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Matrix converter based power quality enhancement using UPQC

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Abstract

This paper presents a new control method to compensate the power quality problems through a three-phase unified power quality conditioner (UPQC) under non-ideal mains voltage and unbalanced load conditions. The proposed UPQC system can improve the power quality at the point of common coupling (PCC) on power distribution system 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. In this proposed system the application of fuzzy logic in control of shunt and series active power filters for control of three-phase active power filter. The performance of proposed control system was analyzed using simulations with MATLAB/Simulink program, and experimental results with the hardware prototype.

INTRODUCTION

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. It is commonly configured with two voltage source converters connected back to back through a DC link capacitor. However, 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 mentioned problems are overcome by using current source inverter (CSI). CSI-based UPQC has a fast phase voltage control loop and inherent short circuit protection Capability. The matrix converter uses the matrix of switches so that any of the input phase voltage can be connected to any of output fload phases ;there is exactly ones witch for each of possible connection between supply and load. It provides bidirectional power flow ,sinusoidal input/output currents and controllable input power f actor. The PV panel absorbs the solar radiation from the sun by maximum power point tracking and converted to dc current by using of photovoltaic method. by using of the boost increase the voltage level and gives to the inverter through the dc link ,it will smooth the voltage level .the inverter operates based on the power electronics switches to turn on and off of the switches depend upon the grid power matches ,it synchronization with grid.

EXISTING SYSTEM

The UPQC consists of two voltage source inverters connected back to back with each other sharing a common dc link. 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 Vs is itself already unbalanced & distorted &is applied critical load that require high power quality .On the other hand, part of the total load include nonlinear loads that inject a large amount of harmonic current into the network, which should be filtered. Current iL represents all nonlinear loads that should be compensated. The shunt active filter of the UPQC can compensate all undesirable current components, including harmonics, imbalances due to negative- and zero sequence components at 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 VL at load terminal and compensated current that is drawn from the power system become balanced, so that they contains no unbalance from negative- and zero sequence components at 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.

PROPOSED SYSTEM

This chapter presents a novel control strategy for the case of three phase four wire Unified Power-Quality Conditioner (UPQC) based on the concepts of fuzzy hysteresis band voltage and current control. Using fuzzy hysteresis band voltage and current control, voltage sags and swells, and along with current and voltage harmonics compensation, reactive power compensation has been simulated and the results are analyzed. The advantages of fuzzy control are that it does not depend on the precise mathematical model of object to overcome the impact of nonlinear. Hence it has a good dynamic response and strong robustness to the parameter-changes of the regulating object. The operation and capability of the proposed system was analyzed through simulations with MATLAB / SIMULINK.

BLOCK DIAGRAM

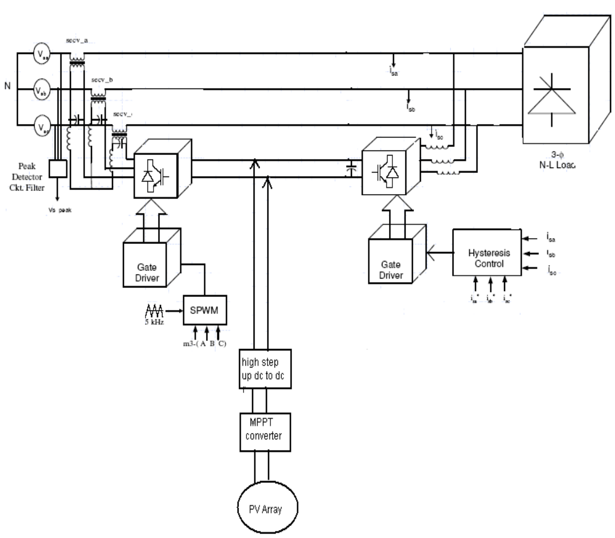


Figure 4.1 Unified Power Quality Conditioner (UPQC)

FUZZY LOGIC BASED UNIFIED POWER QUALITY CONDITIONER

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 good dynamic response.

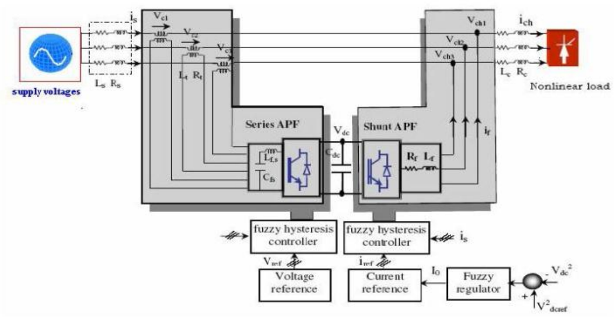


Figure 4.2.Fuzzy Logic Based Unified Power Quality Conditioner

The active power filtering has proven to be one of the best solutions for mitigation of major power quality problems. The shunt APF is utilized to overcome all current related problems, such as current harmonics, reactive current and current unbalance. Whereas, all voltage related problems, such as voltage harmonics, voltage sag and swell, and voltage unbalance, are handled by using the series APF. The UPQC is controlled in such a way that the voltage at load bus is always sinusoidal and has a desired magnitude.

