Improvement of Power Quality Using a Hybrid UPQC with ANFIS Controller

Shaik Roshan[1], Dr. Ashok Kusagur[2]

[1]PG Student, Department of EEE, University of BDT college of Engineering, Davangere -577004, India

[2]HOD & Associate Professor, Department of EEE, University of BDT college of Engineering, Davangere -577004, India

Abstract: ***This paper proposed ANFIS based hybrid UPQC with distributed generator for power quality improvement. This work involves three phase three wire UPQC, there has been significant improvement in the performance of the UPQC under the imbalance source voltage status in this hybrid approach. The UPQC adopted to compensate current and voltage equality problems of sensitive loads and suppressing the load current harmonics under distorted supply conditions. The dc link voltage control is based on the ANFIS controller. The object of this work is to develop the power quality all over and done with a new unified grid-connected inverter-based distributed power system by using ANFIS-UPQC. In this paper ANFIS based UPQC is being used as a Facts controller to mitigate together current & voltage distortions at the consumer end of Distribution system. The concert of ANFIS-UPQC has very precise dynamic response by means of a very simple design of control circuit. This paper shows validation of ANFIS based UPQC and Results are compared with UPQC by means of hysteresis control Band by means of fuzzy logic controller and improvements are observed. The ANFIS-UPQC reduces the harmonics at highly accepted level compared to fuzzy logic Controller based UPQC. The simulation results, carried away by MATLAB/Simulink, shows that ANFIS-UPQC has a less THD and the output voltage/Current profiles are improved compared to fuzzy logic Controller based UPQC.***

Keywords: Power Quality (PQ), UPQC, PI Controller, ANFIS, MATLAB/SIMULINK

1. Introduction

Electricity is the most important part of today's fast growing world, It's always a challenge to distribute the electric power without loss and it is necessary to retain the power quality within the limits. For achieving this, one of the newly developed Facts controllers is UPQC. It's a Facts device that consists of end-to-end connected two 3-ϕ active power filters(APFs) i.e. series and shunt inverters with a common DC-link. The shunt inverter of UPQC acts as a CSI for injecting current from end to end of a transform ring parallel, while the series inverter acts as a VSI for feeding voltage across a transformer in series. PCC can be extremely distorted; also the changes in highly rated load linked to PCC may result into voltage distortions on the PCC has been discussed. Here, using of UPQC at PCC is an effective approach to care for the distribution system from sensitive loads. UPQC is a flexible device that can compensate nearly all power quality issues such as voltage sags/swell, voltage distortions, current distortions etc. The effect of sags can be less destructive than swells. For example, the high voltage during swell condition may cause insulation damage or breakdown in components or equipments. Due to unexpected changes of line current in the source impedance, voltage sag/swells takes place in the distributed system. The main aims to keep the load bus voltage to be sinusoidal and the chief concern is the flow of active & reactive power in this situation. Among latest technical options available to enhance power quality, UPQC has set up more promising for compensate of current/voltage harmonics at the same time. As per literature review, application of UPQC for alleviation of voltage/current harmonics has been presented. It is normally constituted with two VSC connected back to back through a DC link capacitor. The distributed generation is connected in between the dc link of the UPQC. The wind or solar power is connected as DG parallel to DC link. This wind energy DG is suitable for the wind source location however the wind source is not available the solar energy is used as DG. The ANFIS Controller is used in the shunt converter controller of the UPQC in conventional method, the hybrid UPQC consisting of ANFIS in series converter controller. The result obtained from the hybrid approach clearly shown that power quality of the distribution system is increased from that of the conventional method. The simulation of the proposed method has been carried out by MATLAB software. The THD is compared without UPQC,FLC-UPQC&ANFIS-UPQC and also compared from the source side and load side it shown that new scheme has been compensates the disturbances on both side with superior capability.

2. Configuration of hybrid UPQC

The proposed method includes Low Rating Star-based Transformer Based Together with UPQC DG Three phase source Taken from grid. Series converter is Connect line through series reactor similarly the shunt converter is through a shunt reactor. Linked to series and shunt converter Normal DC link and capacitor The DG is connected in the DC link of this UPQC. The series converter control strategy is based on the ANFIS.

