indices (ξ and ζ1,2) is introduced in additionbecause the results of the investigation towards their accuracy institution. The Mathematical equations describing the event of a Combined Voltage Index (CVI) arebestowedin additionbecause the results obtained by the verification method. The index supervises the ability of a system, through characterizing voltage sags [4]. The voltage sagssquare measure caused by a rise in reactive demand owing to induction motor beginning.

A feeder can be modelled by an equivalent two-port network, as shown in Figure 1. The sending end voltage and current of the system can be represented by equations (1) and (2).

$$\boldsymbol{U_s\angle\delta_s = AU_r\angle\delta_r + BI_r 1}$$

$$\boldsymbol{I_s = CU_r\angle\delta_r + DI_r 2}$$

Where I_s the sending end current, U_s is the sending end voltage, U_r the receiving end voltage, I_s the sending end current, I_r the receiving end current, δ_r the receiving end voltage angle, δ_s the sending end voltage angle, and ABCD are the two port network constants.

For a short length line, equivalent to distribution network, the two port network parameters are often approximated as: A=D=1, B= Z ∠θ, C=0.Where Z is that the line resistivity vector magnitude, and θ the line resistivity vector angle.

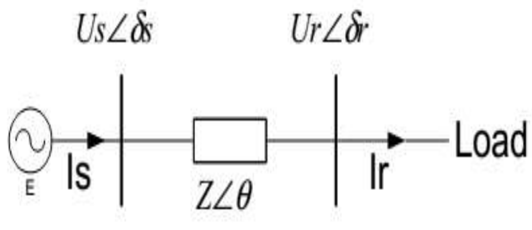


Fig. 1. The equivalent two port network model.

The line power flow, for the active power at the sending and receiving end of the line, can be described by (3) and (4).

$$\boldsymbol{P_r = \frac{U_s U_r}{Z}\cos(\theta + \delta_r - \delta_s) - \frac{U_r^2}{Z}\cos(\theta)} \quad 3$$

$$\boldsymbol{P_s = \frac{U_s^2}{Z}\cos(\theta) - \frac{U_s U_r}{Z}\cos(\theta + \delta_s - \delta_r)} \quad 4$$

*A. **For multi-channel three phase measurement***

The voltage sag starts once the RMS voltage URMS (1/2), drops below the threshold in a minimum of one in all the channels, and ends once the RMS voltage recovers on top of the threshold in all channels. The preserved voltage for a multi-channel activity is that the lowest RMS voltage in any of the channels. many strategies are investigated resulting in one index for every event. Though this ends up in higher loss of data, it simplifies the comparison of events, sites and systems. [4] the final downside of any single-index technique is that the result not directly relates to equipment behavior. Single indices are shortly represented below.

Voltage Loss: The loss of voltage "L_v" is defined as the integral of the voltage drop during the sag event.

$$L_V = \int \{1 - V(t)\}\, dt \qquad 5$$

Energy Loss: The loss of energy "LE" is defined as the integral of the drop in energy during the event:

$$L_E = \int \{1 - V(t)^2\}\, dt \qquad 6$$

The energy of voltage sag (EVs) as:

$$E_{Vs} = (1 - V_{Pu})^2 \times t \qquad 7$$

Where 't' is the sag duration.

The concept of 'energy loss during a sag event' was found, in such how that the lost energy for events on the Computer Business Equipment Manufacturers Association (CBEMA) curve is constant for three-phase measurements. The lost energy is another for the three phases:

$$W_a = \left\{1 - \frac{V_a}{V_a nominal}\right\}^{3.14} \times t \qquad 8$$

To include non-rectangular events an integral expression may again be utilized. The event severity index (S_e) is taken from the event magnitude in Pu and the event duration. Also needed for the method is the definition of a reference Curve.

$$S_e = \frac{1 - V}{1 - V_{ref}(d)} \qquad 9$$

Where $V_{ref}(d)$is the event magnitude value of the reference curve for the same event duration. This method is observed by the use of the CBEMA and Information Technology Industry Council (ITIC) as reference curves. However, the method is equally applicable with other curves also.

