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Pi & Fuzzy Logic Controller Based Multi Converter Unified Power Quality Conditioner

B.Rajani, P.Sangameswara Raju

Abstract- A new unified power-quality conditioning system (MC-UPQC) , is proposed in this paper as a new custom power device for a two-bus/two-feeder distribution system. The response of the Multi converter unified power quality conditioner, for different types of controllers are studied. This paper capable of simultaneous compensation for voltage and current in multibus/multifeeder systems. In this configuration, one shunt voltage-source converter (shunt VSC) and two or more series VSCs exist. The system can be applied to adjacent feeders to compensate for supply-voltage and load current imperfections on the main feeder and full compensation of supply voltage imperfections on the other feeders. In the proposed configuration, all converters are connected back to back on the dc side and share a common dc-link capacitor. Therefore, power can be transferred from one feeder to adjacent feeders to compensate for sag/swell and interruption. In order to regulate the dc-link capacitor voltage, Conventionally, a proportional controller (PI) is used to maintain the dc-link voltage at the reference value. The transient response of the PI dc-link voltage controller is slow. So, a fast acting dc-link voltage controller based on the energy of a dc-link capacitor is proposed. The transient response of this controller is very fast when compared to that of the conventional dc-link voltage controller. By using fuzzy logic controller instead of the PI controller the transient response is improved. The detailed simulation studies are carried out to validate the proposed controller. The performance of the proposed configuration has been verified through simulation studies using MATLAB/SIMULATION on a two-bus/two-feeder system.

Keywords: Power quality (PQ),MATLAB/SIMULATION unified power-quality conditioner (UPQC), voltage-source converter (VSC), fuzzy logic controller.

I. INTRODUCTION

With the development in the process control and digital electronics communications, a number of sensitive critical loads which require sinusoidal supply voltage for their proper operation are extensively used. At the same time increased use of nonlinear loads by both electric utilities and end users has been affecting the quality of electric power, by causing major power quality disturbances in the distribution system such as voltage and current harmonics, imbalances, voltage flicker, voltage sag/swell and voltage interruptions etc. As such improvement of power quality in distribution systems is a major issue for utilities. It is well established by the application of custom power controllers in distribution sector that power quality can be significantly improved. A unified power quality conditioner (UPQC) which integrates a series and a shunt active power filters is used to mitigate voltage and current imperfections in a distribution feeder. The shunt compensator of UPQC compensate for load current related problems such as current harmonic unbalance, power factor correction and reactive power required by the load while the series compensator can compensate for all voltage related problems such as voltage sag/swell, voltage harmonics etc. Many researchers have shown that UPQC as a versatile device to improve the power quality in distribution systems .

A Unified Power Quality Conditioner (UPQC) can perform the functions of both D-STATCOM and DVR. The UPQC consists of two voltage source converters (VSCs) that are connected to a common dc bus. One of the VSCs is connected in series with a distribution feeder, while the other one is connected in shunt with the same feeder. The dc- links of both VSCs are supplied through a common dc capacitor. It is also possible to connect two VSCs to two different feeders in a distribution system is called Interline Unified Power Quality Conditioner (IUPQC). This paper presents a new Unified Power Quality Conditioning system called Multi Converter Unified Power Quality Conditioner (MC-UPQC).

A multi-converter unified power quality conditioner (MC-UPQC) having three VSCs connected back to-back by a dc link is to compensate both current and voltage imperfections in one feeder and voltage imperfections in another feeder. As shown in this figure.1 two eeders connected to two different substations supply the loads L1 and L2. The MC-UPQC is connected to two buses BUS1 and BUS2 with voltages of ut1 and ut2, respectively. The shunt part of the MC-UPQC is also connected to load L1 with a current of il1.Supply voltages are denoted by us1 and us2 while load voltages are ul1 and ul2. Finally, feeder currents are denoted by is1 and is2 and load currents are il1 and il2. Bus voltages ut1 and ut2 are distorted and may be subjected to sag/swell. The load L1 is a nonlinear/sensitive load which needs a pure sinusoidal voltage for proper operation while its current is non-sinusoidal and contains harmonics. The load L2 is a sensitive/critical load which needs a purely sinusoidal voltage and must be fully protected against distortion, sag/swell and interruption. These types of loads primarily include production industries and critical service providers, such as medical centers, airports, or broadcasting centers where voltage interruption can result in severe economical losses or human damages.