The line current *(IL)* to compensate the voltage sags/swell for the series converter as in (1).

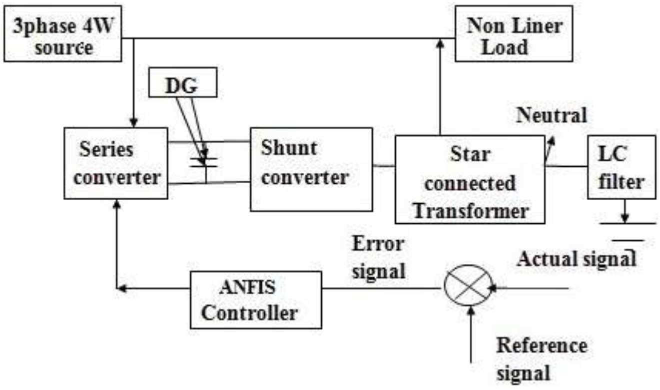

Figure 1: Proposed UPQC model

$$I_L = \frac{2v \sin \delta/2}{x} + \frac{v_c}{x} \quad (1)$$

The power flow in the line is used for the series converter modeling and it is expressed as in (2)

$$P = VI_L \cos(\delta/2) \quad (2)$$

Where

V is the magnitude of voltage is the angular Difference of the line

X is the series reactance of the transmission Line

The power balance equation is used for shunt converter modeling and it is expressed as in (3)

$$V_{dc}I_{dc} = \frac{3}{2}(E_{sR}I_{sR}+E_{sI}I_{sI}) \quad (3)$$

Where

V_{dc} is the voltage value of DC link

I_{dc} is the current Value of DC link

E_{sI} is the power injected in the shunt converter

E_{sR} is the power injected in the shunt reactance

I_{sI} is the magnitude of shunt current

I_{sR} is the magnitude of shunt reactance current

The common DC link modeling is based on the shunt converter DC side circuit as in (4)

$$\frac{dv_{dc}}{d} = \frac{-1}{c_s}\left(I_{dc}+\frac{V_{dc}}{R_p}\right) \quad (4)$$

Where

C_s is the capacitor value of DC link

I_{dc} is the current value of DC link

V_{dc} is the voltage value in the DC link

Rp is the resistance in the circuit

UPQC is associated with a low rating star connected transformer neutral is connected to LC filter with earth. This hybrid approach will reduces phase current harmonics and neutralizes the flow. During peak Load and load is more than the generation from the main source, DG provide the desired power to compensate and Power quality to end users

The result is obtained with and without the UPQC and DG Analyzed with the source side as well as the load side.

3. Adaptive neuro fuzzy inference system controller

ANFIS is one of the recent controllers used for regulate dc-link voltage for UPQC. In this paper ANFIS based UPQC is on produced to regulate dc link voltage. This techniques is used for the compensating current to eliminate the harmonics And it can be generated by the system. The membership function can be optimized by using fuzzy logic implemented network neuron. ANFIS can construct an input/output mapping and set up the data pairs based on both human knowledge (in the form of fuzzy IF- THEN rules) and simulation input output membership function and rules can be created using fuzzy logic. The various researches have been performed in the power quality maintenance. Some of the devices such as dynamic voltage restorer (DVR), uninterruptible power supplies (UPS) and many devices used for maintaining the quality power supply. But, these devices are capable of maintaining the power quality in the distribution network Hence this paper, a new technique an neuro fuzzy based on Takagi Sugeno fuzzy inference system is introduced. The generated fuzzy rules can be trained by using the neural network and we get a desired output of an UPQC FACTS device, designed for both compensate both source side and load side problems. The UPQC combines shunt active filter and series active filter t in a back to back connection, to reduce the power quality problems and power factor correction in a distribution network. Reactive can be performed. Hence this paper proposed Neuro fuzzy technique can be used to regulate DC link voltage of an STATCOM and load waveforms can be maintained as constant. The DC link capacitor voltage maintained as constant