III. UPQC State of Art

Generally, the construction of unified power quality conditioner is different from all other facts devices. It consists of both series active power filter and shunt active power filter. UPQC employs two voltage source inverters that are connected to common DC energy storage capacitor [8] - [19]. One of these two VSIs is connected in series with ac line while the other is connected in shunt with the same line[5].It is installed in the power transmission system to execute both series and shunt compensation at the same time.

Figure 2 illustrates the schematic structure of Unified Power Quality Conditioner. The series APF is installed to compensate the source side issues like sag, swell, interruption, etc. And the shunt APF is employed to tackle the load side issues like harmonic and power factor.

$$i_{sh}(\omega t) = \hat{i_s}(\omega t) - i_l(\omega t) \qquad 10$$

$$v_{se}(\omega t) = v_l(\omega t) - v_s(\omega t) \qquad 11$$

The shunt inverter should inject a current as governed by above equation (6) to eliminate the harmonics generated by the non-linear loads in the distribution system. Also, the basic operation of a series inverter can be represented in equation (7).

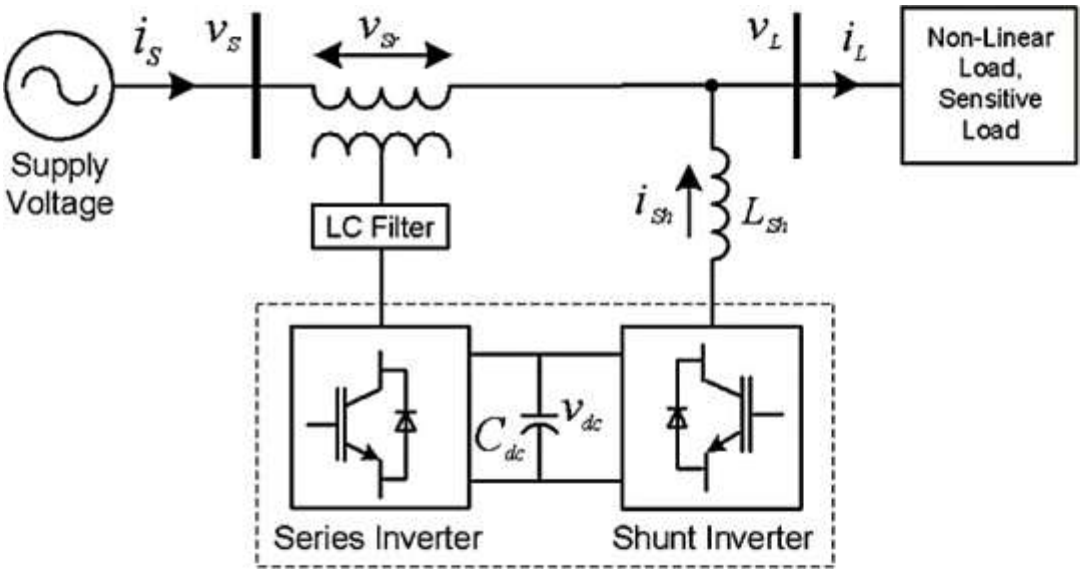
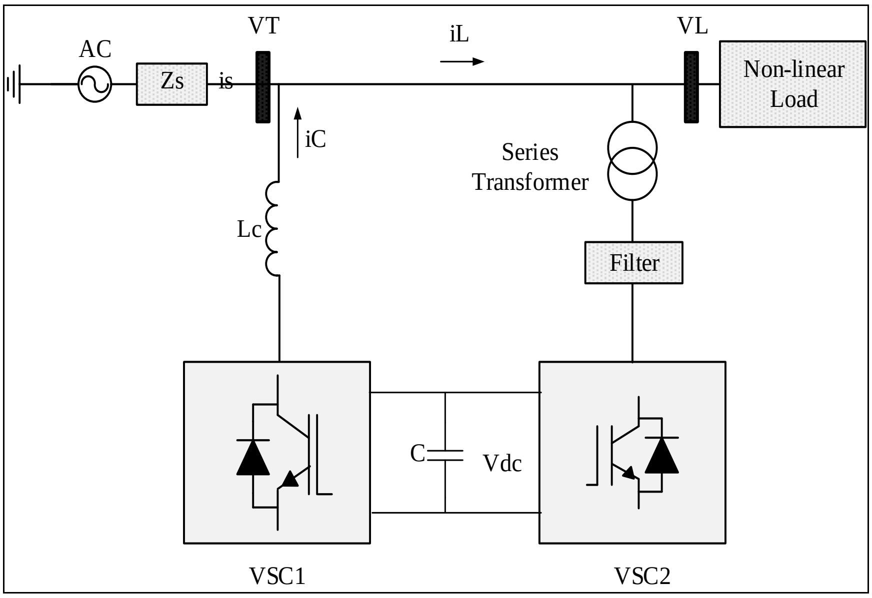


