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# Enhancement For Power Quality Conditioner With Fuzzy Integrated Upqc With Fuel Cell In Smart Grid Network

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**Abstract:** Quality of power supply has become an important issue with the increasing demand of Distributed Generation (DG) systems either connected to the grid through some power electronics grid-tie inverters or to work in isolated (microgrid) mode towards the development of a smart grid network. In this paper a technical review of Integration of Unified Power Quality Conditioner (UPQC) in Distributed Generation Network has been presented. The ANFIS controller is designed like a Sugeno fuzzy architecture and trained offline using data from the proportional–integral controller. The obtained results proved that the proposed FCI-UPQC compensated power quality problems such as voltage sag, swell, harmonics, neutral current, source current imbalance in the three-phase four-wire distribution grid. The presence of fuel cell in this work makes more effectiveness of the proposed system by providing real power support during supply interruption on the grid side.

**Keywords:** UPQC, FCI-UPQC, ANFIS controller, Smart Grid Network.

## 1.0 Introduction

Quality of power supply has become an important issue with the increasing demand of DG systems either connected to the conventional grid, smart grid or microgrid [1]. The need for monitoring of desired power quality in transmission levels as well as in low voltage distribution levels are increasing due to better customer service demand, reasonably priced meters, telecommunication development, network planning, operation and regulation requirements which are also very important for the implementation of a smart grid distribution network. According to the IEC – International Electrotechnical Commission, “Smart Grid is the concept of modernizing the electric grid [2,3]. The Smart Grid is integrating the electrical and information technologies in-between any point of Generation and any point of Consumption The National Institute of Standards and Technology (NIST) has also developed the Smart Grid Conceptual Model, which provides a high-level framework for the smart grid that defines seven important domains: Bulk Generation, Transmission, Distribution, Customers, Operations, Markets and Service Providers where power quality has been considered as an important component in the Smart Grid Network [4,6]. The compensation by shunt active filter depends on reference current signal generated by the controller. The series active filter compensation depends on reference voltage signal generated by the controller. In recent years, several control techniques are used to generate reference signals for UPQC [7]. However, artificial intelligence-based controller having higher impacts when compared with conventional controllers. First, artificial neural networks (ANNs) are the electronic model based on the brain's neural structure [8,10]. It is an interconnection of artificial neurons that can learn from experience to provide a decision that is more accurate. It has the ability to develop complex non-linear models with high speed and adaptability that can be trained at new frequencies Second, fuzzy logic is the technique which mimics the human reasoning capabilities and it consists of fuzzification, inference mechanism and defuzzification have proposed a deep learning-based fuzzy inference model that can extract useful patterns from the input vectors to obtain more accurate fuzzy rules [13]. Finally, the adaptive neuro-fuzzy inference system (ANFIS) combines both neural and fuzzy capabilities Here a neural network is used to automatically adjust membership functions and decrease the rate of errors to determine rules of the fuzzy logic.

## 2.0 Power quality problems in dg integrated network

Electric power is the result of a production process and according to the Council of European Energy Regulators (CEER) the quality of electric power supply should comprise in three main areas, shown in Figure where the power quality means the continuity of supply and voltage quality. Again, Green House Gas (GHG) emission and the Global Warming are the side effects of the conventional electric power production process [14]. Therefore, developed countries are also trying to reduce their overall GHG emission by introducing and increasing the share of renewable energy into their electric grid system. Hence, the quality of power supply has become an important issue with the high penetration of DG systems either connected to the grid or microgrid [15]. As the solar, wind, micro-hydro are the most leading sources of DG systems therefore power quality problems related to this DG system along with diesel