3.1 Working procedure

1) Initialization of the input variables.
2) Fuzzification and defuzzification is done using Fuzzy operators like as AND, OR operators.
3) The membership function can be performed through the learning process.
4) The parameters of an membership function changes through the learning process.
5) Fuzzy rules can be created input and output membership function of the system.
6) After creating fuzzy rules, the results can be defuzzyfied to get an optimal output of an system.
7) Neural network can be trained implemented by means of fuzzy logic.
8) The error is minimized by performing various iterations in the neural network.

4. Control Objectives of UPQC

4.1 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

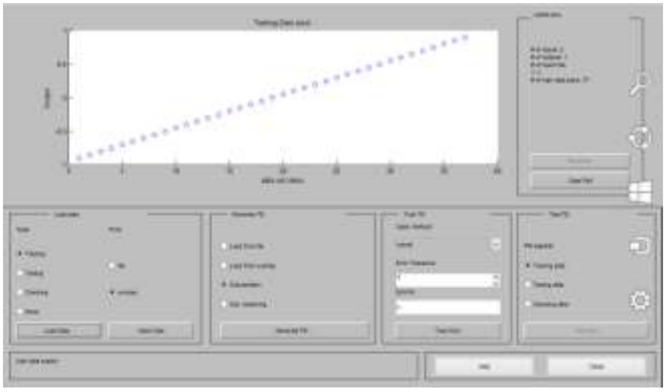

Figure 2: ANFIS data taining

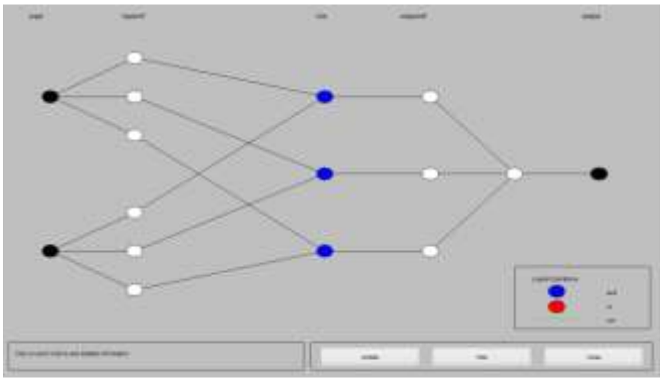

Figure 3: ANFIS model structure

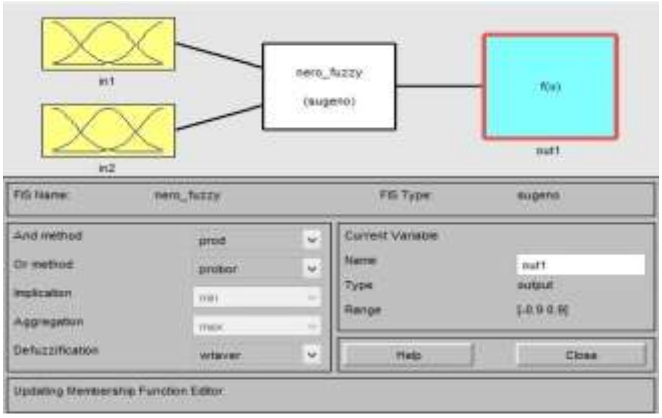

Figure 4: Fuzzy membership function & FIS editor

3) The compensate for the harmonics in the load current by injecting the required harmonic currents
4) To control the power factor by injecting the required reactive current (at fundamental frequency)
5) To regulate the DC bus voltage.

