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Fuzzy Controlled Unified Power Quality Conditioner with DC Voltage Feedback Controller

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Abstract
The role of a Unified Power Quality Conditioner (UPQC), which provides both shunt and series compensation, in enhancing the ride through capability is investigated under both full and partial voltage restoration. Shunt compensation is used for current compensation and series compensation is used for voltage compensation. PQ theory is used as control for both compesators. Parks transformation is used for easy control. A fuzzy logic based shunt compesation is used for harmonic reduction. The design is done in matlab simulink software.

Keywords- ***ultra-capacitor energy storage (UCES), UPQC, Voltage sag, Fuzzy logic controller, neural networks.***

Introduction

Power quality is the set of limits of electrical properties that allows electrical system to function in proper manner without significant loss of performance. Like flexible ac transmission system, the term custom power use for distribution system. Just as facts improve the reliability and quality of power transmission system, the custom power enhances the quality and reliability of power that is delivered to customers. The main causes of a poor power quality are harmonic currents, poor power factor, supply voltage variations, etc.

In recent years the demand for the quality of electric power has been increased rapidly. Power quality problems have received a great attention nowadays because of their impacts on both utilities and customers. Voltage sag, swell, momentary interruption, under voltages, over voltages, noise and harmonics are the most common power quality disturbances. There are many custom power devices. The devices either connected in shunt or in series or a combination of both. The devices include D-STATCOM, DVR and UPQC etc.One of the most common power quality problems today is voltage dips. A voltage dip is a short time event during which a reduction in R.M.S voltage magnitude occurs. Despite a short duration, a small deviation from the nominal voltage can result in serious disturbances. A voltage dip is caused by a fault in the utility system, a fault within the customer's facility or a large increase of the load current, like starting a motor or transformer energizing.

Unified power quality conditioner (UPQC) is one of the best custom power device used to compensate both source and load side problems [1]. It consists of shunt and series converters connected back to back to a common dc link. It can perform the functions of both DSTATCOM and DVR. In this paper a fuzzy logic controller is used to compensate voltage sag and it is compared with neural network based controller.

The addition of energy storage through an appropriate interface to the power custom device leads to a more flexible integrated controller. The ability of the UPQC-ESS to supply effectively active power allows expanding its compensating actions. Various types of advanced energy storage technologies can be incorporated into the dc bus of the UPQC, namely superconducting magnetic energy storage (SMES), ultra-

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capacitor energy storage (aka super-capacitor energy storage - UCES/SCES respectively) and flywheel energy storage (FES), among others. However, ultra-capacitors (UC) have distinct potential advantages for energy storage which make them almost unbeatable in many applications.

UPQC Methods With Control Methods

UPQC mainly includes three parts: the series active power filters, shunt active power filters and energy storage capacitors.

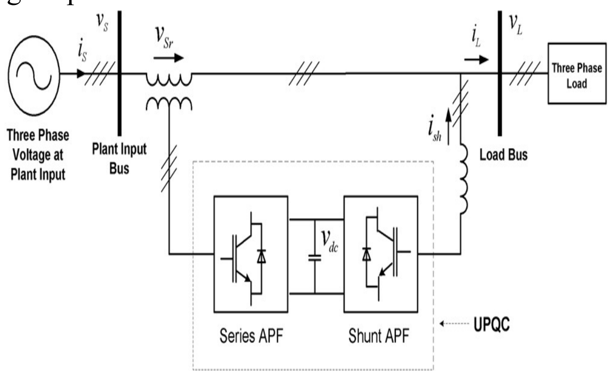

Fig 1 Topology of upqc

The series and shunt active power filter couples together through the DC-link energy storage capacitors. Series APF connected to the grid and load by coupling transformer is mainly used to adjust the load voltage amplitude and compensate the power supply voltage sag in the controlled voltage source mode. Shunt active filter connected to the load is used to compensate load currents.

