Power Quality Improvement using Fuzzy Logic based UPQC

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Abstract-A Unified Power Quality Controller(UPQC) using a Fuzzy Logic Controller(FLC) has been proposed .The obtained through FLC are good in terms of dynamic response because of the fact that FLC is based on linguistic variable set theory and does not require a mathematical model of the system .Moreover ,the tuning of the PI controller is not required in case of FLC .Simulation are carried out using MATLAB/Simulink to validate the theoretical findings.

Terms-Fuzzy logic controller ,harmonics ,PI controller, unified power quality controller ,total harmonics distortions.

I. INTRODUCTION

There has been a continuous rise of non linear loads over the years due to intensive use of power electronics control in industry as well as by domestic consumers of electrical energy. The utility supplying these non linear load has to supply large vars. The basic requirement for compensation process involve precise and continuous VAR control with fast response and online elimination of load harmonics .To satisfy these criterion the traditional method of VAR compensation using switched capacitor and thyristor controlled inductor[1-3] coupled with passive filters are increasingly replaced by active power filters(APF)[4-8].The APF are of two types;the shunt APF and the series APF.

The shunt APF are used to compensate current related problem,such as reactive power compensation ,current harmonic filtering ,load unbalance compensation, etc .The series APF are used to compensate voltage related problem, such as voltage harmonic ,voltage sag ,voltage swell, voltage flicker, etc. The unified power quality conditioner(UPQC) aims at integrating both the shunt and series APF through a common dc link capacitor .The UPQC is similar in construction to a unified power quality conditioner(UPQC) [9].The UPFC is employed in power transmission system whereas UPQC is employed in power distribution system. The primary objective of UPQC is to control the flow of power at fundamental frequency. On the other hand UPQC controls distortion due to harmonics and unbalance in voltage in addition to control of flow of power at fundamental frequency .The schematic block diagram of UPQC is shown in Fig. 1. It consists of two voltage source invertors connected back to back, sharing a common dc link in between .One of the VSI act as shunt APF ,where as the other as a series APF. The performance of UPQC mainly depends upon how quickly and accurately compensation signals are derived .Control scheme of UPQC based on PI controller is a tedious job. Further, the control of UPFC based on the conventional PI control is prone to severe dynamic interaction between active and reactive power flow[10].In this work the conventional PI controller has been replaced by fuzzy controller(FC).The FC has been used in APF in place of conventional PI controller for improving the dynamic performance[14,15].The FC is basically non linear and adaptive in nature. The results obtained through FC are superior in the cases where the effect of parameter variation of controller are also taken into consideration .The FC is based on linguistic variable set theory and does not require a mathematical model. Generally, the input variables are error and rate of change of error. If the error is coarse , the FC provides coarse tuning to the output variable and if the error is fine, it provides fine tuning to the output variable .In the normal operation of UPQC , the control circuitry of shunt APF calculates the compensating current for the current harmonics and the reactive power compensation .In the error signal thus derived is processed in a controller .A suitable sinusoidal reference signal in phase with the supply voltage is multiplied with the output of the PI controller to generate the refrence current. Hysteresis band is normally (most often but not always) is imposed on top and bottom of this refrence current. The width of the hysteresis band is so adjusted such that the supply current total harmonic distortion (THD) remains within the international standards. The function of the series APF calculates the reference voltage to be injected by the series APF by comparing the terminal voltage with a reference value of voltage.

