Evaluation of control strategies of Unified Power Quality Conditioner using PI and fuzzy logic controllers

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Abstract: In recent years unified power quality conditioner (UPQC) is being used as a universal active power conditioning device to compensate both harmonics as well as reactive power. UPQC is an advanced version of unified power flow controller (UPFC). The performance of UPQC mainly depends upon how quickly and accurately compensation signals are derived. The UPQC mitigates harmonics and provides reactive power to the power systems network so as to improve the power factor close to unity. The UPQC is a combination of shunt active and series active power filters connected through a dc bus.
Keywords-UPQC(Unified Power Quality Conditioner),PI Controller

I. INTRODUCTION

Traditionally, linear loads consume major part of electrical power. However situation has changed now as more and more electrical power are being developed using power electronic devices due to their energy efficiency and control. Power electronic devices possess inherent non linear characteristics. The nonlinear characteristics of this devices results in two important limitations, drawing of large reactive volt-amperes and injection of harmonics into the utility. Large reactive volt-amperes drawn from the utility leads to increase voltage drops at various buses. The harmonics increase the losses in transformers, generators, motors, capacitors, conductors, etc. some of the control devices interfaced with the utility starts malfunctioning due to excessive harmonic currents.

The UPQC is the most versatile and complex of the FACTS devices, combining the features of the STATCOM and the SSSC. The UPQC can provide simultaneous control of all basic power system parameters, transmission voltage harmonic compensation, impedance and phase angle. It is recognized as the most sophisticated power flow controller currently, and probably the most expensive one. The basic components of the UPQC are two voltage source inverters (VSIs) sharing a common dc storage capacitor, and connected to the power system through coupling transformers. One VSI is connected to in shunt to the transmission system via a shunt transformer, while the other one is connected in series through a series transformer. A basic UPQC functional scheme is shown in the following figure.

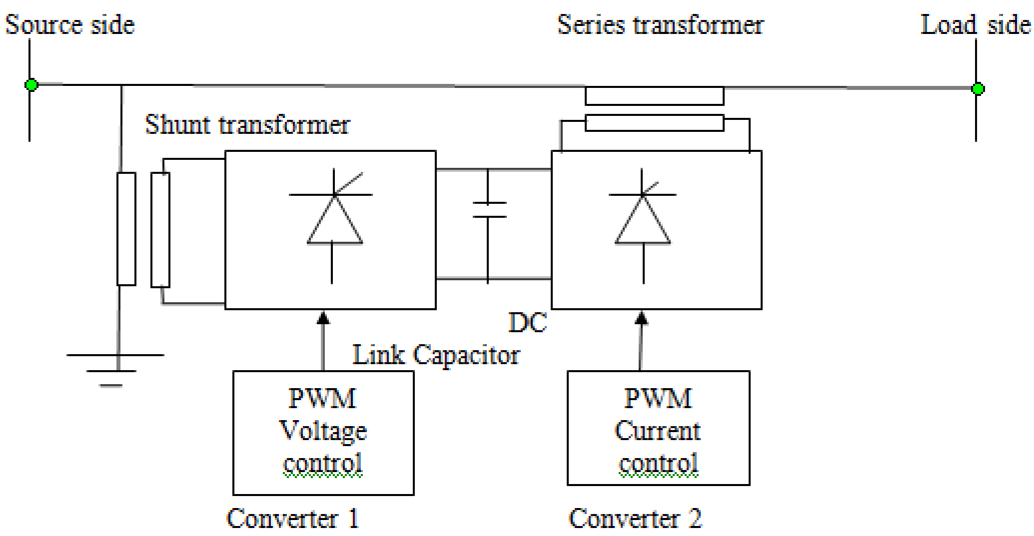
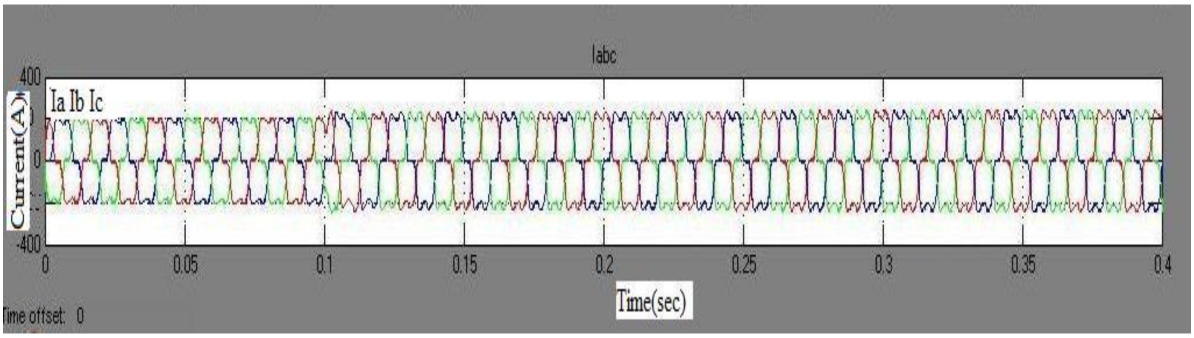