4.2 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

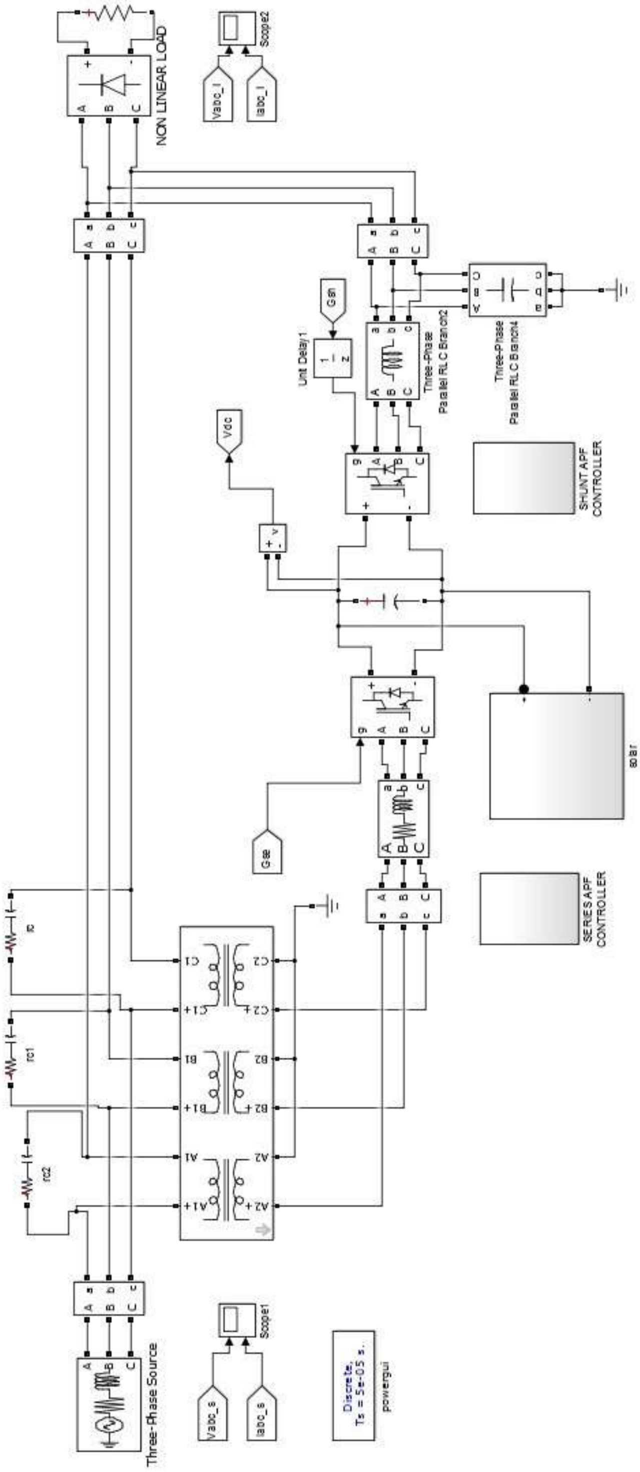

Figure 5: Matlab Simulink Model of the Hybrid UPQC

5. Results and Discussion

The UPQC has simulated using the proposed hybrid UPQC with DG. The source voltage waveform before and after connecting the UPQC are analyzed. It noticed that the source voltage is distorted before connecting the UPQC and it becomes sinusoidal after connecting the UPQC.

The voltage & current waveform on source side without UPQC is shown in Fig 6 and with UPQC is shown in Fig 7&8. It has clearly shown that the voltage sag and swell present in the waveform is compensated after connecting the UPQC. The voltage sags and swell present in the load side are also reduced, due to source side compensation.