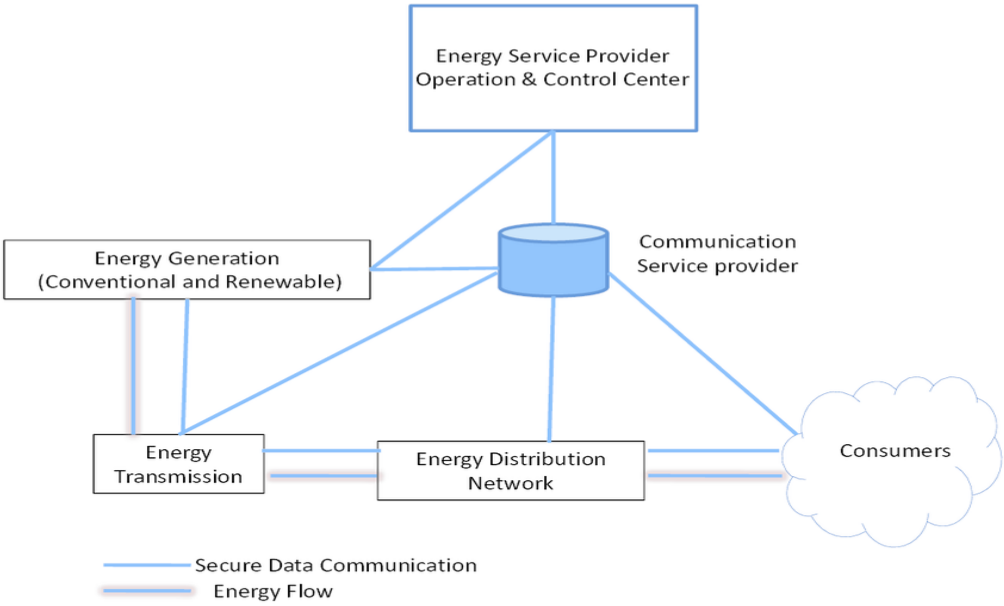


Fig 1: Conceptual model of Smart Grid

## 3.0 Proposed system:

The proposed system consists of an FCI-UPQC with ANFIS controller. The topology of the proposed system is exposed in Fig It has two IGBT-based voltage source converters connected back-to-back through a common DC-link capacitor. The FC is integrated through DC-link of the UPQC. The shunt part of the FCI-UPQC has four-leg converter will inject both reactive and harmonic components of load current to make source current as sinusoidal and balanced. It also eliminates the neutral current through fourth-leg. Similarly, the series part of the FCI-UPQC having three-leg VSC and it will inject both fundamental and harmonic voltages. The series VSC is connected before sensitive linear load to protect the load from any voltage distortion from the source side and to make load voltage as sinusoidal. The performance of the proposed system is analysed in the three-phase four-wire system with three different loads: non-linear, unbalanced, sensitive. Three-phase uncontrolled rectifier with resistive and inductive loads on the DC side acts as a non-linear load whereas three single-phase resistive and inductive loads with different rating act as an unbalanced load. Three-phase resistive and inductive loads are used as a sensitive linear load. These three loads are applied to different feeders.