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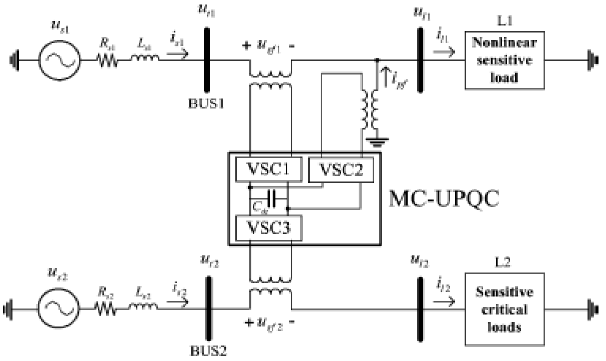

Fig.1: Typical MC-UPQC used in a distribution system.

II. FUZZY LOGIC CONTROLLER

Fuzzy control is a control method based on fuzzy logic. Just as fuzzy logic can be described as "computing with words rather than numbers. Fuzzy control can be simply described as "control with sentence rather than equations". Controllers based on fuzzy logic give the linguistic strategies control conversion from expert knowledge in automatic control strategies. The development of control system based on fuzzy logic involves the following steps:

a. Fuzzification strategy
b. Data base building
c. Rule base elaboration
d. Interface machine elaboration
e. Defuzziffication strategy.

In addition, design of fuzzy logic controller can provide desirable both small signal and large signal dynamic performance at same time, which is not possible with linear control technique. The development of fuzzy logic approach here is limited to the design and structure of the controller. Here the input is voltage and its variations; the output constrain as the *ref I* .The inputs of FLC are defined as the voltage error, and change of error. The fuzzy controller ran with the input and output normalized universe (-1,1).Fuzzy sets are defined for each input and out put variable. There are seven fuzzy levels (NB-negative big, NM-negative medium, NS-negative small Z-zero, PS-positive small, PM-positive medium, PB-positive big) the membership functions for input and output variables are triangular. The min-max method interface engine is used. The fuzzy method used in this FLC is center of area. The complete set of control rules is shown in Table.1. Each of the 49 control rules represents the desired controller response to a particular situation. The block diagram presented in Fig.2 shows a FLC controller in the MATLAB simulation. The simulation parameters are shown in Table1. By using the fuzzy controller instead of PI controller the transient response of the MC-UPQC is very fast. In this paper we have taken fuzzy logic controller. From the conventional PI dc-link voltage controller PI controller is replaced by fuzzy logic controller and is taken as conventional fuzzy logic controller and from the fast acting dc-link voltage controller the PI controller is replaced by fuzzy controller and is taken as fast acting fuzzy logic controller. The fuzzy logic dc-link voltage controller gives fast transient response than that of PI dc-link voltage controllers. The transient response of the conventional and fast acting fuzzy logic dc-link controllers are shown in Fig.7. and Fig.10.