PWM Control of Active Power Filter

The main aim of an active power filter (APF) is to generate compensating currents into the power system for canceling the current harmonics contained in the nonlinear load current. This will thus result in sinusoidal line currents and unity power factor in the input power system. Fig. 2. shows the configuration of a three-phase active power filter. The active power filter is connected in parallel with a nonlinear load. It consists of a power converter, a DC-link capacitor (C_2) and a filter inductor (L_2). To eliminate current harmonic Components generated by nonlinear loads, the active power filter produces equal but opposite harmonic currents to the point of connection with the nonlinear load. This results in a reduction of the original distortion and correction of the power factor. The inductor L_2 is used to perform the voltage boost operation in combination with the DC-link capacitor C_2 and functions as a low pass filter for the line current of an active power filter

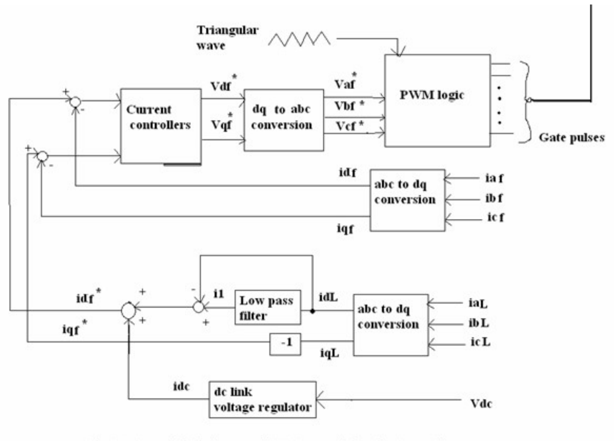

Fig 2 Control Block Diagram of PWM Controlled Active Power Filter

Series Control Strategy

The proposed algorithm is based on the estimation of reference supply currents. It is similar to the algorithm for the control of a shunt compensator like DSTATCOM for the terminal voltage regulation of linear and nonlinear loads [6]. The proposed control algorithm for the control of DVR is depicted in Fig 3.

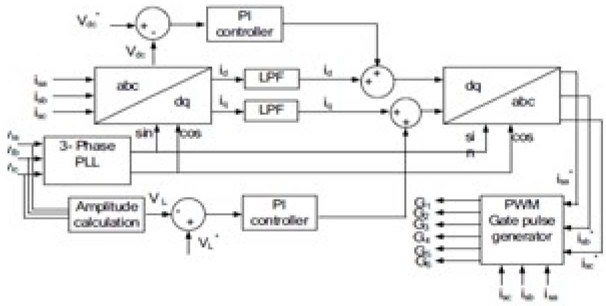

Fig 3 Control scheme of the DVR

The series compensator known as DVR is used to inject a voltage in series with the terminal voltage. The sag and swell in terminal voltages are compensated by controlling the DVR and the proposed algorithm inherently provides a self-supporting dc bus for the DVR. Three-phase reference supply currents (i_{sa}*,

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i_{sb}*, i_{sc}*) are derived using the sensed load voltages (V_{la}, V_{lb}, V_{lc}), terminal voltages (V_{ta}, V_{tb}, V_{tc}) and dc bus voltage (V_{dc}) of the DVR as feedback signals. The synchronous reference frame theory based method is used to obtain the direct axis (i_d) and quadrature axis (i_q) components of the load current. The load currents in the three-phases are converted into the d-q-0 frame using the Park's transformation as,

$$\begin{bmatrix} i_d \\ i_q \\ i_0 \end{bmatrix} = \frac{2}{3} \begin{bmatrix} \cos\theta & -\sin\theta & \frac{1}{2} \\ \cos\left(\theta - \frac{2\pi}{3}\right) & -\sin\left(\theta - \frac{2\pi}{3}\right) & \frac{1}{2} \\ \cos\left(\theta + \frac{2\pi}{3}\right) & \sin\left(\theta + \frac{2\pi}{3}\right) & \frac{1}{2} \end{bmatrix} \begin{bmatrix} i_{la} \\ i_{lb} \\ i_{lc} \end{bmatrix} \quad (5.1)$$

A three-phase PLL (phase locked loop) is used to synchronies these signals with the terminal voltages (vta, vtb, vtc). The d-q components are then passed through low pass filters to extract the dc components of id and iq. The error between the reference dc capacitor voltage and the sensed dc bus voltage of DVR is given to a PI (proportional-integral) controller of which output is considered as the loss component of current and is added to the dc component of id. Similarly, a second PI controller is used to regulate the amplitude of the load voltage (Vt). The amplitude of the load terminal voltage is employed over the reference amplitude and the output of PI controller added with the dc component of iq. The resultant currents are again converted into the reference supply currents using the reverse Park's transformation. Reference supply currents (isa*, isb*,isc*) and the sensed supply currents (isa, isb, isc) are used in PWM current Controller to generate gating pulses for the switches. The PWM controller operates at a frequency of 10 kHz and the gating signals are given to the three-leg VSC for the control of supply currents. [7].

