ANFIS Based UPQC for Power Quality Improvement

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ABSTRACT

Analysis of a three-phase three wire Unified Power Quality Conditioner (UPQC) controlled with Adaptive Neuro Fuzzy Inference System based controller is presented in this project. UPQC is a custom power device which is integrated by series and shunt active power filters (APF) sharing a common dc bus capacitor. The shunt and series APFs are realized with the help of three – phase, three leg voltage source converters that are sharing a common DC capacitor. The fundamental voltages, currents are extracted by modified synchronous reference frame technique; switching pulses for both the filters are generated by conventional hysteresis based controller. The capacitance voltage is balanced by ANFIS based controller. Performance of the ANFIS based control algorithm of shunt active filter with series active filter is evaluated in terms of eliminating the power quality problems in a three phase, three-wire distribution system with non-linear and unbalanced load conditions. Adaptive neuro fuzzy logic control is used for dc capacitance balancing. System taken for test and the control algorithm are implemented with the help of Sim power systems and ANFIS editor of MATLAB / SIMULINK.

KEYWORDS: *Non Linear Load,UPQC, Compensation, ANFIS Control*

1. Introduction

PQ studies have emerged as a significant topic because of the extensive use of sensitive electronic equipments. A broad definition of power quality that includes the definitions of technical quality and supply continuity states that the limits specified in the standards and regulations should not be exceeded by electrical PQ or in other words frequency, number and interval of interruption, interruption in voltage, sine waveform and voltage unbalance . Nowadays power quality is definitely a big issue and the inclusion of advanced devices, whose functioning is extremely sensitive to the quality of power supply, makes it especially important. Due to the increasing anxiety over supplying pure electrical energy to the consumers in the availability of non sinusoidal waveforms, PQ has gained much interest in recent years.

The basic requirements for compensation process involve precise and continuous VAR control with fast dynamic response and on-line elimination of load harmonics. To satisfy these criterion, the traditional methods of VAR compensation using switched capacitor and thyristor controlled inductor coupled with passive filters are increasingly replaced by active power filters (APFs). The APFs are of two types; the shunt APF and the series APF.

The shunt APFs are used to compensate current related problems, such as reactive power compensation, current harmonic filtering, load unbalance compensation, etc. The series APFs are used to compensate voltage related problems, such as voltage harmonics, voltage sag, voltage swell, voltage flicker, etc. The unified power quality conditioner (UPQC) aims at integrating both shunt and series APFs through a common DC link capacitor. The UPQC is similar in construction to a unified power flow controller (UPFC) [9]. The UPFC is employed in power transmission system, whereas the UPQC is employed in a power distribution system. The primary objective of UPFC is to control the flow of power at, fundamental frequency. On the other hand the UPQC controls distortion due to harmonics and unbalance in voltage in addition to control of flow of power at the fundamental frequency.

2. Problem Identification

From the review of the research work shows that, an intelligent technique which is adopted in various electrical and electronics applications. In the previous paper this intelligent technique is being used for improving the power quality problem compensating performance of UPQC. This technique combines the properties of both the neural network and the fuzzy logic which makes it more robust and efficient. A neural network suggests the possibility of solving the problem of learning from the given data, the trained neural network is generally understood as a black box. Neither it is possible to extract structural information from the trained neural network nor can we integrate special information into the neural network in order to simplify the learning procedure.

Alternatively, a fuzzy logic controller is designed t work with the structured knowledge in the form of rules and nearly everything in the fuzzy system remains highly transparent and easily interpretable. However, there exists no formal framework for the choice of various design parameters and generally the optimization of these parameters is done by trial and error method. Hence, a\ combination of neural networks and fuzzy logic presents the possibility of solving tuning problems and design difficulties of fuzzy logic. The resulting network will be more flexible and can be easily recognized in the form of fuzzy logic control rules or semantics. This new approach combines the well established advantages of both the methods and avoids the drawbacks of both. In this paper, adaptive neural-fuzzy controller architecture is proposed, which is an improvement over the existing Neuro fuzzy controllers.