Therefore the voltage injected by series APF must be equal to the difference between the supply voltage and the ideal load voltage. Thus the series APF acts as controlled voltage source. The function of shunt APF is to maintain the dc link voltage at constant level. In addition to this the shunt APF provided the vary required by the load, such that the input power factor will be unity and only fundamental active power will be supplied by the source .The control scheme of a shunt active power filter must calculate the current reference waveform for each phase of the inverter, maintain the dc voltage constant, and generate the inverter gating signals. Also the compensation effectiveness of an active power filter depends on its ability to follow the reference signal calculated to compensate the distorted load current with a minimum error and time delay.

There are two control techniques including indirect control and direct control, and the former is relatively common used. On the method, the series inverter is controlled as a non-sinusoidal voltage source, whereas the shunt inverter is controlled as a non-sinusoidal current source. It's needed to detect the voltage distortion and the fundamental wave deviation of power grid. These quantities are used as voltage commands to control the series inverter output compensated voltages which are contrary with the commands, in order to ensure the load voltage is the rated sinusoidal voltage. It is also needed to detect the reactive current and harmonic current of loads. These quantities are used as current commands to control the shunt inverter to output compensated currents which are contrary with the commands, in order to ensure the input current of power grid is the sinusoidal current and the power factor is unity. The other advantage of this method is that UPQC is not needed to change the operation modes when power grid is outage or recovered, because the shunt inverter is controlled as a voltage sinusoidal source all the time.

GENERATING COMPENSATING CURRENT

The output, isp is considered as magnitude of three phase reference currents. Three phase unit current vectors (usa , usb and usc) are derived in phase with the three phase supply voltages (vsa, vsb and vsc). These unit current vectors (usa, usb and usc) form the phases of three phase reference currents. Multiplication of magnitude Isp with phases (usa, usb and usc) results in the three-phase reference supply currents (isa*, isb* and isc*). Subtraction of load currents (ila, ilb and ilc) from the reference supply currents (isa*, isb* and isc*) results in three phase reference currents (isha*, ishb* and ishc*) for the shunt inverter. These reference currents iref (isha*, ishb* and ishc*) are compared with actual shunt compensating currents iact (isha, ishb and ishc) and the error signals are then converted into switching pulses using PWM technique which are further used to drive shunt inverter. In response to the PWM gating signals the shunt inverter supplies harmonic currents required by load. In addition to this it also supplies the reactive power demand of the load.

GENERATING COMPENSATING VOLTAGE

The series inverter, which is also operated in current control mode, isolates the load from the supply by introducing a voltage source. This voltage source compensates supply voltage deviations such as sag, swell, and flicker and spikes. In closed loop control scheme of the series inverter, the three phase load voltage (vla, vlb and vlc) are subtracted from the three phase supply voltage (vsa, vsb and vsc), and are also compared with reference supply voltage which results in three phase reference voltages (vla*, vlb* and vlc*).These reference voltages are to be injected in series with the load. By taking recourse to a suitable transformation, the three phase reference currents (isea*, iseb* and isec*) of the series inverter are obtained from the three phase reference voltages (vla*, vlb* and vlc*). These reference currents (isea*, iseb* and isec*) are fed to a PWM current controller along with their sensed counterparts (isea, iseb and isec). The gating signals obtained from PWM current controller ensure that the series inverter meets the demand of voltage sag and swell, flicker etc. There by providing sinusoidal voltage to load. Thus series inverter plays an important role to increase the reliability of quality of supply voltage at the load, by injecting suitable voltage with the supply, whenever the supply voltage undergoes sag.

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 part for compensating network voltage sag. If a power imbalance occurs, because of load changing 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 where in the effects of parameter variation of controller is present. Fuzzy control is based on the principles of fuzzy logic. It is a non-linear control method, which attempts to apply the expert knowledge of an experienced user to the design of a controller. Fuzzy modeling provides the ability to linguistically specify approximate relationships between the input and desired output. The relationships are represented by a set of fuzzy If-then rules in which the antecedent is an approximate representation of the state of the system and the consequent provides a range of potential responses..

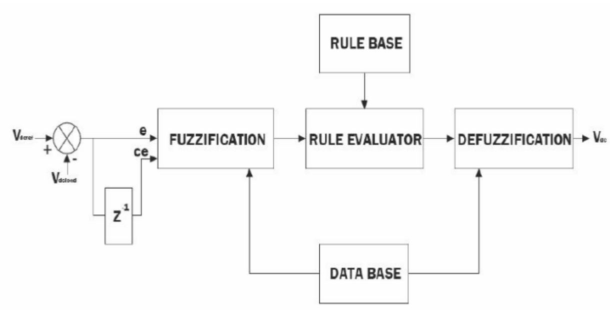
FUZZY CONTROL ALGORITHM

In Fuzzy Logic Control, basic control action is determined by setoff linguistic rules. These rules are determined by the system variables. Since the numerical variables are converted into linguistic variables, mathematical modeling of the system is not required in FLC. Fuzzy logic uses linguistic variables instead of numeric variables. The process of converting a numeric variable to a linguistic variable (fuzzy set) is called fuzzification

The fuzzy control algorithm consists of a set of fuzzy control rules which reflects the experience gained from the plant operation. The rules are combined by using the implication and the compositional inference. The FLC comprises of three parts: Fuzzification, Interference engine and Defuzzification. 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 Madman’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.