Fuzzy Logic Controllers

The logic of a approximate reasoning continues to grow in importance, as it provides an in expensive solution for controlling know complex systems [2]. Fuzzy logic controllers are already used in appliances washing machine, refrigerator, vaccum cleaner etc. Computer subsystems (disk drive controller, power management) consumer electronics (video, camera, battery charger) C.D.Player etc. and so on In last decade, fuzzy controllers have convert adequate attention in motion control systems [5],[6],[7].The implication was introduced for the evaluation of individual rules.

Methods:

a) MAMDANI

b) SUGENO

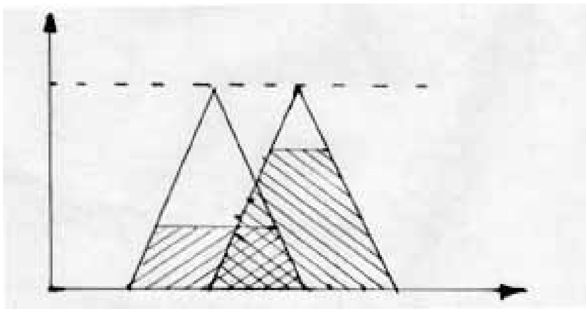
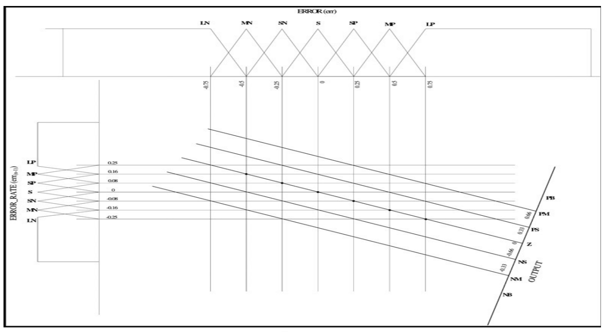


Fig 4 Center of – area, method of defuzzification

Fig.4: shows the above operation in a graphical way, it can be seen that this defuzzification method takes into account the area of U as whole. Thus if the area of two clipped fuzzy sets constituting 'U' overlap, then the over lapping are is not reflected in the above formula. This operation is computationally rather complex and therefore results in quite slow inference cycles.

Denormalization is the process to convert per unit quantities into actual quantities.

Designs And Rules of Different Membership Functions



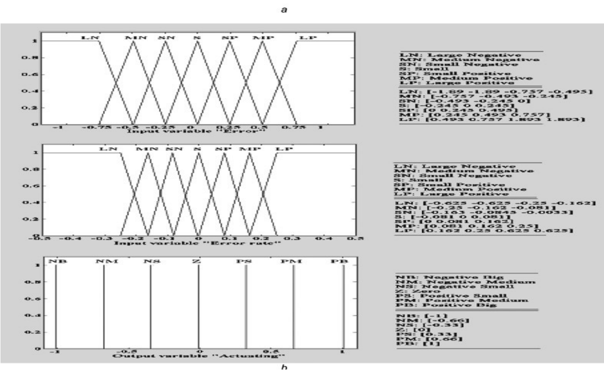


Fig 5 Membership figures for input and output

Design of UPQC Matlab Simulation

To verify the operating performance of the proposed UPQC, a 3-phase electrical system, a fuzzy logic controller with reference signal generation method is designed for UPQC and compared its performance with Artificial neural network based controller is simulated using MATLAB software.