3. Unified Power Quality Conditioner (UPQC)

It consists of two voltage source inverters (VSIs) connected back-to-back, sharing a common DC link in between. One of the VSIs act as a shunt APF, whereas the other as a series APF. The performance of UPQC mainly depends upon how quickly and accurately compensation signals are derived. The unified power quality conditioner (UPQC) aims at integrating both shunt and series APFs through a common DC link capacitor. The UPQC is similar in construction to a unified power flow controller (UPFC)

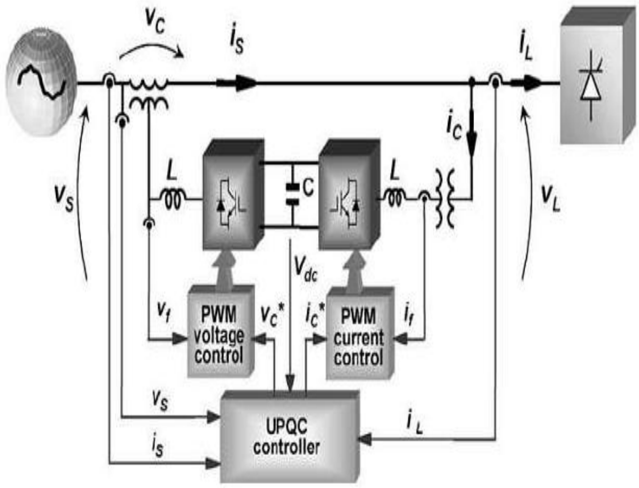

Fig 1- Basic Schematic diagram of UPQC

3.1 Control Objectives Of Upqc

The shunt connected converter has the following control objectives

1. To balance the source currents by injecting negative and zero sequence components required by the load
2. The compensate for the harmonics in the load current by injecting the required harmonic currents
3. To control the power factor by injecting the required reactive current (at fundamental frequency)
4. To regulate the DC bus voltage.

The series connected converter has the following control objectives

1. To balance the voltages at the load bus by injecting negative and zero sequence voltages to compensate for those present in the source.
2. To isolate the load bus from harmonics present in the source voltages, by injecting the harmonic voltages
3. To regulate the magnitude of the load bus voltage by injecting the required active and reactive components (at fundamental frequency) depending on the power factor on the source side
4. To control the power factor at the input port of the UPQC (where the source is connected. Note that the power factor at the output port of the UPQC (connected to the load) is controlled by the shunt converter.

The operation of a UPQC can be explained from the analysis of the idealized equivalent circuit shown in Fig. 2. Here, the series converter is represented by a voltage source VC and the shunt converter is represented by a current source IC

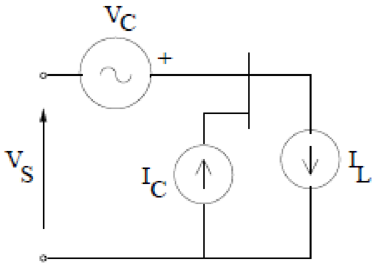

Fig 2-equivalent circuit of UPQC

4. ANFIS BASED UPQC

UPQC is power electronics based power conditioning device, designed to compensate both source current and load voltage imperfections. This device combines a shunt active filter together with a series active filter in a back to back configuration, to mitigate any type of voltage and current fluctuations and power factor correction in a power distribution network. UPQC is able to compensate current harmonic reactive power, voltage distortions and control load flow but cannot compensate voltage interruption because of not having sources. Hence in this paper we have proposed a hybrid technique called the adaptive Neuro fuzzy inference system (ANFIS). By adding an ANFIS device to the UPQC system the discharging time of the DC link capacitor is maintained at a lower level. Accordingly the system performance is enhanced dramatically.