4.3. 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 6.3 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..

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.

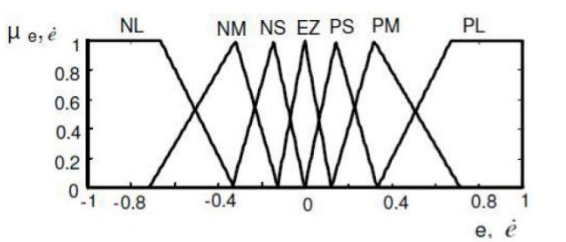


Figure 4.4.Membership Functions For Input And Output Variables

FUZZY ADAPTIVE HYSTERESIS CURRENT CONTROLER

The core of active filter is the control section that must be able to derive the reference current waveform matching the harmonic content of the line current and to drive the inverter producing a filtering current faithfully tracking the reference one. The objective is to get sinusoidal line currents in phase with the supply voltages at the common coupling point. The current control strategies can be classified as hysteresis current control, the ramp comparison control methods associated with linear controller and the predicted current control. Hysteresis current control methods very simple and easy to implement, but has the disadvantage of an uncontrollable high switching frequency. This high frequency produces a great stress for the power transistors and induces switching losses. The second and third methods allow operating at a fixed switching frequency and are usually performed by software using the system parameters. In this case, the operating conditions must be known to meet sufficient and accurate control. Consequently, a fuzzy hysteresis band circuit control for a sinusoidal input current is involved for our application. The fixed hysteresis band method has the drawbacks of variable switching frequency, heavy interference between the phases in case of three phase active filter with isolated neutral and irregularity of the modulation pulse position. These problems result in high current ripples, acoustic noise and difficulty in designing input filter. To overcome these difficulties, this chapter presents an adaptive hysteresis band current control technique in which the hysteresis bandwidth is determined by the fuzzy logic controller. Adaptive fuzzy hysteresis band current control technique can be programmed as a function of the active filter and supply parameters to minimize the influence of current distortions on modulated waveform. The Hysteresis band (HB) can be modulated at different points of fundamental frequency of the cycle to control the PWM switching pattern of the inverter.

SIMULATION AND MODEL-BASED DESIGN

Simulink is a block diagram environment for multi domain simulation and Model-Based Design. It supports system-level design, simulation, automatic code generation, and continuous test and verification of embedded systems. Simulink provides a graphical editor, customizable block libraries, and solvers for modeling and simulating dynamic systems. It is integrated with MATLAB, enabling you to incorporate MATLAB algorithms into models and export simulation results to MATLAB for further analysis

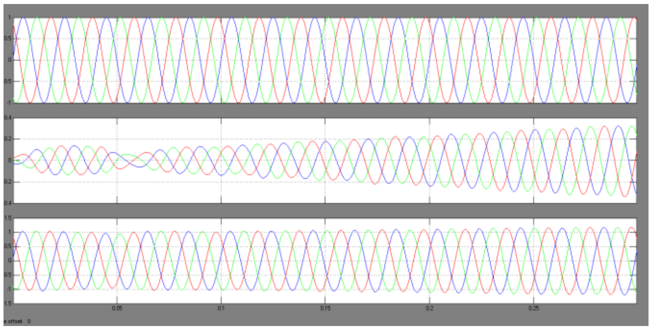


Figure2 Output of voltage waveform

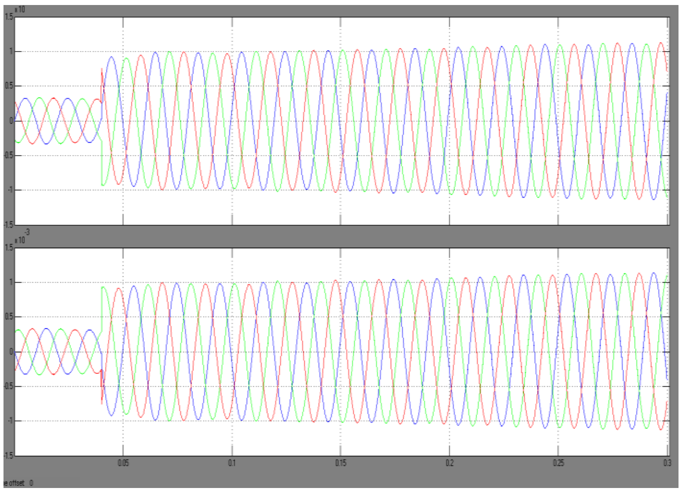


Figure 2 Output of current waveform

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 fuzzy logic controller (FLC) is tuned with large number of data points. Then conventional compensator was replaced with fuzzy logic controller and simulated using MATLAB/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. It is also observed that the response time for derivation of compensation signals reduces significantly with improved accuracy.

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