Fig.1 Basicstructureof UPQC Usingbacktobackconverter

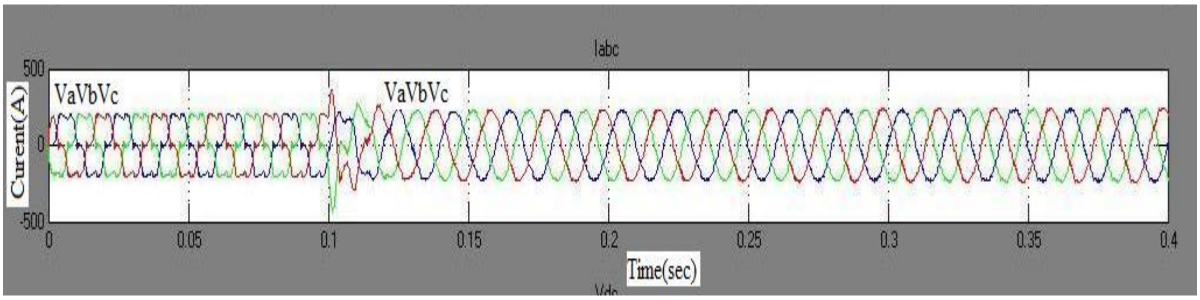
The series inverter is controlled to inject a symmetrical three phase voltage system of controllable magnitude and phase angle in series with the line to control active and reactive power flows on the transmission line. So, this inverter will exchange active and reactive power with the line. The reactive power is electronically provided by the series inverter, and the active power is transmitted to the dc terminals. The shunt inverter is operated in such a way as to demand this dc terminal power (positive or negative) from the line keeping the voltage across the storage capacitor V_{dc} constant. So, the net real power absorbed from the line by the UPQC is equal only to the losses of the inverters and their transformers.

II. SIMULATION OF UPQC USING PI CONTROLLER

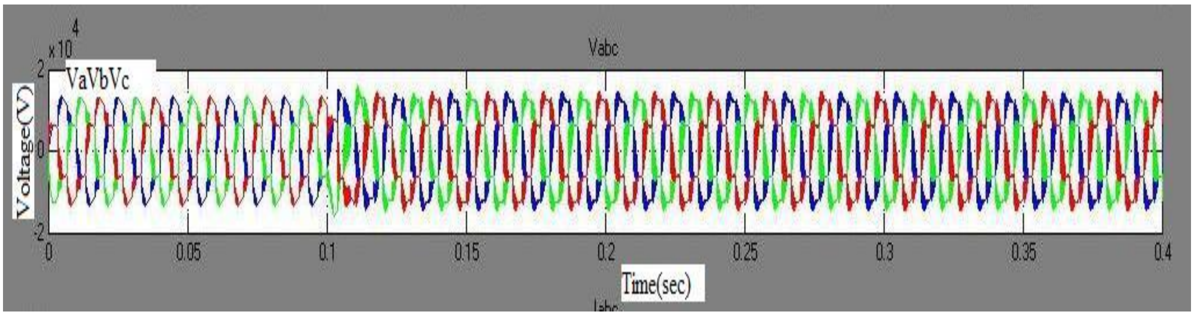
An ideal three-phase sinusoidal supply voltage of 11kV, 50Hz is applied to the non-linear load (diode rectifier feeding an *RL* load) injecting current harmonics into the system. Fig (b) shows supply current in three phase before compensation from 0s to 0.1s, and after compensation from 0.1s to 0.4s. Shunt inverter is able to reduce the harmonics from entering into the system. The Total Harmonic Distortion (THD), which was 20.02% (Fig.a) before compensation was effectively reduced to 4.04 % (Fig.b) after compensation using PI controller.