The general structure of proposed ANFIS based UPQC consists of two inverters and it is connected with a bias voltage generator. The inputs of the bias voltage generator are reference voltage *Vref* and the calculated voltage *Vcal*, which is calculated from ANFIS. The Inverter II is connected in series with an inductance that is denoted by *LSLC*. The purpose of the synchronous link inductor is to generate a voltage with respect to PQ disturbance. The inverter I is connected in series with a low pass filter and the purpose of the filter is to pas the low frequency component, and to reduce the high frequency component of the specific voltage signal. Then, the output of low pass filter is applied to the voltage injection transformer. Hence, the obtained output from injection transformer maintains PQ in the operating system. The injected line voltage, voltage source, current source and load current and load voltage are denoted as Vinj Vs, Is, IL and VL respectively .

4.1. ANFIS based bias voltage generator

The bias voltage generator is used for eliminating the high discharging time of the D.C link capacitor. The ANFC is a hybrid technique which combines Fuzzy Inference System (FIS) and NN. The fuzzy logic is operated based on fuzzy rule and NN is operated based on training data set. The neural network training datasets are generated from the fuzzy rules and the error and change in error voltage of the device is determined which is shown below.

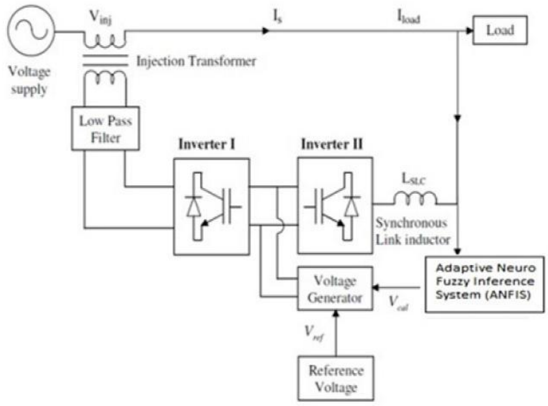

Figure 3: Schematic diagram of ANFIS based UPQC

$$E(k) = V_{dc}(ref) - V_{dc}$$

$$\Delta E = E(k) - E(k-1)$$

Where, E (k-1) is the previous state error. The error voltage and change of error voltage are calculated by using the above formula and the value are applied to the input of ANFIS. From the output of NFC, the *Vout* is determined.

4.2. Working Procedure of ANFIS

Step-1: At first the initialization of the input variables called the parameters is done which is in a binary form and the input variables are fuzzy field.

Step-2: After input fuzzification, output fuzzification is done by applying fuzzy operators like AND, OR operators.

Step-3: Membership functions are defined and are computed to track the given input/output data.

Step-4: The parameters associated with the membership function changes through the learning process.

Step-5: Fuzzy rules are created basing on the input output relationship of the system.

Step-6: After creating rules, aggregation of various outputs is done and then the resulted functions are de fuzzyfied to get an optimal output.

Step-7: The obtained output is then trained by applying it to the Neural network through the back propagation method.

Step-8: The error is minimized by performing various iterations in the Neural network and we get an optimized output.

5. Simulation Results

The model for UPQC control using ANFIS method has been successfully modeled and tested using MATLAB/SIMULINK toolbox. The performance in steady state condition is evaluated using FFT simulation.