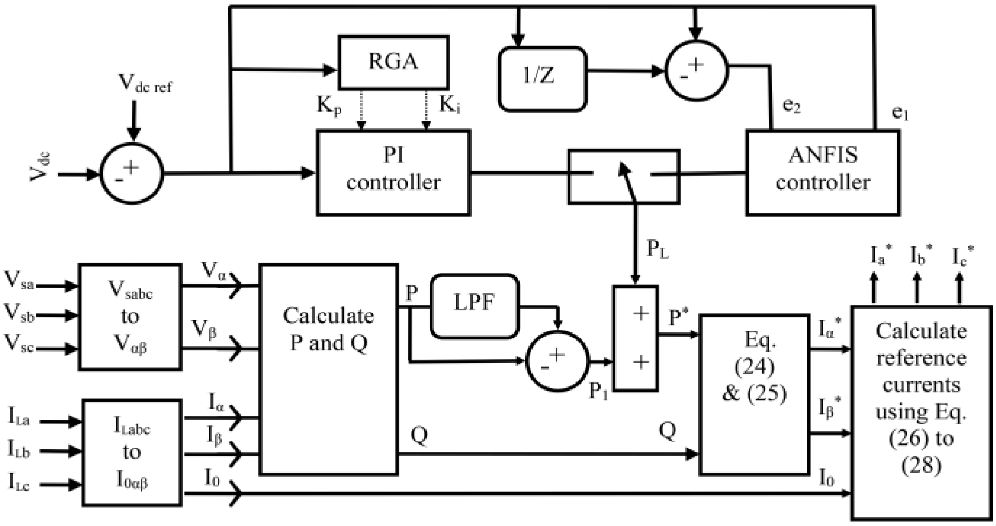


Fig 2: Extraction of reference current using ANFIS controller-based IRP theory

### 3.1 UPQC-PV Structure

The internal structure of a UPQC-PV is shown in Fig. It consists of two voltage source converters which are connected back-to-back through a common dc-link capacitor. In the proposed configuration, voltage source converter1 is connected in series with BUS and voltage source converter2 is connected in parallel with load at the end of Feeder.

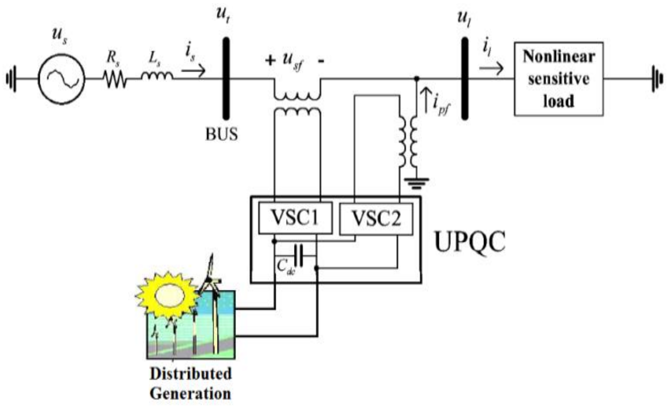


Fig 3. UPQC with DG connected to the DC link

PV source is connected to a DC link in the UPQC as an energy source. In this case, UPQC finds the ability of injecting power using PV to sensitive load during source voltage interruption. Common grid connected PV system structure is shown in fig. 4 which is composed of PV array, DC/DC and DC/AC converters.

Interconnected mode; where PV transfers power to load and source Islanding mode; where the source voltage is interrupted and PV provides a part of load power separately.

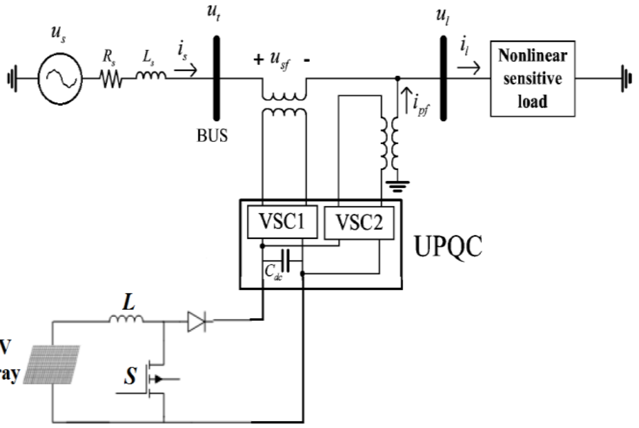


Fig 4: Configuration of proposed UPQC with PV

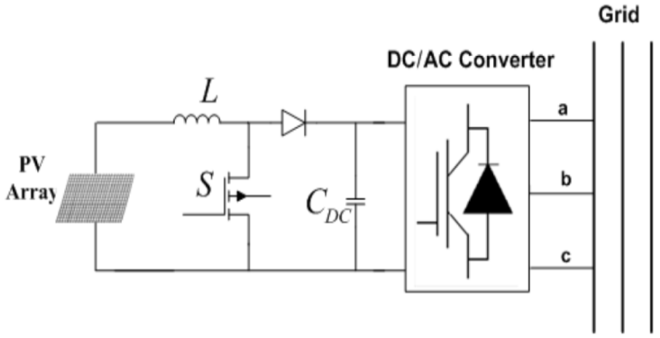


Fig 5: General structure of grid connected PV systems

Each of the three VSCs in Fig is realized by a three-phase converter with a commutation reactor and high-pass output filter as shown in Fig. The commutation reactor ($L_f$) and high-pass output filter ($R_f$, $C_f$) are connected to prevent the flow of switching harmonics into the power supply.