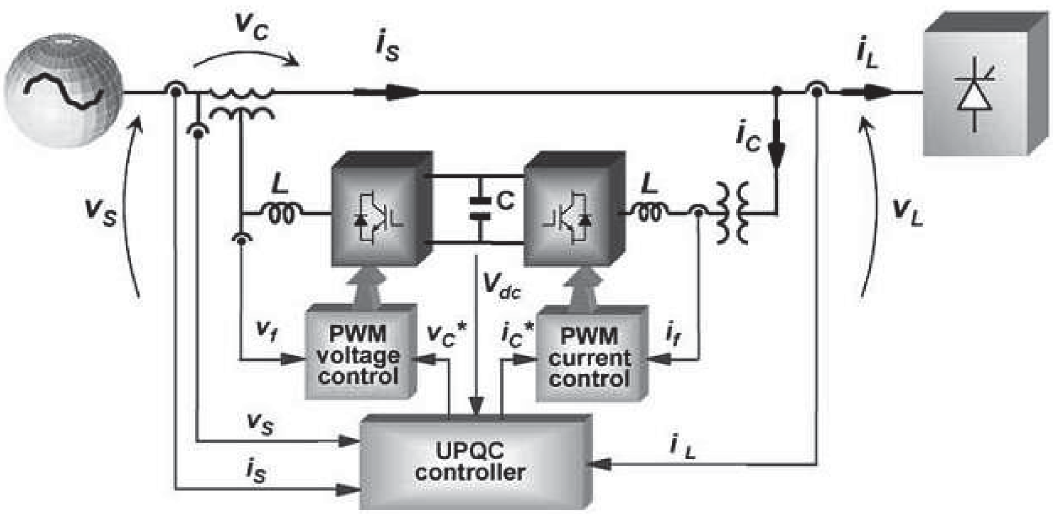


Fig.1.Single line diagram of a UPQC

II. MODEL EQUATIONS OF THE UPQC

Computation of Control Quantities of Shunt Inverter

The amplitude of the supply voltage is computed from the three phase sensed values as:

$v_{sm}=[\ 2/3(v_{sa}^{2}+ v_{sb}^{2}+v_{sc}^{2})]^{1/2}$ (2.1)

The three phase unit current vectors are computed as:

$u_{sa}= v_{sa}/v_{sm}$; $u_{sb}= v_{sb}/v_{sm}$; $u_{sc}= v_{sc}/v_{sm}$ (2.2)

Multiplication of three phase unit current vectors (u_{sa}, u_{sb} and u_{sc})with the amplitude of the supply current (isp) results in the three-phasereference supply currents as:

$i_{sa}^* = i_{sp}.u_{sa}$; $i_{sb}^* = i_{sp}.u_{sb}$; $i_{sc}^* = i_{sp}.u_{sc}$ (2.3)

To obtain reference currents, three phase load currents are subtracted from three phase reference supply currents:

$i_{sha}^* = i_{sa}^* - i_{la}$; $i_{shb}^* = i_{sb}^* - i_{lb}$

$i_{shc}^* = i_{sc}^* - i_{lc}$ (2.4)

These are the iref for Direct current control technique of shunt inverter. The iref are compared with iact in PWM current controller to obtain the switching signals for the devices used in the shunt inverter.

Computation of Control Quantities of Series Inverter

The supply voltage and load voltage are sensed and there from, the desired injected voltage is computed as follows:

$v_{inj}= v_s-v_l$ (2.5)

The magnitude of the injected voltage is expressed as:

$v_{inj}= |v_{inj}|$ (2.6)

whereas, the phase of injected voltage is given as:

$i_{nj}= \tan(Re[v_{pq}]/I_m[v_{pq}])$ (2.7)

For the purpose of compensation of harmonics in load voltage, the followinginequalities are followed:

a) v_{inj}<v_{inj} max magnitude control;

b) 0 <inj< 360° phase control;

Three phase reference values of the injected voltages are expressed as:

v_{la}* = 2v_{inj}sin(wt+ inj)

v_{lb}* = 2v_{inj}sin(wt+2 /3+ inj)

v_{lc}* = 2v_{inj}sin(wt-2 /3+ inj) (2.8)

The three phase reference currents (iref) of the series inverter are computed as follows:

i_{sea}* = v_{la}*/z_{se};

i_{seb}* = v_{lb}*/z_{se};

i_{sec}* = v_{lc}*/z_{se}; (2.9)

The impedance zse includes the impedance of insertion transformer .The currents (i_{sea}*, i_{seb}* and i_{sec}*) are ideal current to be maintained through the secondary winding of insertion transformer in order to inject voltages (v_{la}, v_{lb} and v_{lc}), thereby accomplishing the desired task of compensation of the voltage sag. The currents iref(i_{sea}*, i_{seb}* and i_{sec}*) are compared with i_{act}(i_{sea}, i_{seb} and i_{sec}) in PWM current controller, as a result six switching signals are obtained for the IGBTs of the series inverter.

III. FUZZY LOGIC CONTROLLE

In FLC, basic control action is determined by set of linguistic rules. These rules are determined by the system. Since the numerical variables are converted into linguistic variables, mathematical modelling of the system is not required in FC. The FLC comprises of three parts. Fuzzification, Interference engine and Defuzzification.

