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SIMULATION OF FUZZY LOGIC BASED UPQC BY ADDITION OF A SUPERCONDUCTING MAGNETIC ENERGY STORAGE SYSTEM

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Abstract- Modern power grids must be highly reliable and provide power with a high quality. Power quality issues like voltage sags or current harmonics must be minimized, in order to achieve high levels of reliability in the system. One possible way to overcome such problems is through the utilization of active power filters like a Unified Power Quality Conditioner (UPQC).As the demand of electricity is increasing day by day, it is necessary to supply a good quality of power to customers. In the future, distribution system operators could decide to supply their customers with different PQ levels and at different prices. Due to the presence of nonlinear loads in the system many problems like fluctuations, flickers, voltage sag, voltage swell etc. comes in the system. Series compensator which is meant for voltage restoring is controlled by a fuzzy logic controller. Shunt compensator's operation is controlled by extracting d and q axis current from load current and DC link voltage is maintained through a fuzzy logic controller. The performance of UPQC mainly depends upon how quickly and accurately compensation signals are derived. Thus, the combination of weak grids, wind power fluctuation and system load changes produce disturbances in the PCC voltage, worsening the Power Quality is stability. In this paper, a fuzzy logic controller with reference signal generation method is designed for UPQC. This is used to compensate current and voltage quality problems of sensitive loads. The results are analyzed and presented using Matlab/Simulink software.
Keywords—UPQC; SMES; Power Quality.

I. INTRODUCTION

The limited stretch of time Power Quality (PQ) are most important facets of any power way of using voice system today. feeble amount of power quality has an effect on user and can cause loss of producing, damage of appliances and necessary things, increase the power loss and so forward, out, on (in time). In present scenario the use of necessary things based on power electronics has produce force of meeting blow on power quality by harmonics [1-2].Power Quality is a function of power factor

so the use of non-linear and low power factor load such as adjustable speed drives, computer power supplies, furnaces, power converters and traction drives are finding its applications at domestic and industrial levels. These nonlinear loads draw non-linear current and degrade electric power quality. The prime objective of power utility companies is to provide their consumers an uninterrupted sinusoidal voltage of constant amplitude [3-4].These devices can be of series, shunt-shunt or series-shunt type [5].

The main advantage of multi feeder devices is that if any power quality problem occurs in one feeder, other adjacent feeder supplies power for compensating power quality problem. Therefore the multi-feeder PQ devices assure superior performance than single feeder PQ devices [6]. Unified Power Quality Conditioner (UPQC) consists of two IGBT based Voltage source converters (VSC), one shunt and one series cascaded by a common DC bus. The shunt converter is connected in parallel to the load. It provides VAR support to the load and supply harmonic currents. Whenever the supply voltage undergoes sag then series converter injects suitable voltage with supply [7]. Thus UPQC improves the power quality by preventing load current harmonics and by correcting the input power factor. 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 voltage source inverter (VSI). VSI-based UPQC has a faster phase voltage control loop and inherent short circuit protection capability. It also minimizes the cost as in this case passive filter connection between UPQC and the load is not necessary [8-9]. The only disadvantage of VSI-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 FLC is to utilize the qualitative knowledge of a system to design a practical controller [10]. For a process control system, a fuzzy control algorithm embeds the intuition and experience of an operator, designer and researcher. The control does n"t need accurate mathematical model of a plant, and therefore, it suits well to a process where the model is unknown or ill-defined and particularly to systems with uncertain or complex dynamics [11]. In this paper the application of fuzzy logic in control of shunt and series active power filters used a hysteresis band comparator for control of three-phase active power filter. This paper presents a novel method for derivation of compensation signals in VSI-based UPQC using Fuzzy logic Controller. The performance of the system is verified by extensive simulation [12].In recent years, FACTS has appeared as solution of many PQ problems. The FACTS concepts applied in distribution systems has resulted in a new generation of compensating devices. A UPQC is the extension of the UPFC concept at the distribution level. UPQC is the integration of Series APF and shunt APF, active power filters, connected back-to-back on the dc side, sharing a common DC capacitor. The series component of the UPQC is responsible for mitigation of the supply side disturbances: voltage sags/swells, flicker, voltage unbalance and harmonics [13]. It inserts voltages so as to maintain the load voltages at a desired level; balanced and distortion free. The shunt component is responsible for mitigating the current quality problems caused by the consumer: poor power factor, load harmonic currents, load unbalance etc. It injects currents in the ac system such that the source currents become balanced sinusoids and in phase with the source voltages.The overall function of UPQC mainly depends on the series and shunt APF controller.