Table.1 Fuzzy Rules

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

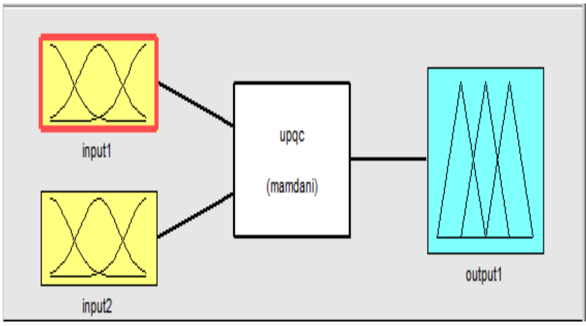

Fig 2.FLC controller in MATLAB simulation

III. SIMULATION STUDIES

The performance of the simulation model of MC-UPQC in a two-feeder distribution system as in figure.1 is analyzed by using MATLAB/SIMULATION The supply voltages of the two feeders consists of two three-phase three-wire 380(v) (RMS, L-L), 50-Hz utilities. The BUS1 voltage (ut1) contains the seventh-order harmonic with a value of 22%, and the BUS2 voltage (ut2) contains the fifth order harmonic feeder1 load is a combination of a three-phase R-L load (R = 10 Ohms, L =30μ H) and a three-phase diode bridge rectifier followed by R-L load on dc side (R = 10 Ohms, L = 100 mH) which draws harmonic current. Similarly to introduce distortion in supply voltages of feeder2 , 7th and 5th harmonic voltage sources, which are 22 % and 35% of fundamental input supply voltages are connected in series with the supply voltages VSC1 and VSC3 respectively. In order to demonstrate the performance of the proposed model of MC-UPQC simulation case studies are carried out. The simulink model for distribution system with MC-UPQC is shown in figure 3.

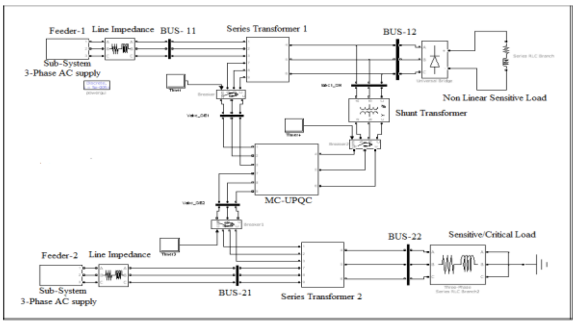

Fig. 3: Simulink model of distribution system with MC-UPQC

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A. COMPENSATION OF CURRENT AND VOLTAGE HARMONICS

Simulation is carried out in this case study under distorted conditions of current in feeder1 and supply voltages in feeder1. Figure. 4 represents three-phase load, compensation and source currents and capacitor voltage of feeder1 before and after compensation without Fuzzy in figure.4 and with Fuzzy in figure 5. It is to be noted that the shunt compensator injects compensation current at 0.1s as in Fig.4. The Effectiveness of MC-UPQC is evident from Fig. 4. as the source current becomes sinusoidal and balanced from 0.5 s. The Total Harmonic Distortion (THD) of load and source currents is identical before compensation and is observed to be 28.5%. After compensation the source current THD is observed to be less than 5 %. Also, the dc voltage regulation loop has functioned properly under all disturbances, such as sag/swell in both feeders. Thus a significant improvement in the frequency spectrum and THD after compensation is clearly demonstrated by MC-UPQC

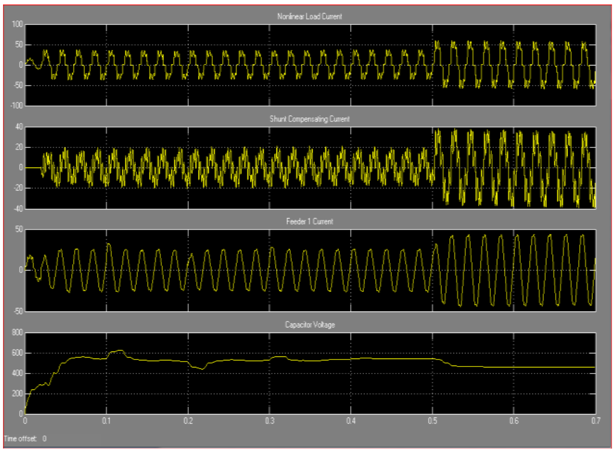

Fig 4.Simulation Result for Nonlinear load current, compensating current, Feeder1 current, and capacitor voltage with out FUZZY