### 3.2 Working principle of UPQC:

UPQC is the integration of series (APFse) and shunt (APFsh) active power filters, connected back-to-back on the dc side, sharing a common DC capacitor shown in Figure The series component of the UPQC is responsible for mitigation of the supply side disturbances: voltage sags/swells, flicker, voltage unbalance and harmonics. 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 basic functional block diagram of a UPQC controller Here, the shunt APF injects the compensating reactive and harmonic current using hysteresis current controller and whereas the series APF uses PWM voltage controller to minimize the voltage disturbances

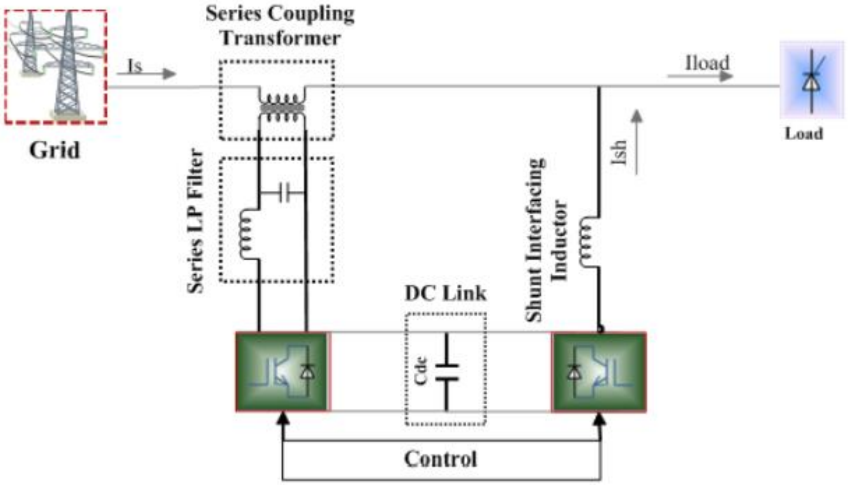


Fig 6: Basic System Configuration of UPQC

### 3.3 DC voltage regulation using ANFIS controller:

The difference between actual DC-link voltage and the reference voltage are given to the ANFIS controller. The output of the controller is used to generate pulses to control the IGBTs of the converter. The real number genetic algorithm was successfully used to optimise the PI controller parameters The nonlinearity of loads leads to distortions in the signals that are usually rectified by using traditional PI controllers that can fail in providing high accuracy, fast processing of the reference signal. Hence, ANFIS controller with the high dynamic response is used for maintaining the stability of the converter system over the wide operating range. The ANFIS controller combines both the learning abilities of a neural network and reasoning abilities of fuzzy logic. The ANFIS controller uses the hybrid algorithm, a combination of the least-squares method and back propagation gradient descent method. The ANFIS is given with two inputs e1 and e2, where the error between actual and reference DC voltages is e1 and change in error as e2. There are five layers of ANFIS architecture.