A. Block Diagram of UPQC

The system configuration of a single-phase UPQC is shown in figure given below.

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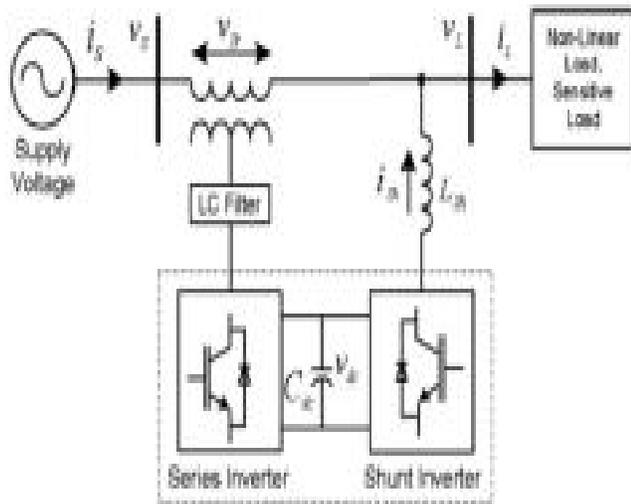
Fig.1.Block Diagram of UPQC.

UPQC consists of two IGBT based VSC, one shunt and one series cascaded by a common DC bus. The main components of a UPQC are series and shunt power converters, DC capacitors, low-pass and high-pass passive filters, and series and shunt transformers. The key components of this system are as follows.

1) Two inverters —one connected across the load which acts as a shunt APF and other connected in series with the line as that of series APF.

2) Shunt coupling inductor L is used to interface the shunt inverter to the network. It also helps in smoothing the current wave shape.

3) A common dc link that can be formed by using a capacitor or an inductor.

4) An LC filter that serves as a passive low-pass filter and helps to eliminate high-frequency switching ripples on generated inverter output voltage.

5) Series injection transformer that is used to connect the series inverter in the network. A suitable turn ratio is often considered to reduce the voltage and current rating of series inverter.

6)The integrated controller of the series and shunt APF of the UPQC to provide the

compensating voltage reference Vc and compensating current reference Ic.

II.SYSTEM OVERVIEW

The designed system is depicted in Fig.2. The simulated grid contains a power source, which was simulated using a three phase programmable power source in Simulink, a pure resistive load and the hybrid system consisting of the UPQC+SMES. The series active filter that builds the UPQC is placed close to the power source and the shunt filter is placed close to the load. Although it is possible to choose a reverse configuration (shunt filter close to the source and series filter close to the load) this arrangement was chosen because it allows a better controllability of the DC bus voltage. This is a fundamental characteristic in this hybrid system because the SMES is connected to this DC bus.
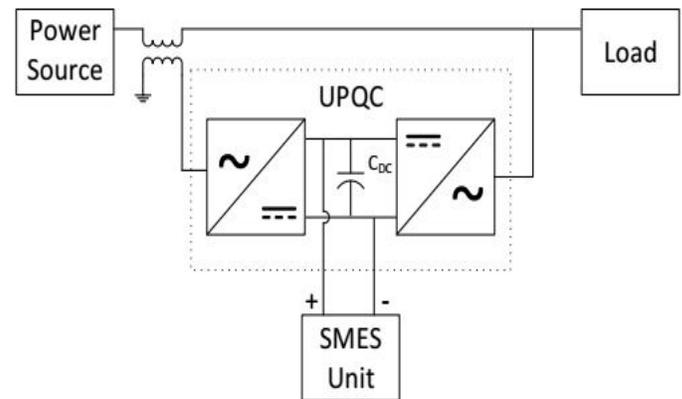
Fig.2.Implemented system.