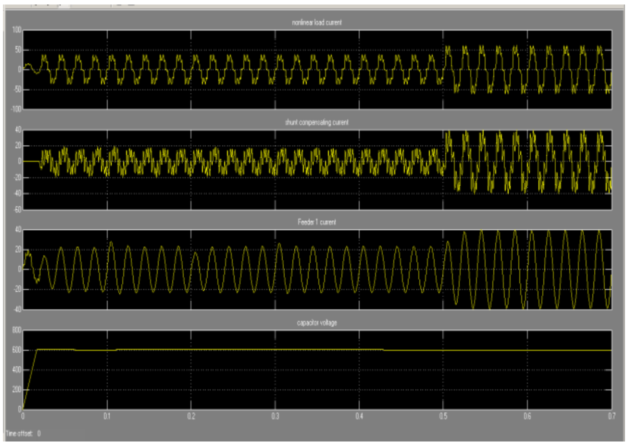

Fig 5.Simulation Result for Nonlinear load current, compensating current, Feeder1 current, and capacitor voltage with FUZZY.

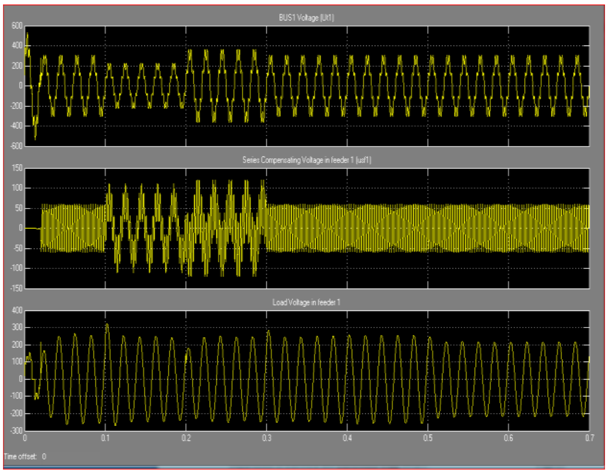

Fig 6.Simulation Result for BUS1 voltage, series compensating voltage, and load voltage in Feeder1

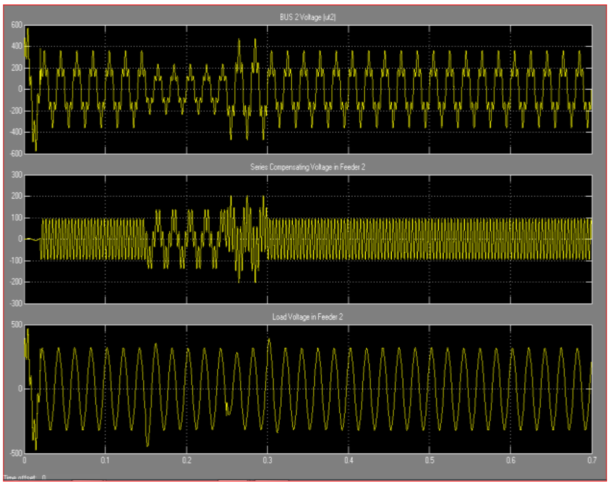

Fig7. Simulation Result for BUS2 voltage, series compensating voltage, and load voltage in Feeder2.

From the simulation results as shown in the above figure.6 and figuer.7 distorted voltages of BUS1 and BUS2 are satisfactorily compensated for across the loads L1 and L2 with very good dynamic response .

B. COMPENSATION OF VOLTAGE HARMONICS, VOLTAGE SAG/SWELL

The BUS1 voltage(ut1) contains seventh-order harmonics with a value of 22%, The BUS1 voltage contains 25% voltage sag from 0.1s to 0.2s and 20% voltage swell from 0.2s to 0.3s. and the BUS2 voltage (ut2) contains the fifth order harmonic with a value of 35%. The BUS2 voltage contains 35% sag from 0.15s to 0.25s and 30% swell from 0.25s to 0.3s The nonlinear/sensitive load L1 is a three-phase rectifier load which supplies an RL load of 10 Ω and 30µH. The MC–UPQC is switched on at t=0.02s. The BUS1 and BUS2 voltages, the corresponding compensation voltages injected by VSC1,and VSC3 and finally load L1 and L2 voltages are shown in figure. 6 and figure. 7 respectively