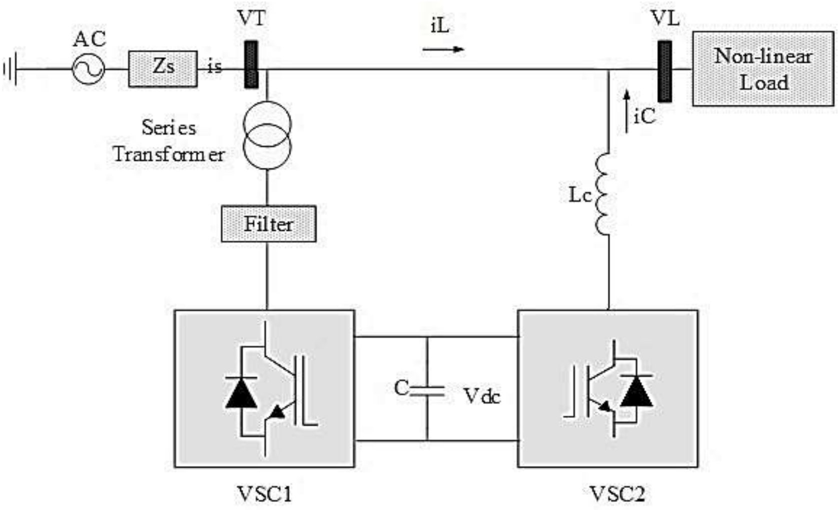
Fig. 2. Structure of UPQC

A. **UPQC Configuration**

Both structures of UPQC, R-UPQC and L-UPQC connected to a single feeder distribution system which supply a sensitive critical non-linear load are shown in Fig. 3. The shunt compensator, VSC 1 which operates as a controlled current source is used to compensate load current harmonics, to provide the reactive power required by the load and to support the real power required by the series compensators to maintain the dc link capacitor voltage at a desired level.[6] The series compensator, VSC2 is used as controlled voltage source to protect the sensitive/nonlinear load against input supply voltage imperfections. Some other UPQC configurations are shown in reference [21]-[25]



(i)



(ii)

Figure 3: Structure UPQC Configuration (i) R-UPQC (ii) L-UPQC

In Fig. 1, vS, vT, vL, vC are source, terminal or point of coupling, load, and compensation voltages, respectively, and iS, iL, iC are supply, load and compensation currents, respectively. In both UPQC topologies the ac side of shunt VSC1 is connected to the distribution system through a commutation reactor which denote by LC where the ac side of the series, VSC2 is connected to the distribution system through a single phase transformer, commutation reactor and small high-pass filter which used to prevent the flow of switching harmonics into the distribution systems.

IV. Fuzzy Logic Controller

Vagueness is the meaning of FUZZY. It is used to solving the uncertainty in the problem. It uses the interval between 0 and 1 for human reasoning. The FUZZY operation works by two stages and are Fuzzificaton and Defuzzification. The process of converting the crisp input to a fuzzy value is called as Fuzzificaton. The output of the fuzzy is developed with the rules. The basic operation of the FLC is constructed from fuzzy control rules utilizing the value of fuzzy sets in general for the error and change of error and control action. The results are combined to provide a crisp output controlling the output variable and this process is called as defuzzification. The sign of the error signal and the output from linguistic codes given in the table.