A.UPQC

The UPQC is the main component of the designed system. Fig.2 shows a schematic of the implemented active power filter. The UPQC flexibility allows a full control of voltage and current. The series power active filter is responsible for voltage control and the shunt filter for current control. This control is possible by measuring the different values of voltages and currents in the grid and comparing them to reference values. The two filters are controlled

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using PWM generators and follow two different control strategies: the reference signal for the PWM generator of the series filter follows a "feedforward" control method, comparing the voltage of the filter to a well-defined reference value; on the other hand, the reference signal for the PWM generator of the shunt filter is obtained following a Synchronous Reference Frame Method [5]. A major responsibility of the UPQC controller is to maintain the DC bus voltage always above a required level. On this particular case, the chosen value is 700 V, which is higher than the minimum voltage necessary to have full controllability of both active filters at all time. The minimum value in this case is 648V, calculated following the formulation presented. The capacitor used in the DC bus has a value of 50 µF.
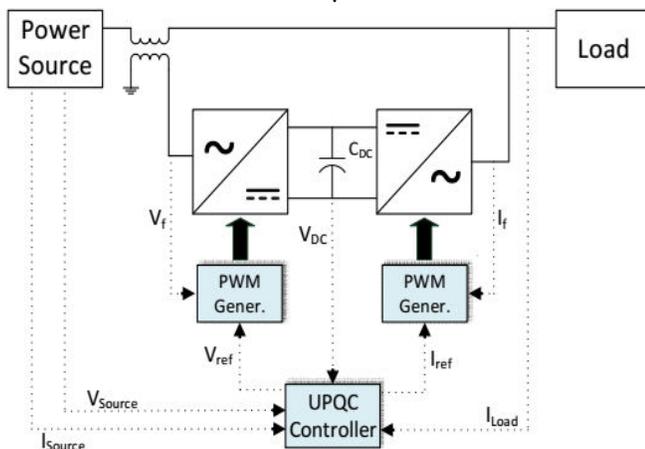
Fig.3. Implemented UPQC

B.SMES

An SMES is a very complex system, composed by three main components: a superconducting (SC) coil (placed inside a cryostat) where energy is stored; a Power Converter System (PCS), which is a power electronics bidirectional converter, responsible for the exchange of energy with the grid to which the SMES is connected, and a Control System (CS) responsible for controlling all energy exchanges with the grid and also for over

viewing and protecting the conditions of the SC coil. Fig.4 depicts a typical configuration of the systems
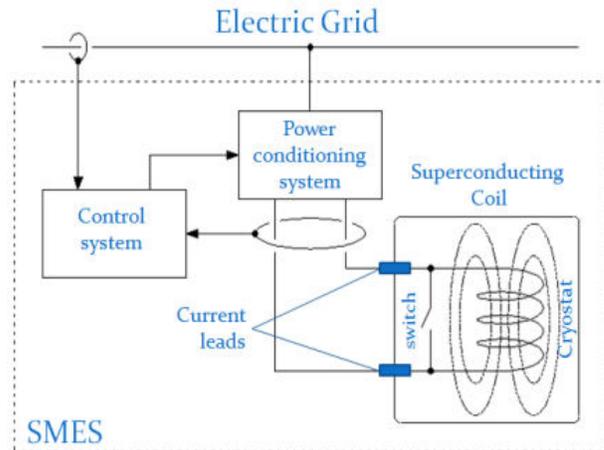
Fig.4.SMES system constitution.

In this particular case, because it is a simulation work and because the SMES is connected to a DC bus, several simplifications are possible. The PCS becomes simpler than the used one when the SMES is connected to an AC grid. In this case, it is necessary to use only a DC/DC converter. The typical choice is a chopper converter, due to its simplicity. The control strategy used in the PCS also becomes simpler due to this fact, which will also decrease the complexity of the CS. Other simulations are performed on the controller of the SMES: all variables related to the cryogenic system and protection of the SC coil are not considered. However, since the hybrid system is supposed to be able to overcome voltage swells, it is necessary to add a resistor in parallel with the SC coil, so that the excess energy (in case of a voltage swell) can be dissipated. This dissipation of energy will only occur if the SMES is already fully charged. The model used for simulation of the SMES is represented in Fig.5. To simulate the chopper two IGBTs (S_1 and S_2) were used.