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C. UPSTREAM FAULT ON FEEDER2

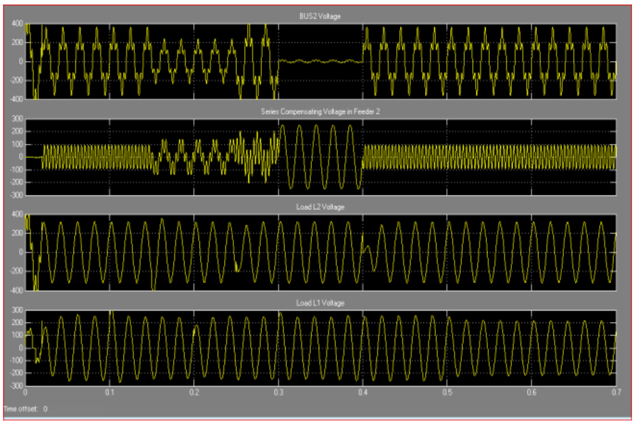

Fig 8.simulation results for an upstream fault on Feeder2, BUS2 voltage, compensating voltage, and loads L1 and L2 voltages.

When a fault occurs in Feeder2 in any form of L-G, L-L-G, and L-L-L-G faults, the voltage across the sensitive/critical load L2 is involved in sag/swell or interruption. This voltage imperfection can be compensated for by VSC2. In this case, the power required by load L2 is supplied through VSC2 and VSC3. This implies that the power semiconductor switches of VSC2 and VSC3 must be rated such that total power transfer is possible. The performance of the MC-UPQC under a fault condition on Feeder2 is tested by applying a three- phase fault to ground on Feeder2 from 0.3s to 0.4 s. Simulation results are shown in figure.8

D. SUDDEN LOAD CHANGE

To evaluate the system behavior during a load change, the nonlinear load L1 is doubled by reducing its resistance to half at 0.5 s. The other load, however, is kept unchanged. In this case load current and source currents are suddenly increased to double and produce distorted load voltages (*Ul1* and U*l2*) the performance of the MC-UPQC is tested when sudden load change occurs in feeder-1 at nonlinear/sensitive load without and with Fuzzy as shown in figure.9 and figure .10

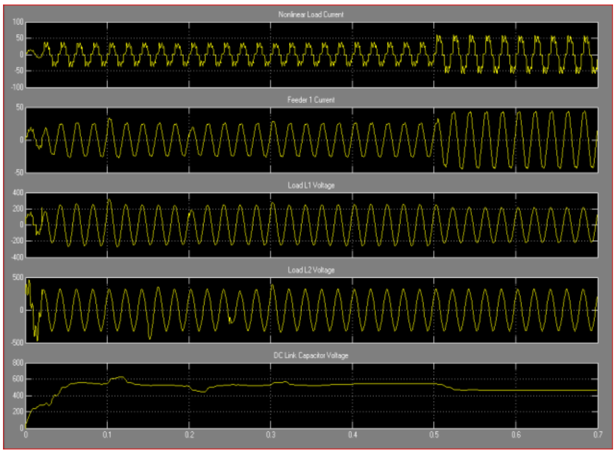

Fig 9.Simulation results for load change: nonlinear load current, Feeder1 current, load L1 voltage, load L2 voltage, and dc-link capacitor voltage with out FUZZY

