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MATLAB/SIMULINK Based Intelligent Power Quality Conditioner Using Fuzzy Logic Controller

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Abstract: The main objective of this project is to design a three phase Unified Power Quality Controller (UPQC) using a Fuzzy Logic Controller (FLC). The unified power quality conditioner aims at integrating both shunt and series APFs through a common DC link capacitor. The UPQC controls distortion due to harmonics and unbalance in voltage in addition to control flow of power at the fundamental frequency. The results obtained through the FLC are good in terms of dynamic response because of the fact that the FLC is based on linguistic variable set theory and does not require a mathematical model of the system. Simulations are carried out using MATLAB/SIMULINK. This project will have more accurate result than the existing system.

Key words: Power Quality · Fuzzy Logic Controller · DC link Capacitor · Active Power Filter · Modelling of UPQC · Simulation

INTRODUCTION

Power Quality (PQ) related issues are of most concern nowadays. Electrical Power quality is the degree of any deviation from the nominal values of the voltage magnitude and frequency [1]. From the customer perspective, a power quality problem is defined as any power problem manifested in voltage, current, or frequency deviations that result in power failure or desperation of customer of equipment. The waveform of electric power at generation stage is purely sinusoidal and free from any distortion. Many of the Power conversion and consumption equipment are also designed to function under pure sinusoidal voltage waveforms. However, there are many devices that distort the waveform [2-5]. These distortions may propagate all over the electrical network. The widespread use of electronic equipment, such as information technology equipment, power electronics such as Adjustable Speed Drives (ASD), Programmable Logic Controllers (PLC), energy-efficient lighting, led to a complete change of electric loads nature. These loads are simultaneously the major causes and the major victims of power quality problems. Mainly there are different power quality problems. Voltage sags, voltage swell, harmonics, very short interruptions, long interruptions, voltage spike, noise, voltage unbalance these are the main PQ problems in power system [6-13].

A wide diversity of solutions to power quality problems is available for both the distribution network operator and end user. The measure of power quality depends upon the needs of the equipment that is being supplied [12]. Custom Power devices are a better solution for these Power Quality related issues in the distribution system. Out of these available power quality enhancement devices, the UPQC has better sag/swell compensation capability. According to the basic idea of UPQC, it consists of back-to-back connection of two three-phase Active Filters (AFs) with a common DC link. The Point of Common Coupling (PCC) could be highly distorted, also the switching ON/OFF of high rated load connected to PCC may result into voltage sags or swells on the PCC have been discussed. There are several sensitive loads, such as computer or microprocessor based AC/DC drive controller, with good voltage profile requirement;

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can function improperly or sometime can lose valuable data or in certain cases get damaged due to these voltages sag and swell conditions. One of the effective approaches is to use a Unified Power Quality Conditioner (UPQC) at PCC to protect the sensitive loads.

A UPQC is a combination of shunt and series APFs, sharing a common DC link. It is a versatile device that can compensate almost all power quality problems such as voltage harmonics, voltage unbalance, voltage flickers, voltage sags & swells, current harmonics, current unbalance, reactive current, etc. Recently more attention is being paid on mitigation of voltage sags and swells using UPQC. The swells are not as common as sags, but the effects of a swell can be more destructive than sag. For example, the excessive over voltage during swell condition may cause breakdown of components or equipment's. The common cause of voltage sags and swell is a sudden change of line current flowing through the source impedance. The steady state analysis of UPQC during voltage sags and swells on the system. The main objective is to maintain the load bus voltage to be sinusoidal and the major concern is the flow of active and reactive power during these conditions. It plays an important role to select the KVA ratings of both shunt and series APFs. Among different new technical options available to improve power quality, the unified power quality conditioner has found to be more promising for compensation of current as well as voltage harmonics simultaneously. It is commonly configured with two voltage source converters connected back to back through a DC link capacitor. However, the voltage source topology of UPQC has a drawback of slow control of inverter output voltage and no short circuit protection. In addition, when the active rectifier inside UPQC is used as a power factor corrector, DC bus voltage oscillations appears which makes the control of the series filter output voltage more difficult. Before mentioning problems are overcome by using Current Source Inverter (CSI). CSI-based UPQC has a faster phase voltage control loop and inherent short circuit protection capability. It also minimizes the cost as in this case the passive filter connection between UPQC and the load is not necessary.