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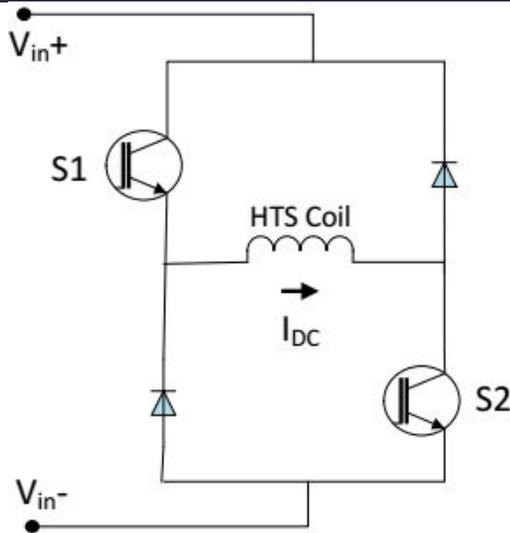
Fig.5.SMES model.

The control of these two switches allows the SMES to work in three different modes:

• S1 and S2 closed – Charging Mode: the coil is charging;

• S1 S2 closed – Discharging Mode: the coil is discharging, due to the occurrence of some fault in the grid;

• S1 open and S2 closed – Persistent Mode: the coil is already full charged and its nominal current value is kept using this mode.

When the SMES is operating alone, the charging process is straightforward. The energy can be extracted from the DC link without any special care. However, in this particular case, since the SMES is connected to the DC bus of an UPQC, its the charging process must take into account the fact that the DC voltage cannot decrease below a certain level. Thus, it is only possible to charge the SMES when the DC voltage is above 700 V (the chosen value for the DC bus voltage). The controller of the SMES (which controls the IBGTs S1 and S2) must consider this aspect.The main characteristics from the SMES unit simulated in this work are presented in table I such characteristics were

obtained following the method presented. The implemented model also considers a resistor (with 0.1 Ω) in series with the coil, to simulate the existence of connectors in the superconducting tape and a capacitor (with 1nF) in parallel, to simulate capacitance between the single pancake coils.

TABLE I
Characteristics Of The Simulated SMES Unit.

Characteristic	Value
Number of pancake coils	4
Number of turns (each coil)	130
Total inductance (H)	0.28
Nominal current value (A)	70
Critical current of SC tape considered (A)	120
Total length of SC tape necessary to implement this SMES (m)	800

In an UPQC operating alone, in the same conditions as in this case, i.e., the same DC voltage (700 V) and the same capacitor in the DC bus (50 µF), the stored energy is 12.25 J.This is a small value, which strongly limits the range of applications of such system, namely when used for voltage sags compensation. In this case, with an SMES with these characteristics connected to the DC link of the UPQC, the stored energy increases to 698.25 J. This represents an increase of 5700% in stored energy, which greatly expands the range of application of the hybrid system, when comparing to the UPQC alone.

C.FAULT DETECTION

To be able to overcome faults, it is first necessary to correctly and rapidly identify those events in the grid. Voltage sags and swells are detected following a method presented. Briefly, this method detects a voltage sag or swell by comparing the grid voltage value with a reference value. This reference value has the same phase and amplitude as the nominal

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voltage of the grid, which is very convenient because this is also used as a reference for the series active power filter.