Table 1: Fuzzy Logic Truth Table

CHANGE IN ERROR	ERROR							
		NB	NM	NS	Z	PS	PM	PB
	NB	NB	NB	NB	NB	NM	NS	Z
	NM	NB	NB	NB	NM	NS	Z	PS
	NS	NB	NB	NM	NS	Z	PS	PM
	Z	NB	NM	NS	Z	PS	PM	PB
	PS	NM	NS	Z	PS	PM	PB	PB
	PM	NS	Z	PS	PM	PB	PB	PB
	PB	Z	PS	PM	PB	PB	PB	PB

V. Simulation Results Comparison

In order to verify the performance of both UPQC topologies (i.e.) R-UPQC and L-UPQC based on FUZZY LOGIC controller, comprehensive simulations studies have been carried out with the help of power system simulation package MATLAB/Simulink. Supply voltage, 400 V, 50 Hz for a single feeder distribution system as in both Fig. 4 & 5 is employed.

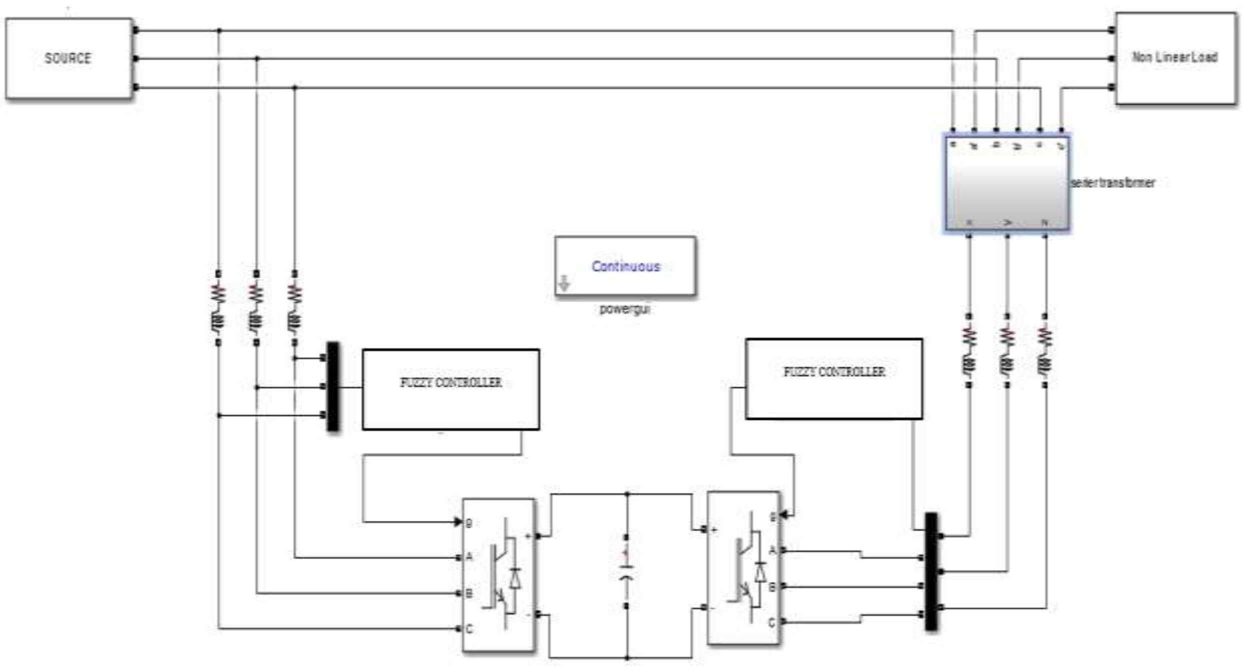


Fig.5. MATLAB/Simulink model for single unit infinite bus system with R-UPQC

A sensitive critical non-linear load assumed as a parallel combination of balanced three-phase R-L load (R=25 Ohms, L = 15.7 mH) and a three-phase diode bridge rectifier followed by R-L load on the dc side (R = 52 Ohms, L = 21 mH) which draws harmonic currents is connected to the feeder.