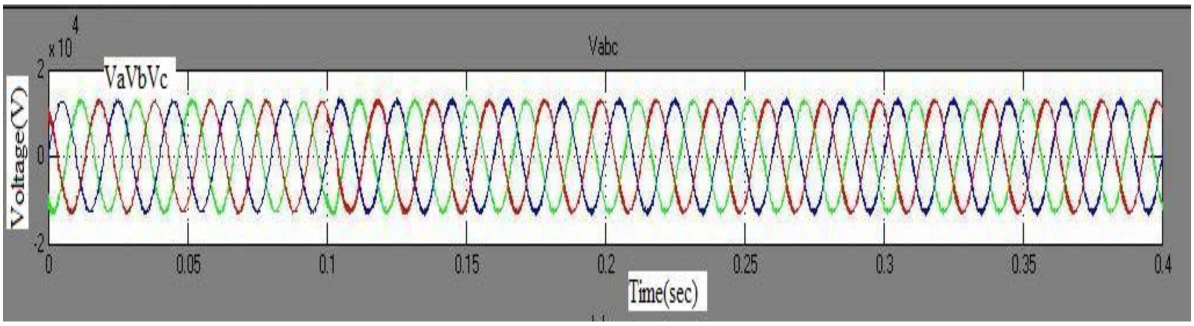
(a)



(b)



(c)



(d)

Fig.2 Simulated results of UPQC (a) load current (b) source current (c) load voltage (d) source voltage

III. FUZZY LOGIC IMPLEMENTATION IN UPQC CONTROLLER

TABLE I SET OF FUZZY RULE REPRESENTATION FOR FPI

E2 E1	**PL**	**PM**	**PS**	**Z**	**NS**	**NM**	**NL**
NL	PL	PL	PL	PM	PM	PS	Z
NM	PL	PL	PM	PM	PS	Z	ZS
NS	PL	PM	PS	Z	NS	NM	NL
Z	PL	PM	PS	Z	NS	NM	NL
PS	PM	PS	Z	NS	NM	NL	NL
PM	PS	Z	NS	NM	NM	NL	NL
PL	Z	NS	NM	NM	NL	NL	NL

The surface viewer can generate a three-dimensional output surface where any two of the inputs vary, but two of the inputs must be held constant because computer monitors cannot display a five-dimensional shape. In such a case, the input is a two-dimensional vector with NaNs holding the place of the varying inputs while numerical values indicates those values that remain fixed. Because this curve represents a two-input one-output case, one can see the entire mapping in one plot