The only disadvantage of CSI-based UPQC is that its DC link inductor is bulky and heavy which leads to high DC link losses. It uses synchronously rotating frame to derive reference signals, which has increased time delay in filtering DC quantities. The concept of the FLC is to utilize the qualitative knowledge of a system to design a practical controller. For a process control system, a fuzzy control algorithm embeds the intuition and experience of an operator, designer and researcher. The control doesn't need an accurate mathematical model of a plant and therefore, it suits well to a process where the model is unknown or ill-defined and particularly for systems with uncertain or complex dynamics. In this paper the application of fuzzy logic in control of shunt and series active power filters for control of three-phase active power filter. Implementation and testing of the proposed system will give the improved output with reduced amount of oscillation then the existing system.

Unified Power Quality Conditioner: The UPQC consists of two voltage source inverters connected back to back with each other sharing a common DC link. The basic configuration of the UPQC. The basic structure of the UPQC is shown in Fig.1. The shunt converter of the UPQC must be connected as close as possible to the non-linear load, instead of the network side. The UPQC approach is the most powerful compensator for a scenario as depicted, where the supply voltage is itself already unbalanced & distorted & is applied critical load that require high power quality. On the other hand, part of the total load includes nonlinear loads that inject a large amount of harmonic current into the network, which should be filtered.

The shunt active filter of the UPQC can compensate all undesirable current components, including harmonics, imbalances due to negative- and zero sequence components at the fundamental frequency and the load reactive power as well. The same kind of compensation can be performed by the series active filter for the supply voltage, hence, the simultaneous compensation performed by the UPQC guarantees that both the compensated voltage at load terminal and compensated current is that is drawn from the power system become balanced, so that they contains no unbalance from negative- and zero sequence components at the fundamental frequency. Moreover, they are sinusoidal and in phase, if the load reactive power is also compensated. Additionally, the shunt active filter has to provide dc link voltage regulation, absorbing or injecting energy from or into the power distribution system, to cover losses in converters and correct eventual transient compensation errors that lead to undesirable transient power flows into the UPQC. It might be interesting to design UPQC controllers that allow different selections of the compensating functionalities.

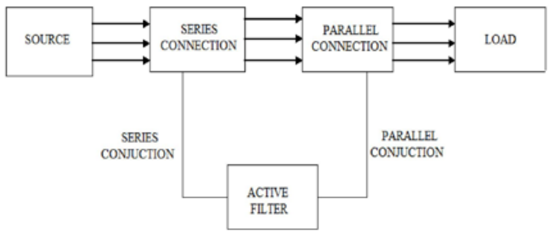

Fig. 1: Unifed Power Quality Conditioner

Block Diagram Explanation: The block diagram of the proposed system is shown in Fig.2. UPQC is being used as a universal active power conditioning device to mitigate both current as well as voltage harmonics at a distribution end of the power system network. The performance of UPQC mainly depends upon how quickly and accurately compensation signals are derived.

UPQC performances will depend on the design of power semiconductor devices, on the modulation technique used to control the switches, on the design of coupling elements, on the method used to determine active filters current and voltage references and on the dynamics and robustness of current and voltage control loops. Control strategies related to fuzzy hysteresis band voltage and current control methods, where the band is modulated with the system parameters to maintain the modulation frequency nearly constant are developed. The FLC-based compensation scheme eliminates voltage and current magnitude of harmonics with a good dynamic response.

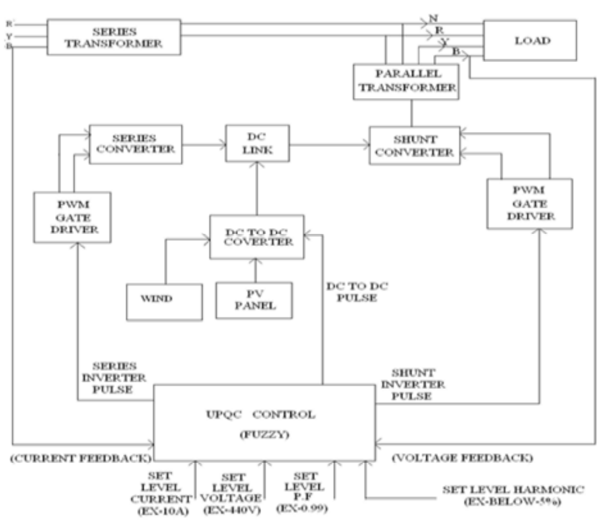

Fig. 2: Block diagram of the proposed system

Proposed System Circuit Diagram: The circuit diagram of the proposed project is given in Fig.3. The construction and connections are same as the existing system. But the current feedback is chosen for voltage control and voltage feedback is chosen for current control. To rectify the error Fuzzy logic control technique is to be applied for this system. The SVPWM techniques also implemented in this system. For the low voltage DC link, the solar and wind energy is connected as supporting sources. (The wing and solar source are to be with DC to DC converter)

AC source can be converted to the pure ac by the H bridge inverter. The wind and solar energy can be converted to a higher level by DC-DC converter. That DC voltage can be connected to the common DC link capacitor that can be inverted for the distribution system. The SVPWM technique can generate the gate signals to the MOSFET by gate driver.