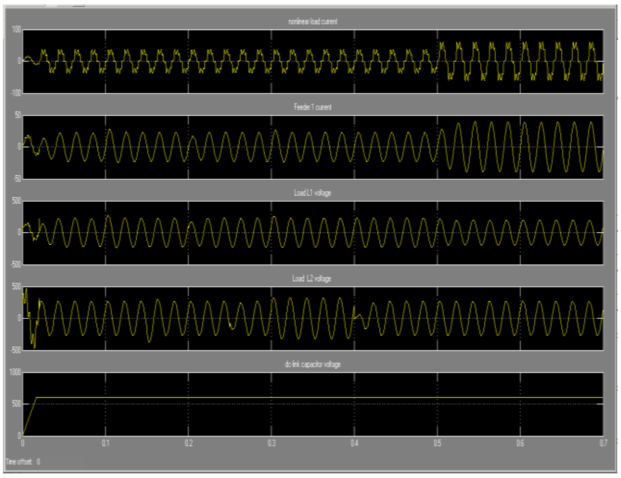

Fig 10.Simulation results for load change: nonlinear load current, Feeder1 current, load L1 voltage, load L2 voltage, and dc-link capacitor voltage with FUZZY

E. UNBALANCED SOURCE VOLTAGE IN FEEDER-1.

The MC-UPQC performance is tested when unbalance source voltage occurs in feeder-1 at nonlinear/sensitive load without and with MC-UPQC. The control strategies for shunt and series VSCs, Which are introduced and they are capable of compensating for the unbalanced source voltage and unbalanced load current. To evaluate the control system capability for unbalanced voltage compensation, a new simulation is performed. In this new simulation, the BUS2 voltage and the harmonic components of BUS1 voltage are similar. However, the fundamental component of the BUS1 voltage(Ut1fundamental) is an unbalanced three-phase voltage with an unbalance factor (U- /U+) of 40%.

The simulation results show that the harmonic components and unbalance of BUS1 voltage are compensated for by injecting the proper series voltage. In this figure, the load voltage is a three-phase sinusoidal balance voltage with regulated amplitude. The simulation results for the three-phase BUS1 voltage series compensation voltage, and load voltage in feeder-1 are shown in Figure.11.

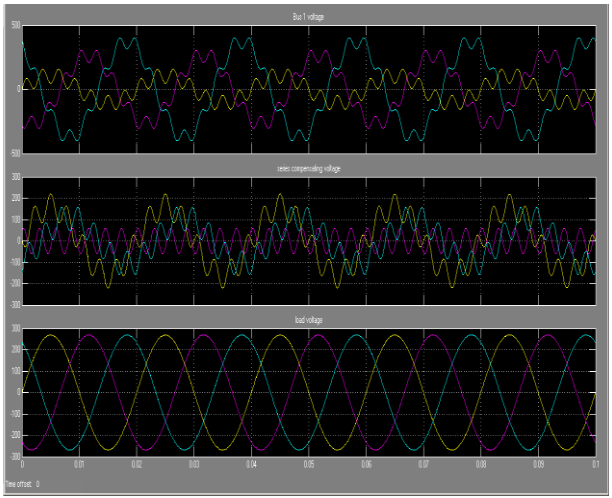

Fig 11.BUS1 voltage, series compensating voltage, and load voltage in Feeder1 under unbalanced source voltage.

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IV. CONCLUSION

A new custom power device named as MC-UPQC mitigate current and voltage harmonics, to compensate reactive power and to improve voltage regulation. The compensation performance of shunt and a novel series compensator are established by the simulation results on a two-feeder, multibus distribution system. The proposed MC-UPQC can accomplish various compensation functions by increasing the number of VSCs. This paper illustrates compensating ac unbalanced loads and a dc load supplied by the dc-link of the compensator is presented. The transient response of the MC-UPQC is very important while compensating fast varying loads. When there is any change in the load it will directly effects the dc-link voltage .The transient response of the conventional dc-link voltage controller is very slow. So, an energy based dc-link voltage controller is taken for the fast transient response. By using fuzzy logic controller instead of these two controllers the transient response is very fast. The conventional fuzzy logic controller gives the better transient response than that of the conventional PI controller. which are discussed above. The efficacy of the proposed controller is established through a digital simulation. It is observed from the above studies the proposed fuzzy logic controller gives the fast transient response for fast varying loads. The MC-UPQC is expected to be an attractive custom power device for power quality improvement of multibus/multi-feeder distribution systems in near future.

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