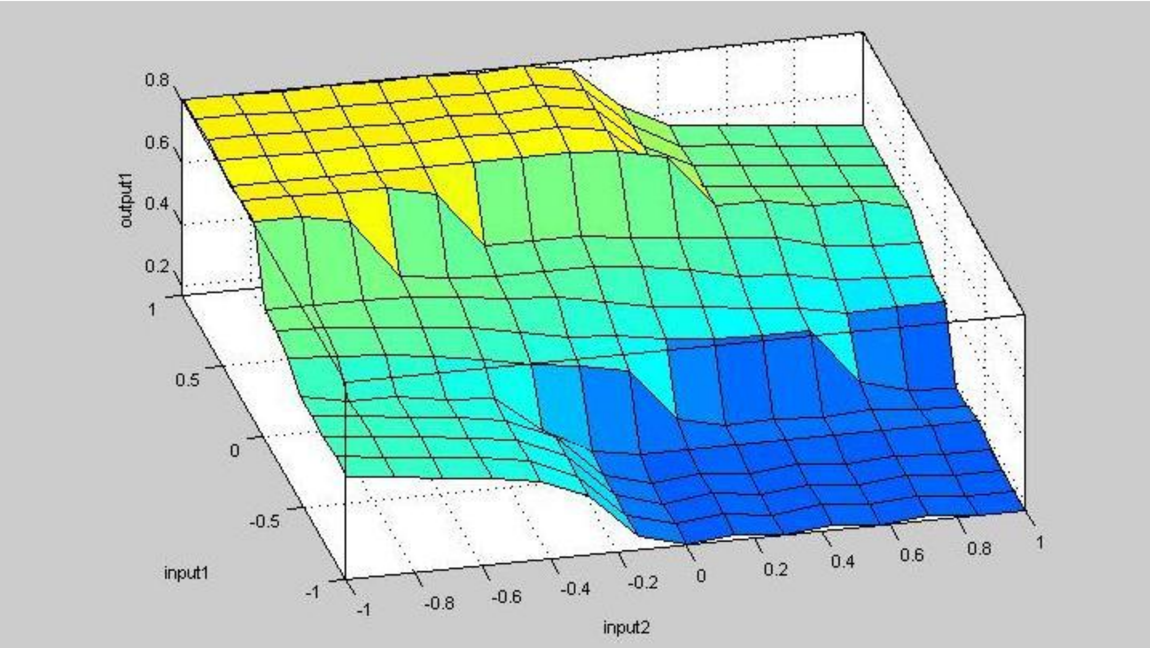


Fig.3 Surface viewer

IV. COMPARISON OF PI CONTROLLER AND FUZZY CONTROLLER

Table 4.1 shows simulated performance parameters of PI controller and fuzzy logic controller. It is clearly evident from the Table that fuzzy logic control having an edge over PI controller. Results shown in Table are verified one by one.

TABLE II. SIMULATION RESULTS OBTAINED

	Factor	**PI Controller**	**Fuzzy Controller**
1	Source current THD	4.04%	3.81%
2	Dynamic response	Slow (0.20s)	Fast (0.10s)
4	Capacitor charging	Slower	Faster
5	Capacitor voltage balance under unbalanced load condition	Less stable	More stable
6	Source current THD with switching RL load	3.52%	3.26%

(1) *Source current THD*

As shown in above table, before compensation when UPQC not connected, source current THD is 20.02%, due to non linear *RL* load. The dominant harmonic is 5th harmonic and its magnitude is 18% of fundamental component. There is passive filter *LC* connected on shunt side which is tuned to 5th harmonic. Fig. 2.15b in chapter 2 shows source current THD after compensation when UPQC connected at 0.1s and PI controller used, source current THD is reduced to 4.04% and the magnitude of the 5th harmonic also reduces to

1% of fundamental component. But when PI controller replaced by the fuzzy logic controller, source current THD reduces to 3.81% as shown in Fig. 1. And the magnitude of the 5th harmonic also reduces to 0.5% of fundamental component. So in the 1st, 3rd factor of Table , fuzzy controller proves to be more a advantageous.

(2) *Dynamic response*

This parameter is the measurement of how quickly controllers respond to the situation, in above table dynamic response (2) shows the time taken by the controller to reduce THD from 20.02% to 4.5%. as shown, time taken by PI controller is 0.20s and time taken by the fuzzy controller is 0.15s. Hence it is proved that dynamic response of th PI controller is faster than the fuzzy logic controller.