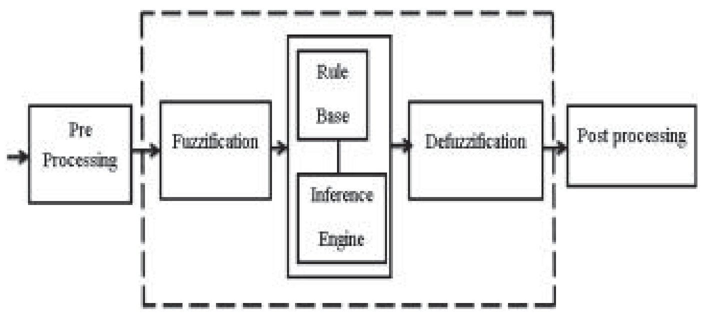


Fig.3 Fuzzy logic Controller.

The FLC is characterized as;

i. Seven fuzzy sets for each input and output.

ii. Triangular membership functions for simplicity.

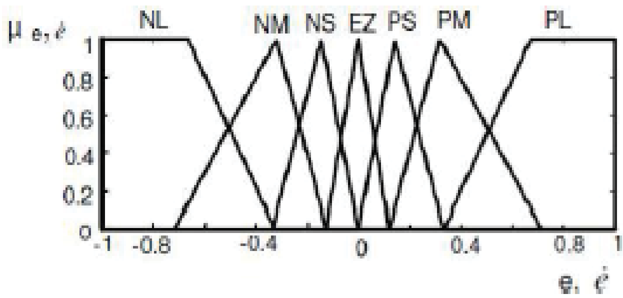
iii. Fuzzification using continuous universe of discourse.

iv. Implication using Mamdani's 'min' operator.

v. Defuzzification using the 'height' method.

The knowledge bases are designed in order to obtain a good dynamic response under uncertainty in process parameters and external disturbances .DC voltage control using Fuzzy Logic. The membership functions are triangular shaped with 50% overlap for a soft and progressive control adjustment .In our application, the fuzzy controller is based on processing the voltage error and its derivation. Figure 5.2 shows the membership functions of the input and the output linguistic variables. Triangle shaped membership function has the advantages of simplicity and easier implementation and is chosen in this application. In the fuzzification stage numerical values of the variables are converted into linguistic variables. Seven linguistic variables namely NB (negative big), NM (negative medium), NS (negative small), ZE (zero), PS(positive small), PM (positive medium), and PB (positive big) are assigned

for each of the input variables and output variable. Normalized values are used for fuzzy implementation. As there are seven variables for inputs and output there are 7 × 7 = 49 input output possibilities as tabulated in Table 5.1.A membership function value between zero and one will be assigned to each of the numerical values in the membership function graph. In this chapter, we applied max-min inference method to get implied fuzzy set of the turning rules.



Membership functions for input and output variables

$\bar{e}$ /e	NL	NM	NS	EZ	PM	PS	PL
NL	NL	NL	NL	NL	NM	NS	EZ
NM	NL	NL	NL	NM	NS	EZ	PS
NS	NL	NL	NM	NS	EZ	PS	PM
EZ	NL	NM	NS	EZ	PS	PM	PL
PM	NM	NS	EZ	PS	PM	PL	PL
PS	NS	EZ	PS	PM	PL	PL	PL
PL	EZ	PS	PM	PL	PL	PL	PL

Fuzzy set rules of inference for the DC voltage

In this system the input scaling factor has been designed such that input values are in between -1 and +1 .The triangular shape of the membership function of this arrangement presumes that for any particular input there is only one dominant fuzzy subset.

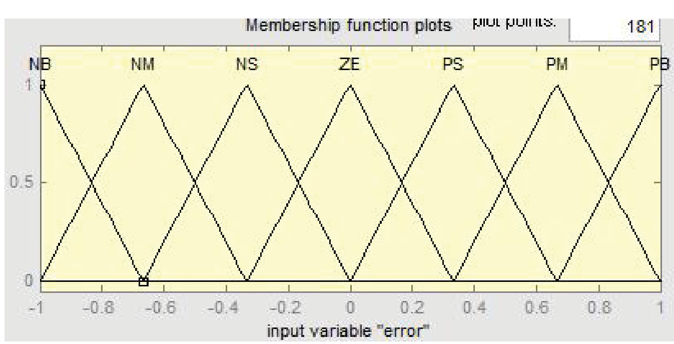


Fig. 4(a)