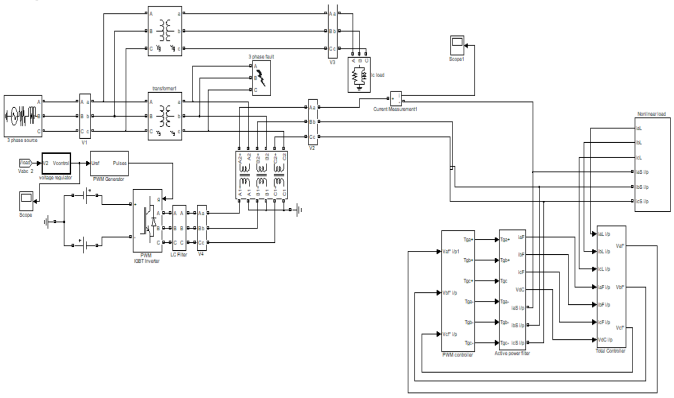


Fig 6 : Simulation Circuit of UPQC

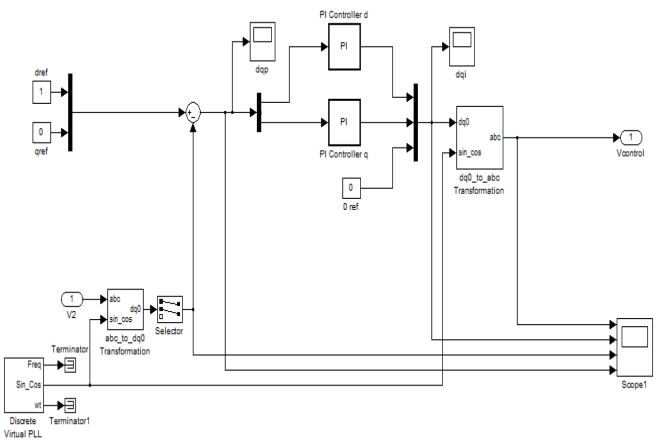


Fig 7: Series Filter Control

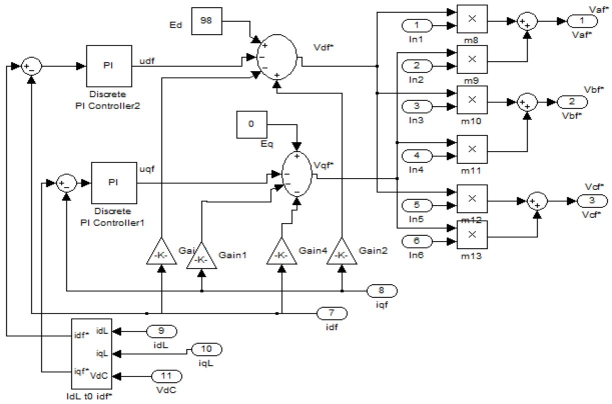


Fig 8: Shunt Filter Control

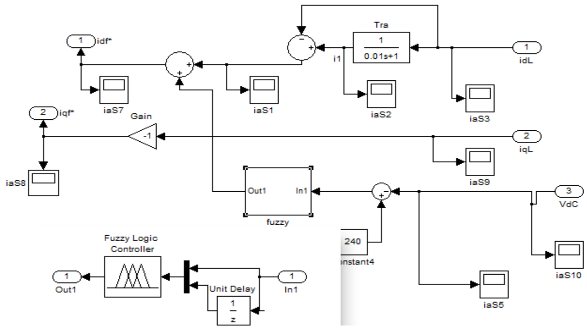


Fig 9 : Active Filter with Fuzzy Controller

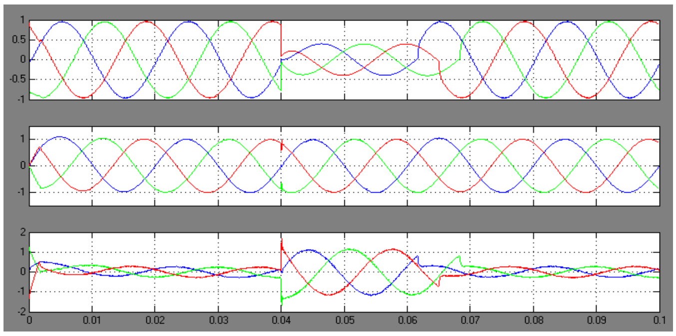


Fig9 : 3 Phase Fault and Voltage Compensation by using Series Active Power Filter