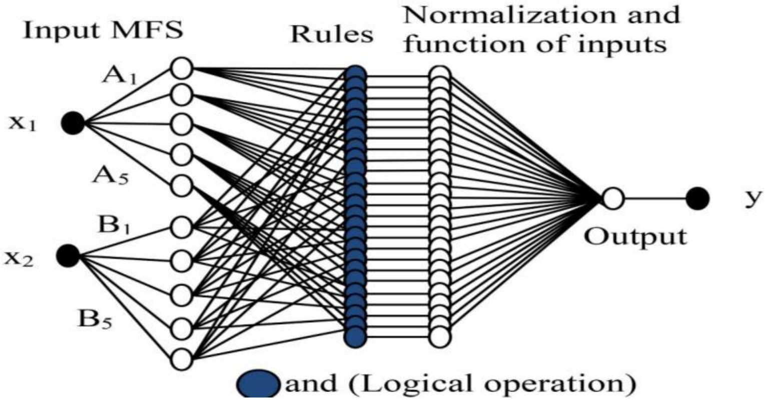


Fig 7: ANFIS architecture

### 4.0 RESULTS AND DISCUSSION:

The performance of the proposed FCI-UPQC is analysed with linear, nonlinear and unbalanced loads under various situations with ANFIS controller using MATLAB/SIMULINK. All the voltage measurements are expressed in per unit system and the current measurement in the actual value system. In the proposed work, the shunt converter of FCI-UPQC is switched on at 0.05 s to clearly represent the role of the shunt converter. The sub-plots of Fig illustrate the performance of FCI-UPQC with ANFIS controller under voltage sag and swell conditions, here the source voltage sag takes place during 0.5–1 s and a voltage swell from 0.15 to 0.2 s. During sag conditions, the corresponding injected voltage will be in phase with the source voltage and during voltage swell conditions the injected voltage will be 180° out of phase with the source voltage. Since the load is non-linear, the load current is not sinusoidal. Hence the authors are using FCI-UPQC to compensate and maintain the quality of source current waveform. During 0–0.05 s, the shunt converter is in off condition, so that the load current will be same as that of the source current without any compensation.