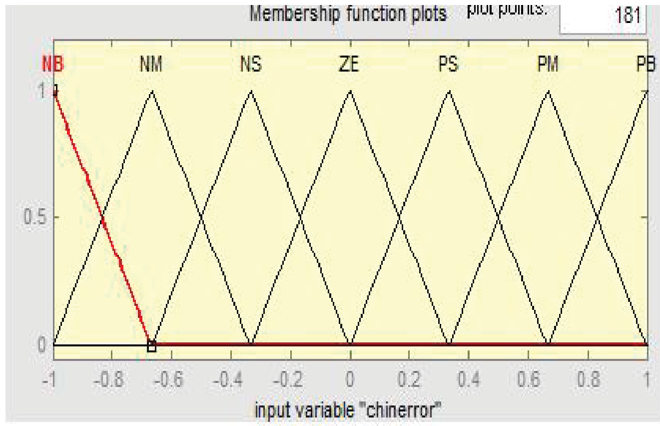


Fig. 4(a) & 4(b) Membership functions

IV. SIMULATION RESULTS

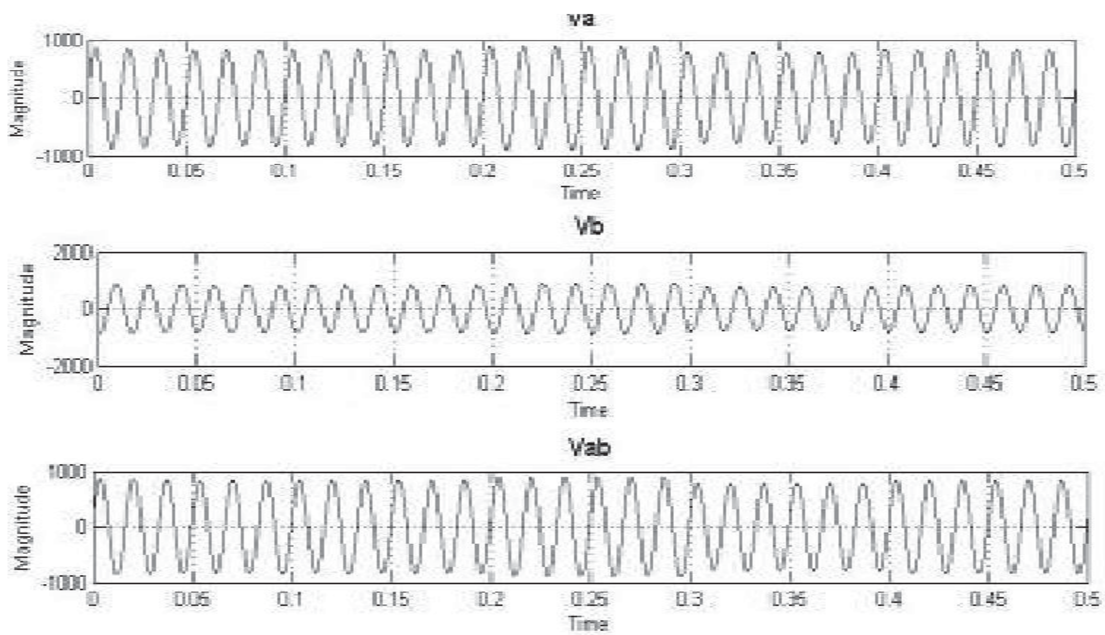


Fig.5 Voltage Waveform of the system without UPQC

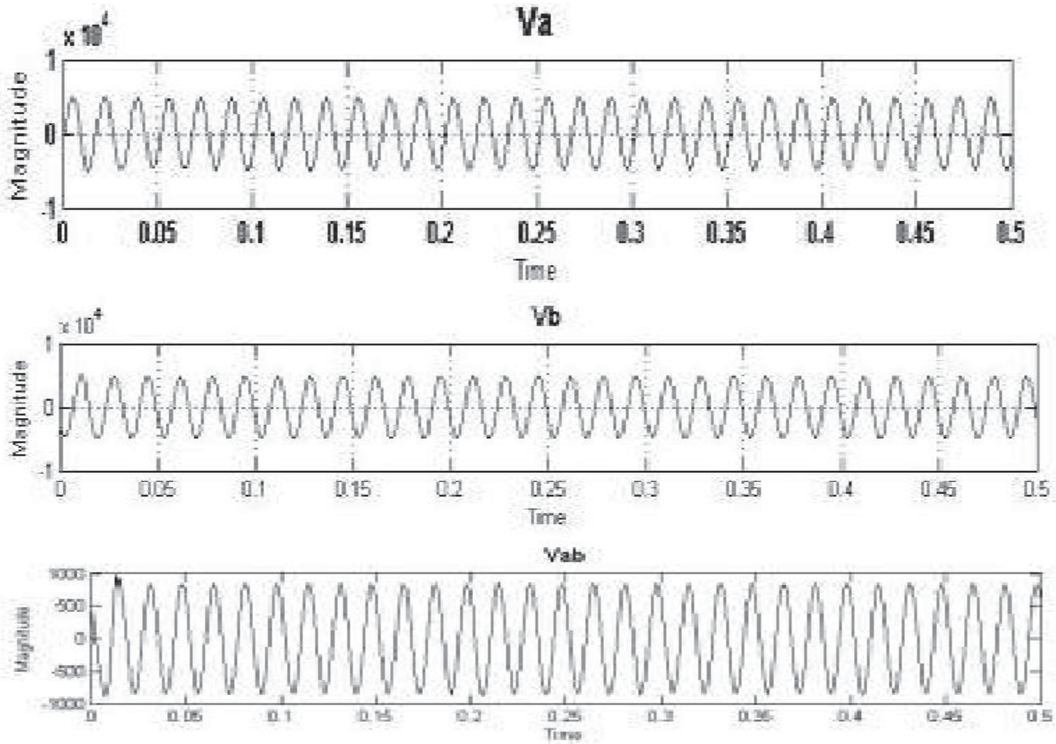


Fig.6 Voltage waveform with FLC controlled UPQC.

In order to test the performance of the UPQC using the proposed FLC, it has been simulated for a 400 V, 50 Hz three-phase AC supply using MATLAB/Simulink. A three-phase diode rectifier feeding an RL load is considered as nonlinear load. The maximum load power demand is considered as 13 kW + j10 kVAR. The values of source resistance Rs = 0.1 Ω and source inductance Ls = 0.1 mH. DC link capacitor value is 2200

μF. To test the operation of UPQC under the voltage sag and swell conditions, 20% sag in line voltage has been created.

The UPQC has been simulated using the proposed FC. The source current waveform before and after connecting the UPQC is shown in Fig. 6. It may be noticed that the source current is distorted before connecting the UPQC and it becomes sinusoidal after connecting the UPQC at 0.1s.