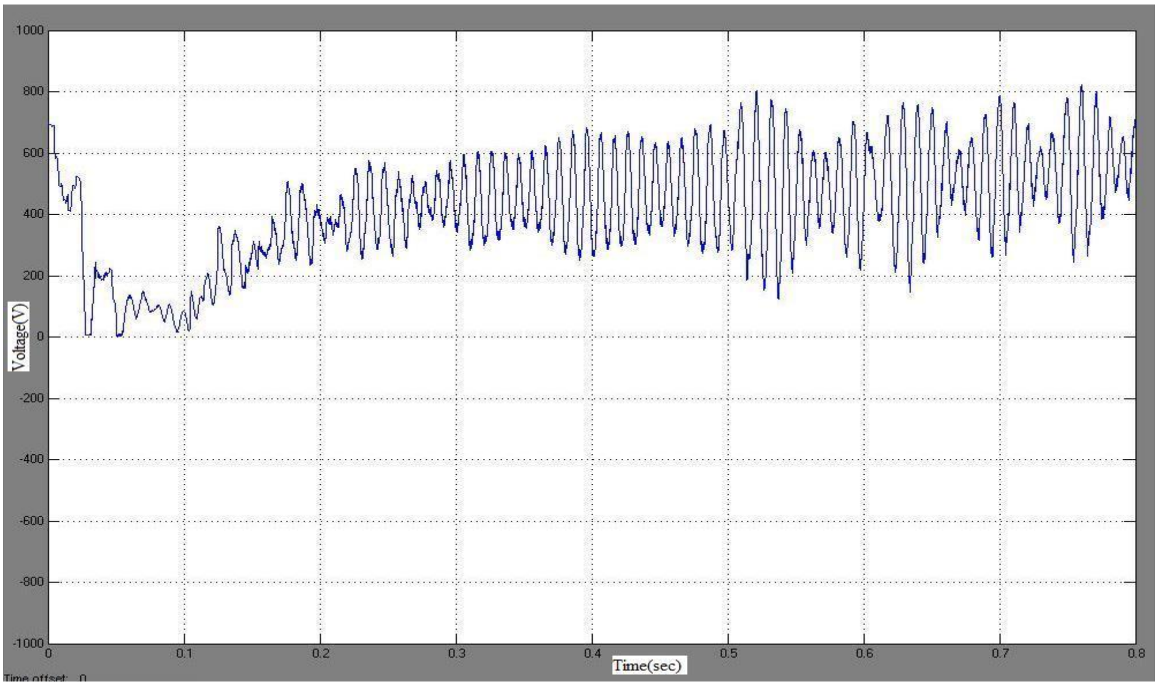


Fig.4. DC capacitor voltage using PI controller

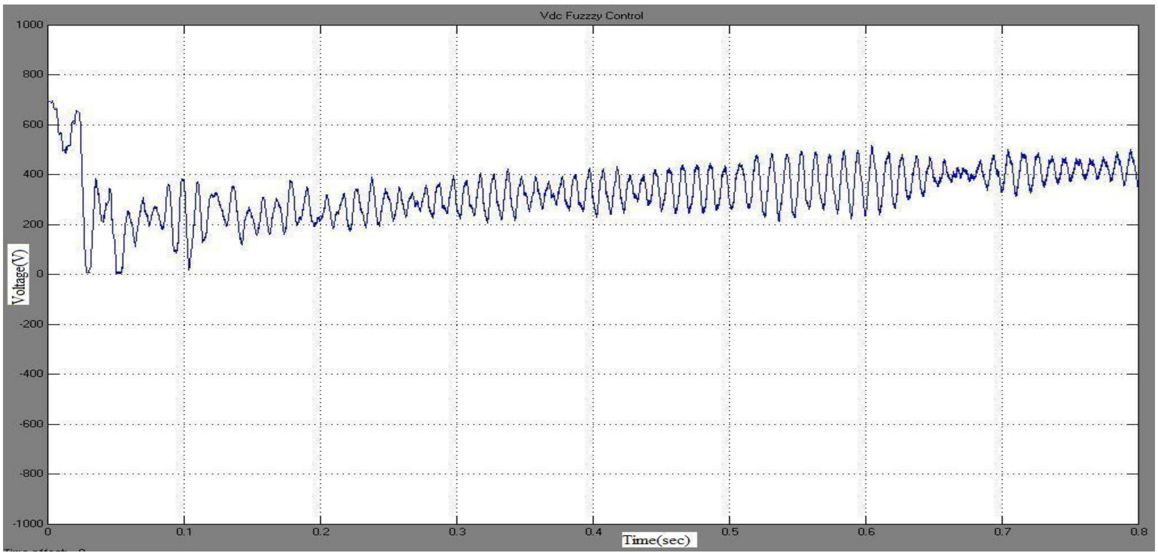


Figure.5 Simulated results (a) source current (b) source voltage (c) dc capacitor voltage of fuzzy logic controller