III. FUZZY LOGIC CONTROL

L. A. Zadeh presented the first paper on fuzzy set theory in 1965. Since then, a new language was developed to describe the fuzzy properties of reality, which are very difficult and sometime even impossible to be described using conventional methods. Fuzzy set theory has been widely used in the control area with some application to power system [5]. A simple fuzzy logic control is built up by a group of rules based on the human knowledge of system behavior. Matlab/Simulink simulation model is built to study the dynamic behavior of converter. Furthermore, 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. Thus, fuzzy logic controller has been potential ability to improve the robustness of compensator. The basic scheme of a fuzzy logic controller is shown in Fig .6. and consists of four principal components such as: a fuzzy fication interface, which converts input data into suitable linguistic values; a knowledge base, which consists of a data base with the necessary linguistic definitions and the control rule set; a decision-making logic which, simulating a human decision process, infer the fuzzy control action from the knowledge of the control rules and linguistic variable definitions; a de-fuzzification interface which yields non fuzzy control action from an inferred fuzzy control action [10].
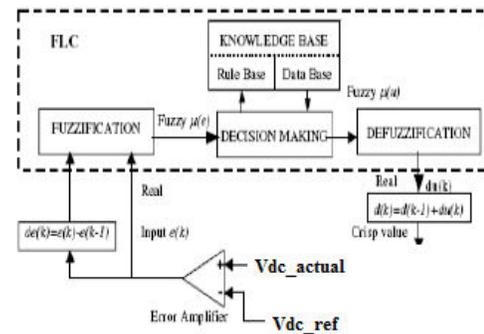
Fig.6.Block diagram of the Fuzzy Logic Controller (FLC) for Proposed Converter.
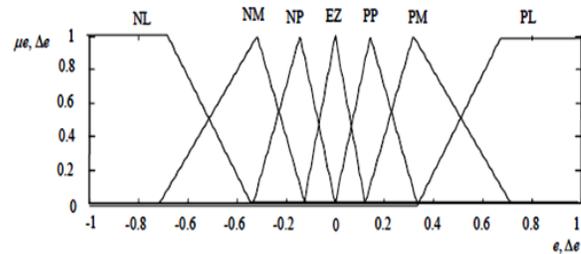
Fig.7. Membership functions for Input, Change in input, Output.

Rule Base: the elements of this rule base table are determined based on the theory that in the transient state, large errors need coarse control, which requires coarse in-put/output variables; in the steady state, small errors need fine control, which requires fine input/output variables. Based on this the elements of the rule table are obtained as shown in Table, with 'Vdc' and 'Vdc-ref' as inputs

Δe \ e	NL	NM	NS	EZ	PS	PM	PL
NL	NL	NL	NL	NL	NM	NS	EZ
NM	NL	NL	NL	NM	NS	EZ	PS
NS	NL	NL	NM	NS	EZ	PS	PM
EZ	NL	NM	NS	EZ	PS	PM	PL
PS	NM	NS	EZ	PS	PM	PL	PL
PM	NS	EZ	PS	PM	PL	PL	PL
PL	NL	NM	NS	EZ	PS	PM	PL