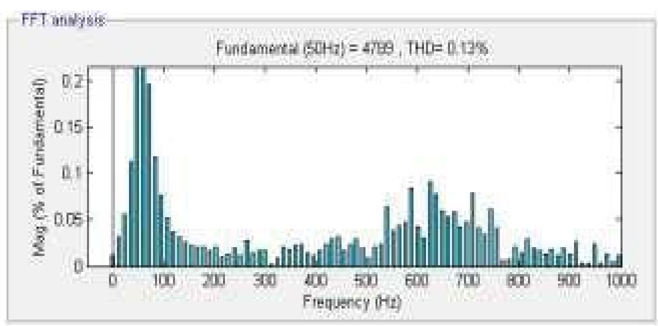


Fig.7 Total Harmonic Distortion of system with FLC.

The THD of the source current before connecting the UPQC is 24.54%. Harmonic spectrum of the source current after connecting the UPQC is shown in Fig. 7. The THD of the source current after connecting the UPQC is 0.13. The DC link capacitor voltage is held constant at its reference value by the FLC. To investigate the performance of the proposed UPQC using FLC, under voltage sag condition, 20% sag has been created in the all the phases of the supply voltage. The simulation results of these cases are shown in Figs. 6 and 11. Fig. 10 (a) shows the supply voltage with 20% voltage sag in all the phases from 0.25s to 0.0.45s.

V. CONCLUSION

UPQC using FC has been investigated for compensating reactive power and harmonics. It is clear from the simulation results that the UPQC using FC is simple, and is based on sensing the line current only. The THD of the source current using the proposed FLC is well below 5%, the harmonic limit imposed by IEEE-519 standard.

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