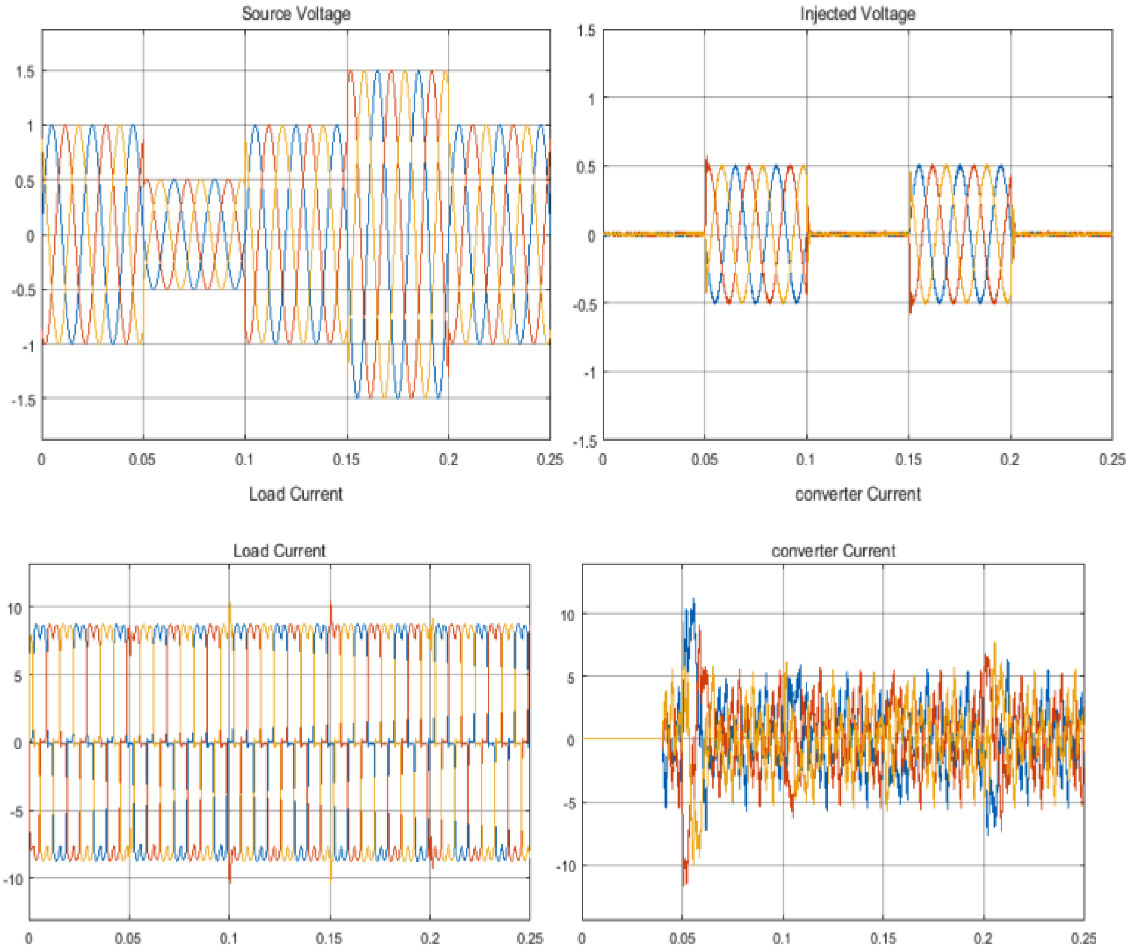


Fig 8: Performance of FCI-UPQC under voltage sag, swell and current harmonics disturbances