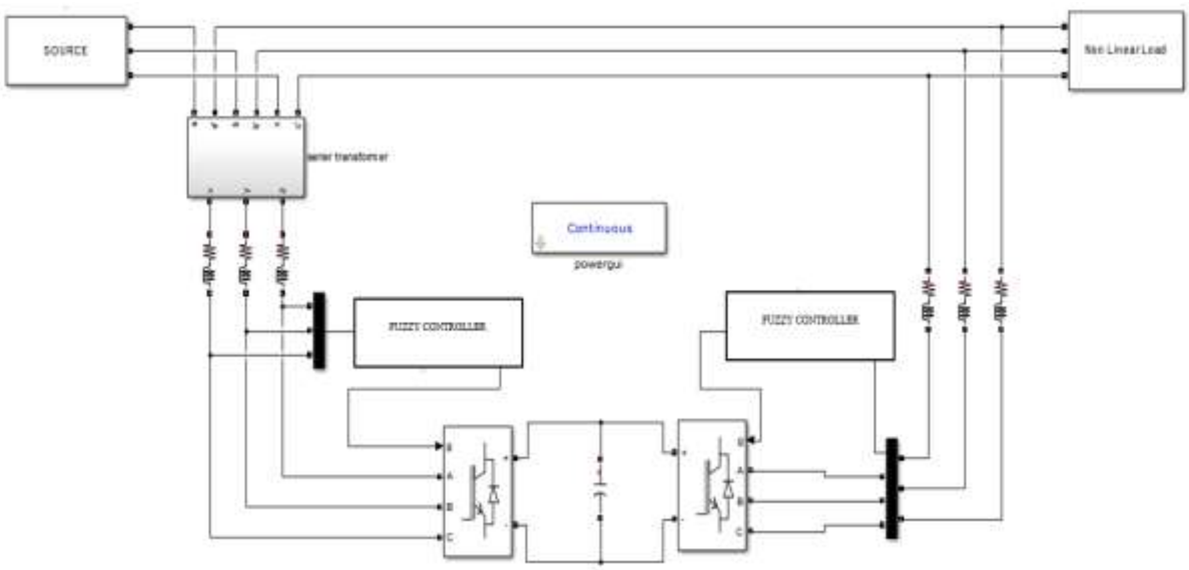


Fig. 6. MATLAB/Simulink model for single unit infinite bus system with L-UPQC

Figure 7 & 8 shows the output results of both R-UPQC and L-UPQC Here we manually trigger the non-linear load at the time of 0.4s. Later we manually operate the active power filters at the time of 0.6s. This process was experimented for quick understanding of UPQC characteristics.