Control of DC Voltage: In the UPQC the management of DC bus concerns the role of the shunt active filter. This one determines the active power (current) necessary to keep constant the DC voltage in steady state or transient conditions. There are three principal factors that affect the voltage fluctuations of the DC capacitor. The first is the alternating power of the load to be compensated, the second is the active power imbalance during transients and the third is the active power absorbed by the series active filter for compensating network voltage sag.

If a power imbalance occurs, because of changing load or voltage dips, the shunt active filter should consume or supply real power. To realize these objectives, a fuzzy logic controller is considered. Fuzzy logic is close in spirit to human thinking and natural language than other logical systems. It provides an effective means of capturing the approximate and inexact nature of systems. The fuzzy control is basically a nonlinear and adaptive in nature, giving the robust performance in the cases wherein the effects of parameter variation of controller are present.

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. Triangle shaped membership function has the advantages of simplicity and easier implementation 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.

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. The membership function of input and output variable is shown in Fig. 4.

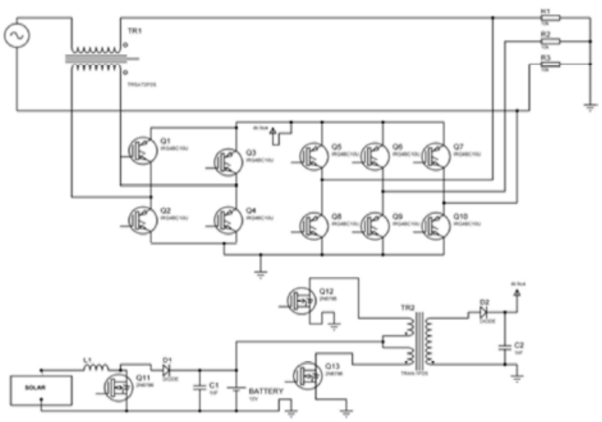

Fig. 3: Circuit diagram of the proposed system

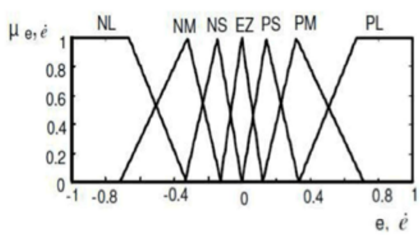

Fig. 4: Membership Functions of Input and Output Variables

PWM Generation: Pulse Width Modulation (PWM), or Pulse Duration Modulation (PDM), is a modulation technique that controls the width of the pulse, formally the pulse duration, based on modulator signal information is shown in Fig.5. Although this modulation technique can be used to encode information for transmission, its main use is to allow the control of the power supplied to electrical devices, especially for inertial loads such as motors. In addition, PWM is one of the two principal algorithms used in photovoltaic solar battery chargers, the other being MPPT.

The average value of the voltage (and current) fed to the load is controlled by turning the switch between supply and load on and off at a fast pace. The longest the switch is on compared to the off periods, the higher the power supplied to the load.

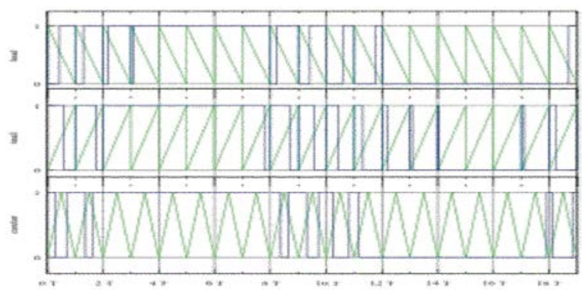

Fig. 5: Pulse Width Modulation

Space Vector Modulation: Space Vector Modulation (SVM) is an algorithm for the control of PWM. It is used for the creation of AC waveforms; most commonly to drive 3 phase AC powered motors at varying speeds from DC using multiple class-D amplifiers. There are various variations of SVM that result in different quality and computational requirements. One active area of development is in the reduction of Total Harmonic Distortion (THD) created by the rapid switching inherent to these algorithms.

Simulation Diagram and Results: The simulation model of the fuzzy controller and overall simulation of the proposed diagram is shown in the Fig.6, Fig.7.