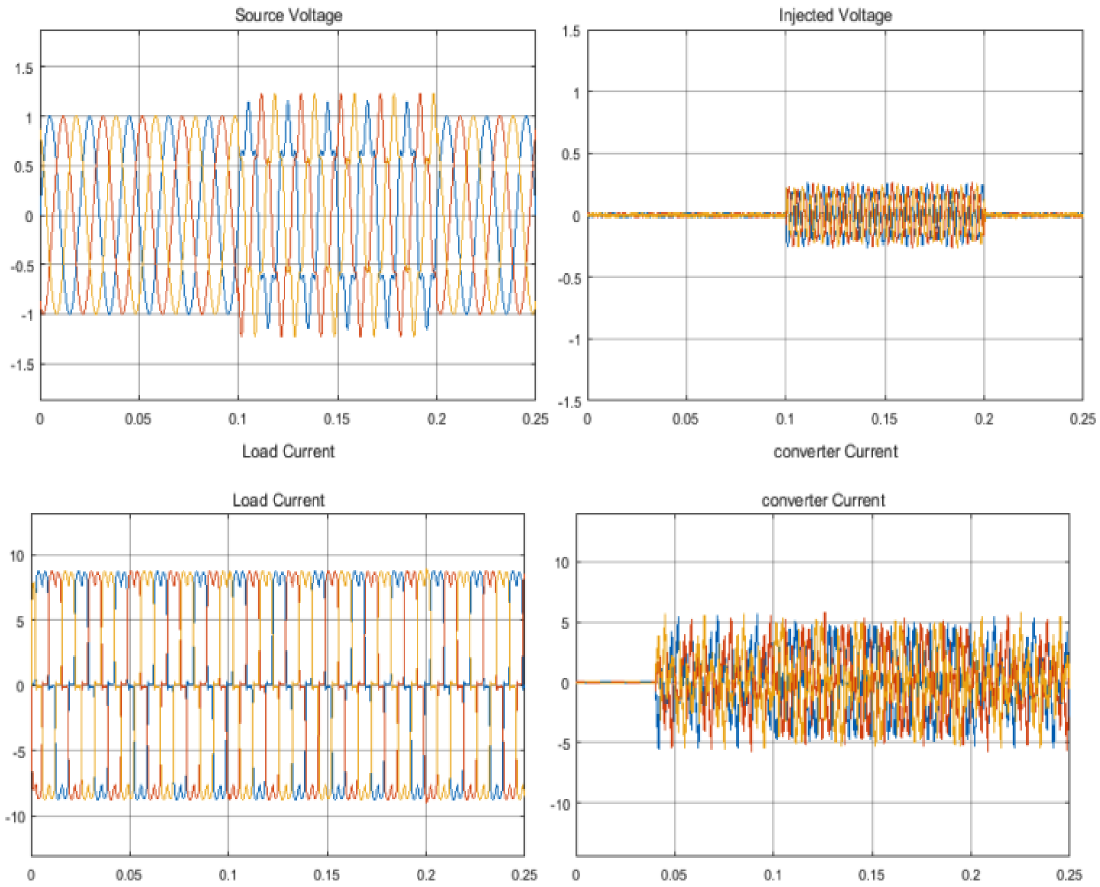


Fig 9: Performance of FCI-UPQC under source side voltage and current harmonics disturbances

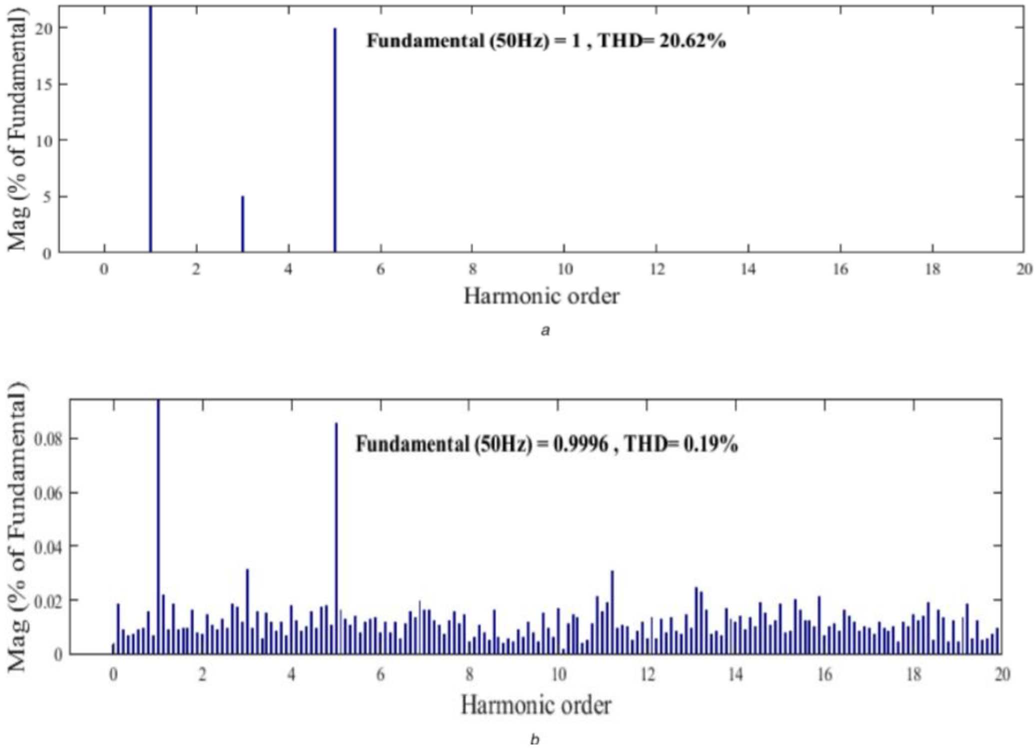
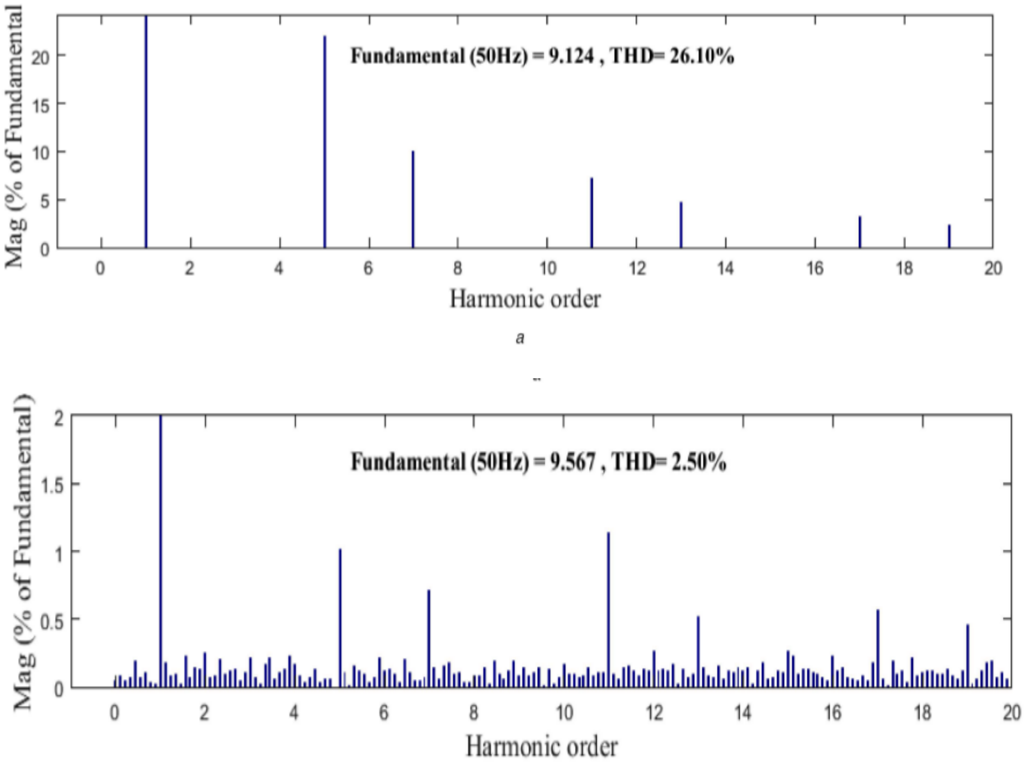