IV.MATLAB/SIMULATIN RESULTS
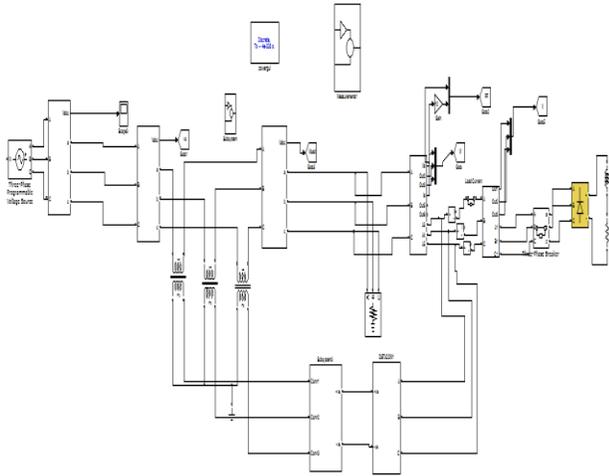
Fig.8.Simulation model of superconducting magnetic energy system of UPQC.
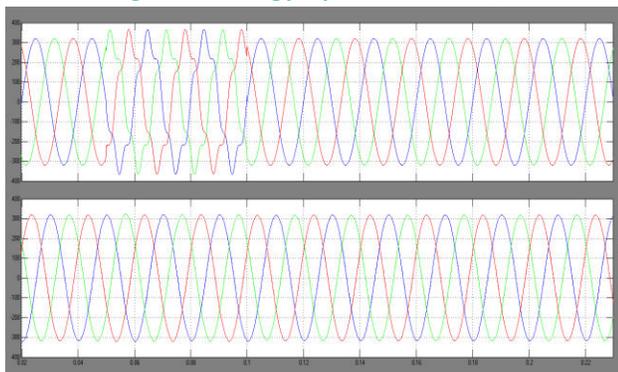
Fig.9.Harmonic distortion compensation: source (above) and load (below) voltages.
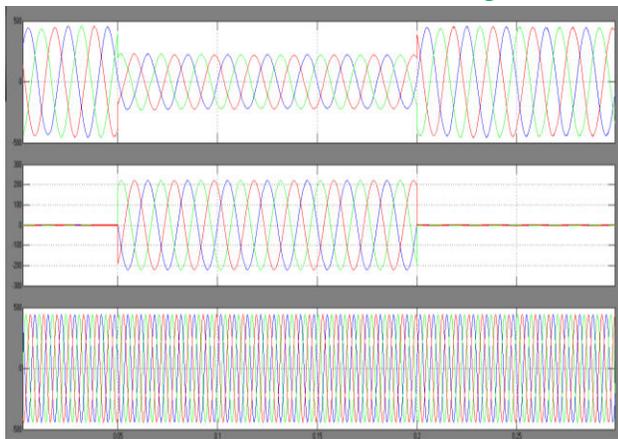
Fig.10.Voltage sag elimination: source (above) and load (below) voltages during the fault.
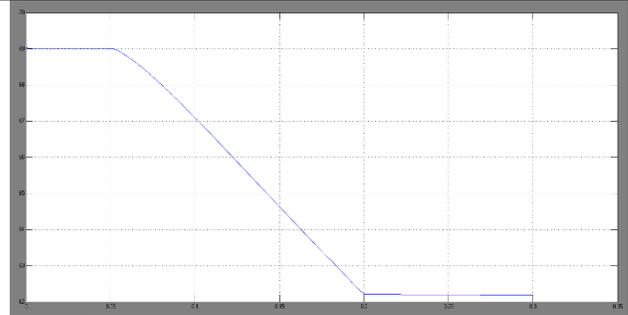
Fig. 11. Current in the SMES during a three phase voltage sag.
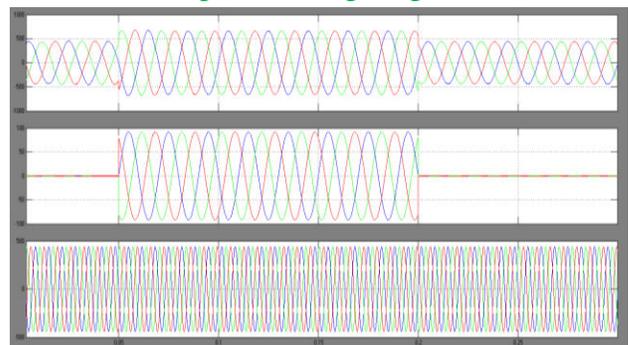
Fig.12.Voltage swell elimination: source (above) and load (below) voltages during the fault
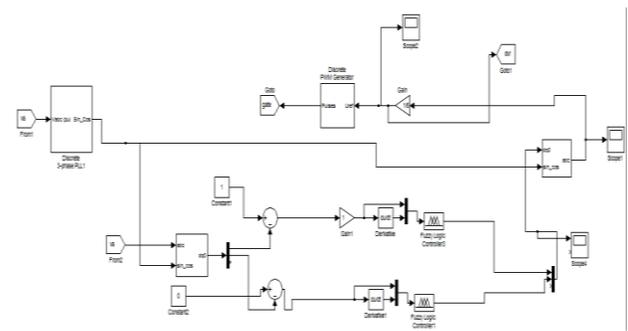
Fig.13.Simulation model of fuzzy logic controller.
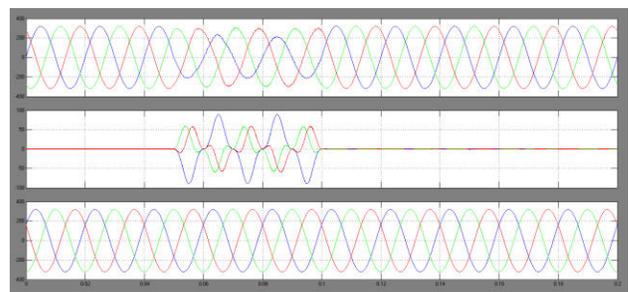
Fig.14.Harmonic distortion compensation: source (above) and load (below) voltages with fuzzy logic controller.

V.CONCLUSION

The UPQC has been simulated using the proposed FC. It may be noticed that the source current is distorted before connecting the UPQC and it becomes sinusoidal after connecting the UPQC. 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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