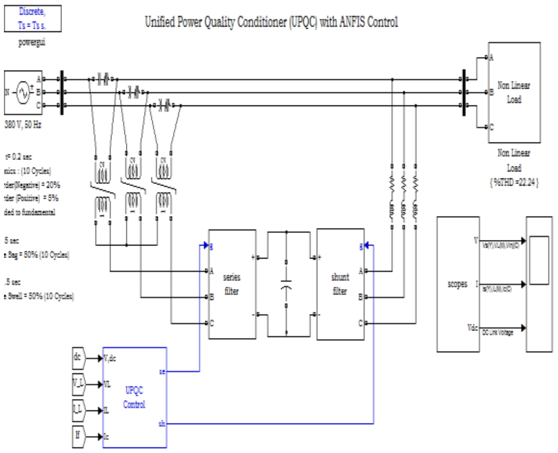

Fig 4: Simulation model of ANFIS based UPQC

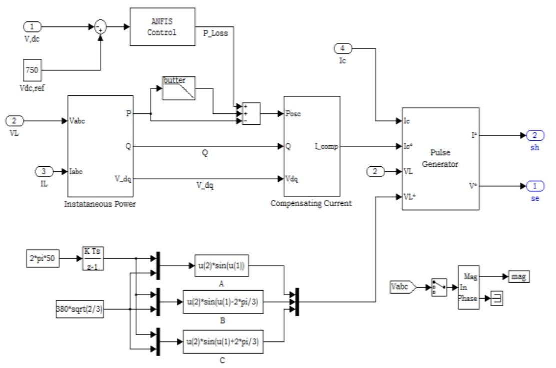

Fig 5: Simulation model of UPQC control

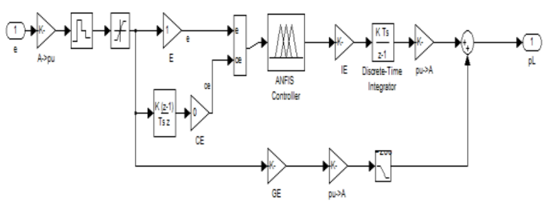

Figure 4: Simulation model of ANFIS control

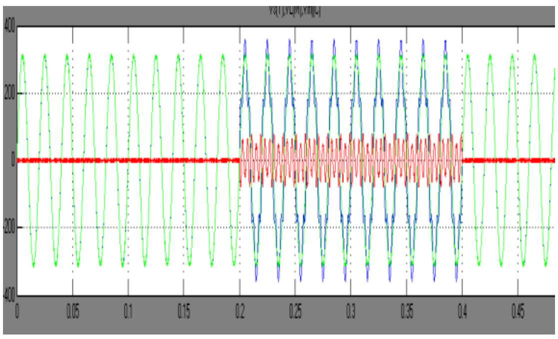

Figure 5: waveform for V injected, load voltage, source voltage

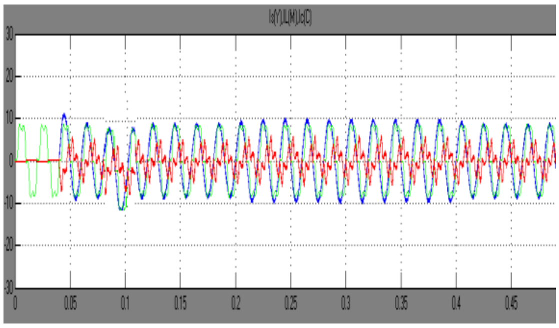

Figure 6: waveform for I injected, load current, source current

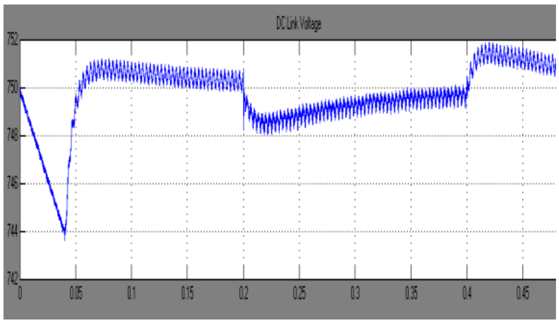

Figure 7: waveform for DC link voltage

6. Conclusion

Different power harmonic sources exist mainly due to nonlinear loads made up of power electronics devices. In this paper, an ANFIS based UPQC controller was proposed for compensating the PQ problem. The proposed controller was implemented using MATLAB/SIMULINK. Proposed controller can achieve a better performance of PQ issues compared with the FLC, NFC and NN based controllers.

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