Figure 10: Voltage THD compensation a) Before compensation, (b) After compensation



a

b

Figure 11: Current THD compensation (a) Before compensation, (b) After compensation

Table1: Comparison of harmonic compensation with different controllers

| voltage /Current | PI Controller % | ANN Controller % | Proposed method ANFIS Controller % |
|---|---|---|---|
| Load Voltage | 20.4 | 25.2 | 0.18 |
| Source Current | 8.6 | 8.5 | 2.55 |

Addition to maintain the source current waveform quality. In addition, the load neutral current (In) produced during the unbalanced load need to be cancelled hence a converter neutral current Icn is injected in opposite phase to maintain the source side neutral current almost near to zero. ANFIS controller offers better harmonic compensation in the distribution grid.

## 5.0 Conclusion:

a novel utility of FCI-UPQC as a compensating and an interconnecting device for a three-phase four-wire distribution grid is extensively simulated in MATLAB/SIMULINK. It was observed that the proposed FCI-UPQC efficiently compensates the problem of load current and supply voltage imperfections with quick response and high reliability at the same time. The performance of the UPQC-PV is evaluated under various disturbance conditions and it offers the following advantages:

- To regulate the load voltage against sag/swell and disturbances in the system to protect the nonlinear/ sensitive load.
- To compensate for the reactive and harmonic components of nonlinear load current.

- To compensate voltage interruption and active power transfer to the load and grid in islanding mode to protect sensitive critical load.
- Depending upon the ratings, the combined system can reduce the cost up to one fifth of the separate system. Capacity enhancement has been achieved using multi-level or multi-module and central control mode, however, the flexibility of UPQC to increase its capacity in future and to cope up with the increase load demand in medium voltage distribution system

The proposed system has an enhanced performance under unbalanced, non-linear and sensitive linear load conditions. It is important to note that the proposed system still having the challenge to mitigate source current harmonics during source side disturbances ANFIS controlled FCI-UPQC is another scope for the future work.

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