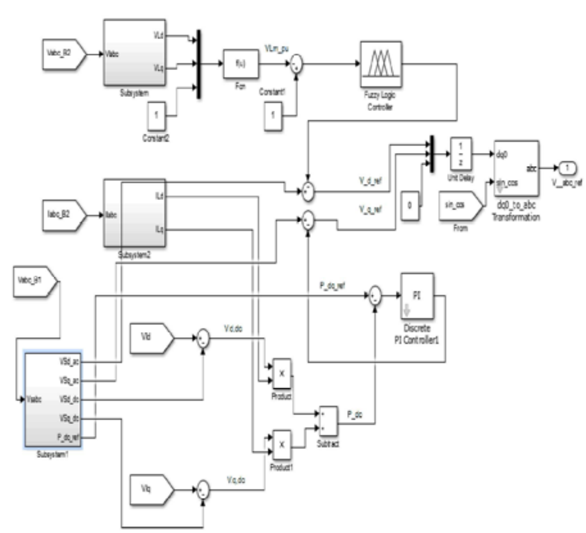

Fig. 6: Simulation Model of Fuzzy Controller

The input voltage and injected voltage output are shown in Fig.8 and Fig.9. The output of the load voltage is shown in Fig.10. The input voltage is controlled using the Fuzzy logic controller then the output voltage is displayed with the help of scope. The output receives the constant three phase output voltage with less harmonics.

The voltage varies with the different load devices, thus it can be controlled using the Fuzzy Logic controller.

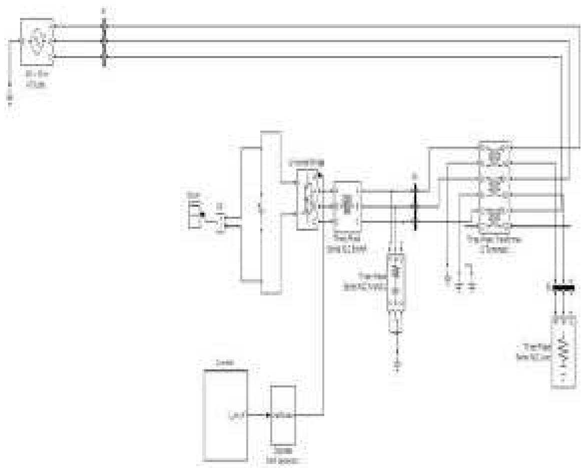

Fig. 7: Simulation Model of the Overall System

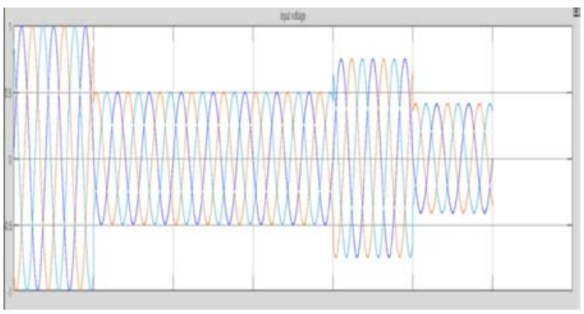

Fig. 8: Input Voltage

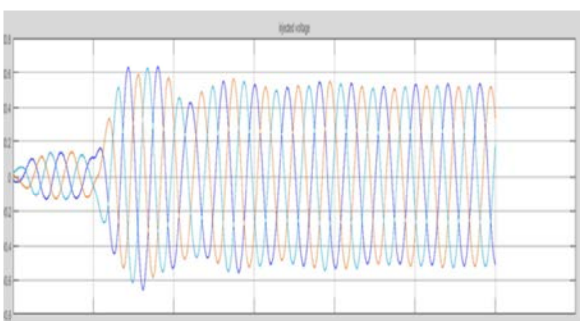

Fig. 9: Injected Voltage Output

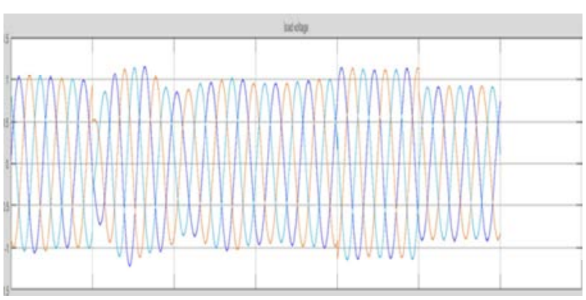

Fig. 10: Load Voltage Output

CONCLUSION

UPQC performance mainly depends upon how accurately and quickly reference signals are derived. The simulated result shows that it has considerable response time for yielding effective compensation in the network. This may not be desirable in modern power system control. Using conventional compensator data, a FLC is tuned with large number of data points. Then conventional compensator was replaced with a fuzzy logic controller and simulated using Mat lab/Simulink for RL load using uncontrolled rectifier. The simulation results have shown that the UPQC perform better with FLC proposed scheme eliminates both voltage as well as current harmonics effectively. UPQC provides compensation and Fuzzy based UPQC gives better results compared to PI based UPQC.

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