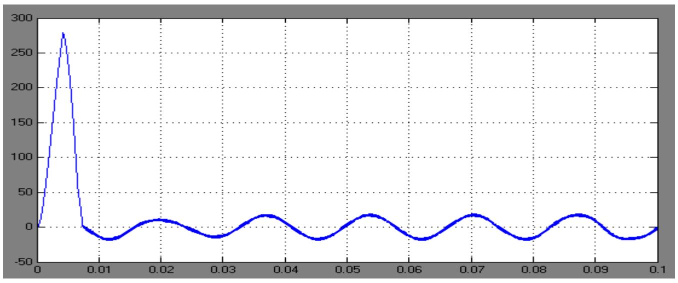


Fig10: Harmonic Compensation in Source current Using PI Controller

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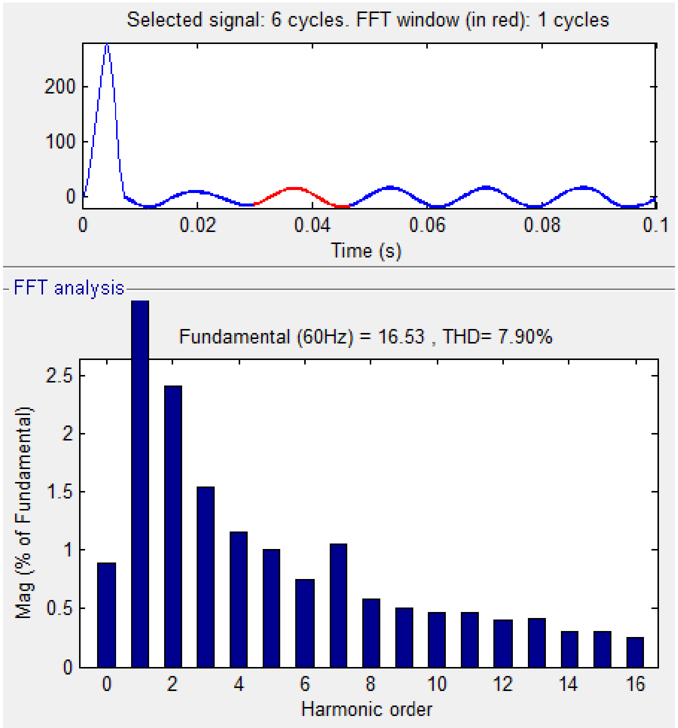

Fig 11 THD in Source Current using PI Contoller

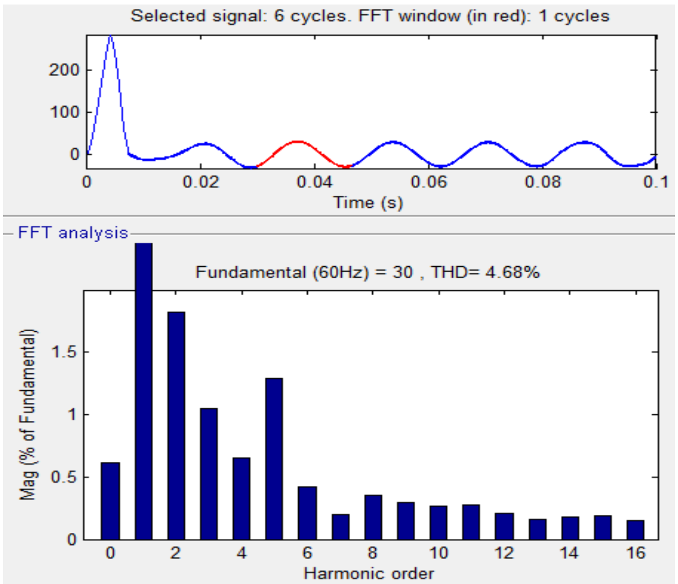

Fig12 THD in Source Cuuent using Fuzzy Controller

Conclusion

This paper is mainly devoted to the study of Power Quality problems and its compensation with **Unified power quality conditioner (UPQC)**. Results obtained from this study provide useful information regarding the behaviour of different controllers used for power quality improvement connected to distribution line. The controllers mainly used for power quality improvement are Fuzzy logic controller based controller. Hence as compared to the response obtained with Fuzzy controller, based controller have great advantage of flexibility.

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