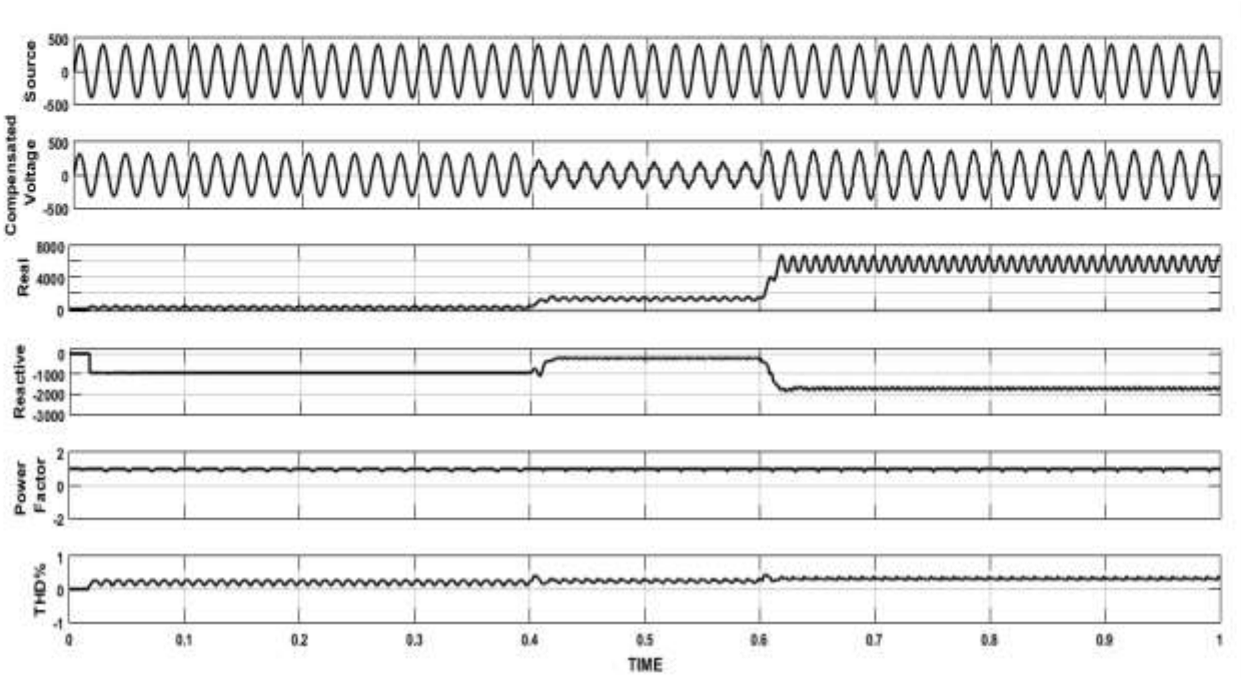


Fig. 7. Simulation Results for R-UPQC

The simulation result of Total Harmonic Distortion (THD) of load and source currents before compensation is observed to be 24.4 %. After compensation the source current THD is significantly reduced to 0.12 % by R-UPQC and to 0.21 % by L-UPQC. It is shown that both UPQC topologies have appreciable effect as current harmonic filters which prevented the load current harmonics from flowing into the source. Table 2 illustrates the results comparison of L-UPQC & R-UPQC.