(3) *DC capacitor voltage regulation*

In the dc link voltage that feeds both the shunt and series inverters,the capacitor is effectively charged to the reference voltage, v_{dc} drawing the charging current from the supply. Once it is charged to required value, it is held constant using PI and fuzzy controller. There is no drop in the capacitor voltage.The dc link voltage which reflects more the disturbance in the supply voltage because use of PI controller. But when fuzzy controller replaced, , it shows less fluctuation and hence smoother exchange of real power between STATCOM and SSSC. From both fig1. and Fig.2, it can be seen that when UPQC switched at 0.1s, dc capacitor voltage using fuzzy controller quickly attains reference value compared to PI controller. In another condition, when extra *RL* load switched at 0.4s, fuzzy controller shows better response compare to the PI controller. This shows that capacitor voltage charging is faster in case of fuzzy controller. So the operating band of dc voltage limited to narrow range which is one of the salient nature of fuzzy logic controller. So in the 4th, 5th factor of Table, fuzzy controller proves to be more a advantageous.

(4) *Source current THD with switching RL load*

(5) *T*he source current THD after switching extra RL load in non linear diode rectifier. Fig. 2.21a shows Source current THD using PI controller and its value is 3.52%. While Fig. 3.7a in chapter 3 shows Source current THD using Fuzzy controller and its value is 3.26%. Fig.b and Fig. 3.7b sh the source voltage THD after switching extra *RL* load in non linear diode rectifier. Fig. b shows Source current THD using PI controller and its value is 1.89%. While b shows Source current THD using fuzzy controller and its value is 1.27%. So it is obvious that under switching condition, fuzzy controller gives better performance then PI controller. So in the 6th, 7th factor of the above Table, fuzzy controller proves to be more a advantageous under switching condition.

V. CONCLUSION

Simulated results of two control strategy of UPQC are discussed in detail with the help of comparison table. Comparison studies show that fuzzy logic controller is more advantageous in terms of compensation, dynamic response and capacitor voltage balancing.

REFERENCES

[1] *IEEE standard 519-1992*, IEEE recommended practices and requirement for harmonic control in electrical power systems, *IEEE, Inc. 1993.*

[2] L. Gyugi, R. A. Otto, and T. H. Putman, “Principles and application of static, thyristor controlled shunt compensators,” *IEEE Trans. on Power Apparatus and Systems*, vol. PAS-97, pp. 1935-1945, sept. /oct. 1978

[3] L. Gyugi, “Reactive power generation and control by thyristor circuit,” *IEEE Trans. Industrial Applications*, pp. 1935- 1945, sept/oct 1979.

[4] L. Gyugyi and E. C. Strycula, “Active ac power filters,” in *Proc. 1976 IEEE/IASAnnual Meeting*,1976, pp. 529-535.

[5] L. Gyugi, ”Unified power flow control concept For flexible ac transmission system, ” *IEE proc.-C,* vol. 139, no. 4, July 92, pp 323-332.

[6] H. Akagi, “Performance and modeling of a shunt active filter for Installation on power distribution systems,” to be presented at the 1996 *IEEE-PES International Conference on Harmonics and Quality of Power*, Oct. 16-18, 1996.

[7] N.G Hingorani, "High power electronics and flexible ac transmission systems" *IEEE. Power Engineering Review*, July 1988.

[8] L. Gyugyi,et al, "The unified power flow controller a new approach for Transmission control " *IEEE Trans. Power System,* 94 SM 474-7 PWRD.

[9] K.K. Sen, E.J. Stacey, “UPFC - unified power flow controller: theory, modeling, and application*", PE-282- PWR-0-12-1997*, *IEEE PES Winter Meeting*, Tamp, FL.

[10] H.Fujita and H. Akagi, “The unified power quality conditioner: The Integration of series- and shunt active filters,” *IEEE Trans. PowerElectronics*, vol. 13, no. 2, pp. 3 15-322, 1998.