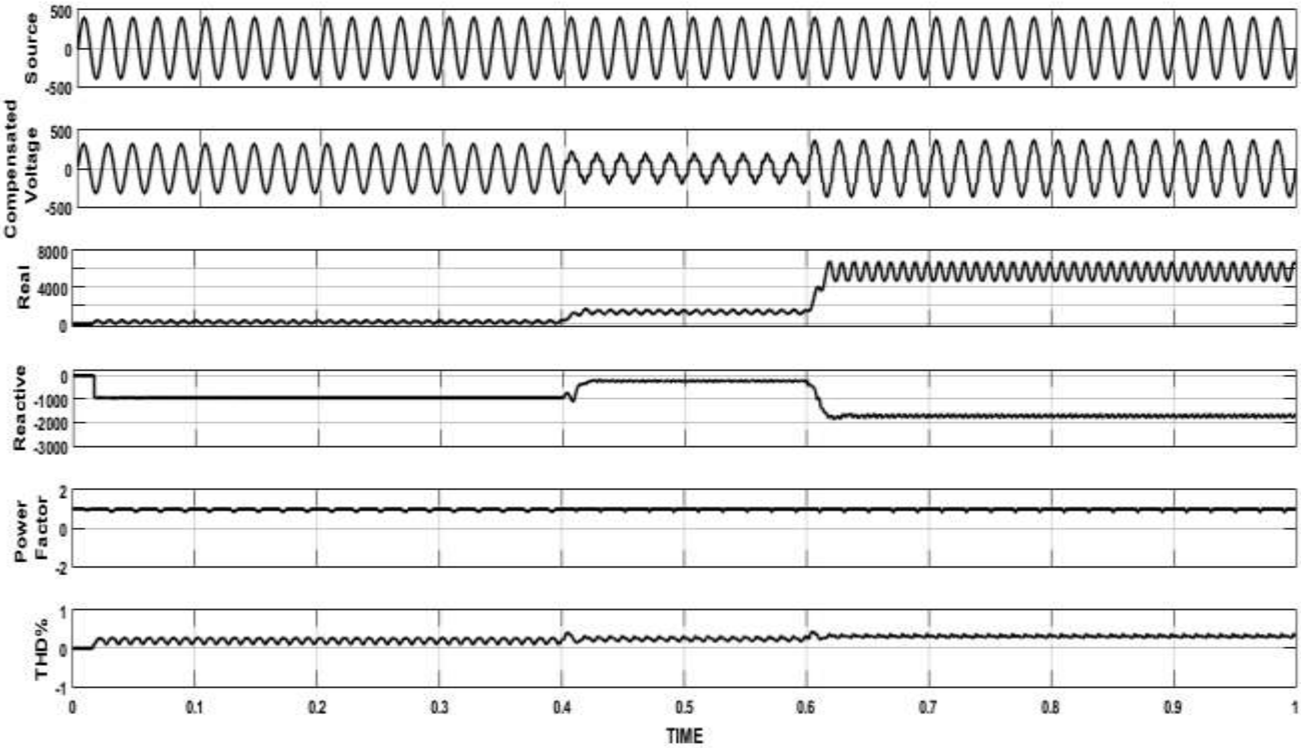


Fig. 8. Simulation Results for L-UPQC

Table 2. Comparison of left and right UPQC

S.No	Factors	L-UPQC	R-UPQC
1	Input Voltage	400V	400V
2	Non-Linear Load	RL	RL
3	THD	0.21 %	0.12 %
4	Power Factor	0.975	0.9989

VI. Future Scope

In this paper new topology of UPQC were simulated with FUZZY LOGIC controller and its results are shown. Future the FUZZY LOGIC controller may be replaced by any newer control strategy to get better achieve results.

VII. Conclusion

In this work both UPQC topology was deeply studied and the compensation performance of UPQC is established by the MATLAB/Simulation results on a single feeder distribution system. It is observed that the L-UPQC, R-UPQC topology only has the capability of operating in zero power absorption/injection modes. It is noticed that R-UPQC gives better compensation than the L-UPQC by reducing the THD of load voltage and source current. However, the UPQC topologies provides better compensation strength to mitigate voltage harmonic and minimize oscillating reactive power component based on FUZZY LOGIC controller.

References

1. S. J. Chapman, Electric machinery and power system fundamentals. Boston: McGraw-Hill, 2002.
2. P. Sivachandran, T. Hariharan, and R. Pushpavathy, “Improvement of power system stability using D-facts controllers: A review,” ARPN J. Eng. Appl. Sci., vol. 10, no. 2, pp. 933–939, 2015.
3. P. Sivachandran, “Enhancement of Power System Stability using Distributed Facts (D-Facts)Controllers.”[Online].Available:https://www.researchgate.net/publication/317165500_Enhancement_of_Power_System_Stability_using_Distributed_Facts_DFacts_Controllers. [Accessed: 08-Nov-2017].
4. A. Polycarpou, “6 Power Quality and Voltage Sag Indices in Electrical Power Systems.”
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. Ananthan N, A. Ganeshkumar “Performance Comparison of Upqc for Improving the Power Quality with Various Controllers Stratagy,” Int. J. Emerg. Technol. Comput. Sci. Electron., vol. 13, no. 2, pp. 976–1353, 2015.
7. P. Sivachandran and R. Muthukumar, “An Overview of Microgrid System”, International Journal of Applied Engineering Research, ISSN: 0973-4562, Vol. 9, No. 22, pp. 12353-12376, 2014
8. Power quality, C. Shankran, CRC Press, 2001.
9. Handbook of power quality, editor: Angelo Baggini, John Wiley & Sons, 2008.
10. Electrical power systems quality Roger C. Dugan et al., Tata McGraw-Hill, 2002.
11. Instantaneous powertheory and application to power conditioning, H. Akagi et al., IEEE Press, 2007
12. Sanjib Ganguly, “Impact of unified power-quality conditioner allocation on line loading, losses and voltage stability of radial distribution systems”, IEEE Transactions on power delivery, May 2014.
13. Yashomani Y.Kolhatkar, Shyama P.Das, “Experimental Investigation of a Single-phase UPQC with minimum VA Loading”, IEEE Transaction on Power Delevery,Vol.22, No.1, January 2007
14. Vinod Khadkikar, Ambrish Chandra, “A New control philosophy for a Unified Power Quality Conditioner (UPQC) to coordinate load reactive power demand between shunt and series inverter”, IEEE Transaction on Power Delivery, Vol.23, No.4, October 2008.
15. A.E. Leon, S.S. Amodeo, J.A. Solsona, “Non-linear optimal controller for unified power quality conditioners”, IET Power electronics, 13th August 2010.

16. Ahmet Teke, Mehmet Emin Meral, Mehmet Ugras Cuma, "OPEN unified power quality conditioner with control based on enhanced phase locked loop", IET Generation, Transmission and Distribution, 16th October 2012.
17. Abdul Mannan Rauf, Amit Vilas Sant, Vinod Khadkikar, H.H. Zeineldin, "A novel ten-switch topology for unified power quality conditioner", IEEE Transaction on power electronics, 2015.
18. Rodrigo Augusto Modesto, Sergio Augusto Oliveira da Silva, "Versatile unified power quality conditioner applied to three-phase four-wire distribution systems using a dual control strategy", IEEE Transaction on power electronics, 2015.
19. Bharath Babu Ambati and Vinod Khadkikar, "Optimal sizing of UPQC considering VA loading and maximum utilization of power-electronic converters", IEEE Transactions on power delivery, vol, 29, no. 3, pp. 1490-1498, June 2014.
20. Pedro E. Melin, Jose R. Espinoza, Luis A. Moran, "Analysis, design and control of a unified power-quality conditioner based ona current-source topology", IEEE Transactions on power delivery, vol. 27, no. 4, pp. 1727-1736, Oct 2012.
21. Srinivas Bhaskar Karanki, Nagesh Geddada, "A Modified three-phase four wire UPQC topology with reduced DC-link voltage rating", IEEE Transaction on Power Delivery,2011.
22. Javier A.Munoz, Jose R. Espinoze, "Design of a modular UPQC configuration integrating a components economic analysis", IEEE Transaction on Power Delivery, Vol.24, No.4, October 2009.
23. Vinod Khadkikar, Ambrish Chandra, "A Novel structure for Three-Phase four wire distribution system utilizing unified power quality conditioner", IEEE Transaction on Industry Application, Vol.45, No.5, September 2009.
24. Amit Kumar Jindal, Arindam Ghosh, "Interline Unified Power Quality Conditioner", IEEE Transaction on Power Delivery, Vol.22, No.1, January 2007.
25. B. Han, B.Bae, S.Baek, "New configuration of UPQC for Medium-Voltage Application", IEEE Transaction on Power Delivery, Vol. 21, No.3, July 2006.

*****

[1]**ANANTHAN NAGARAJAN** received his B.E. in Electrical and Electronics Engineering and M.E. Power Systems Engineering in 2013 and 2015 respectively, from Anna University. He is pursuing his Ph.D. Electrical Engineering degree in Anna University, Chennai.

[2]**Dr.P. Sivachandran** received his B.E. Electrical and Electronics Engineering and M.E. Power Electronics and Drives in 1996 and 1999 respectively, from Bharathidasan University and Ph.D. Electrical Engineering in 2012 from Anna University. Presently he is working as a Professor in EEE Dept. of Vel Tech Multi Tech Dr. Rangarajan Dr. Sakunthala Engineering College, Avadi, Chennai. He has 19 years of diverse experience in teaching and corporate industry.

[3]**Dr.M.V.Suganyadevi** received her B.E. Electrical and Electronics Engineering and M.E. Power System Engineering in 2006 and 2009 respectively from Anna University and Ph.D. Electrical Engineering in 2015 from Anna University. Presently she is working as an Associate Professor in EEE Department of Saranathan College of Engineering, Trichy. She has 9 years of teaching and research experience.

*****