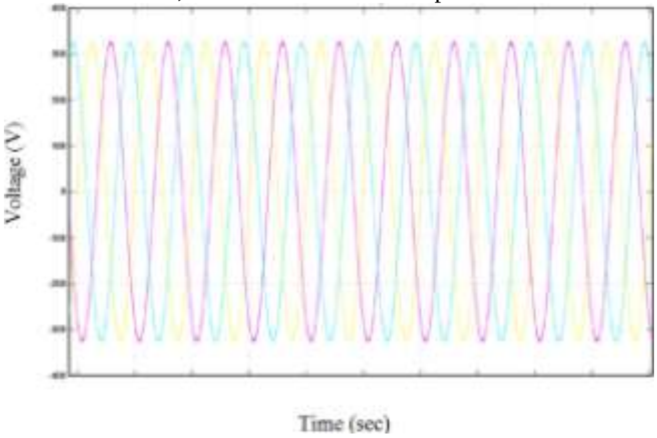

Figure 6: Source Voltage wave form without UPQC

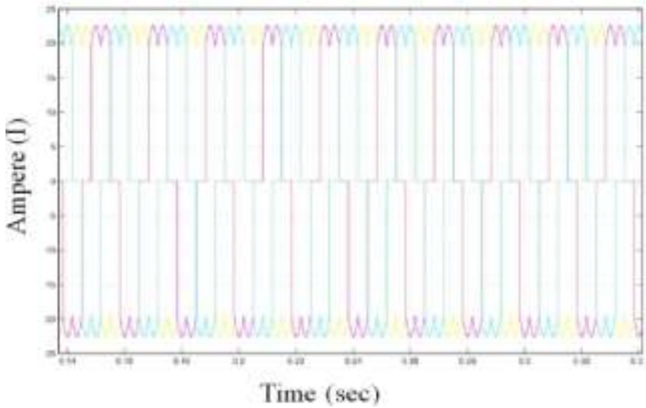

Figure 7: Source & load current wave form without UPQC

The current waveform obtain from the source & load side contains harmonics on before connecting the UPQC as in Fig 7 and after connecting the UPQC as in Fig 9. It shown that high order harmonics present in waveform is reduced after connecting the UPQC.

The harmonic distortion in the system is analyzed in source side as well as the load side. The THD in the load side before connecting the UPQC is 38.39% as in Fig 11 and after connecting the fuzzy UPQC 4.93% is shown in Fig 11. However the THD in the source side before connecting the UPQC is 30.39% as in Fig 8 and after connecting ANFIS UPQC with is 2.42% as in Fig17. It has clearly shown with fuzzy UPQC the THD is 4.89% in load side as in Fig 13.

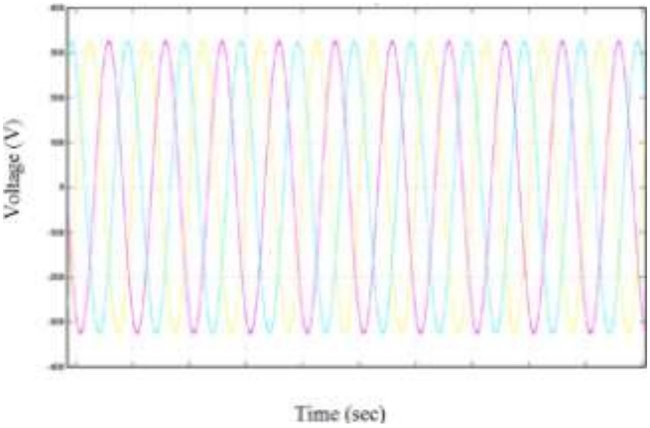

Figure 8: Voltage wave form with ANFIS UPQC

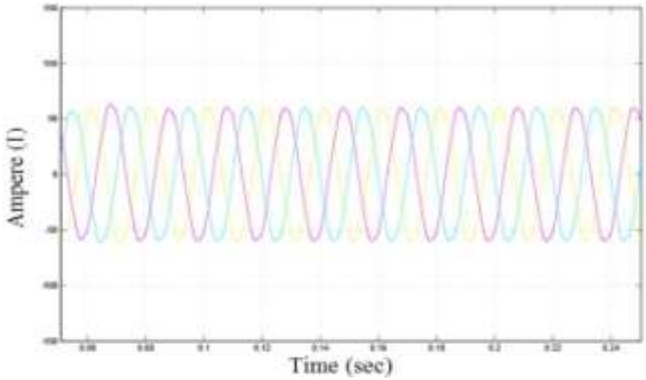

Figure 9: Voltage wave form with ANFIS UPQC

The result obtained from the conventional method in load side before connecting UPQC less improved and after connecting ANFIS UPQC the THD results are more improved.

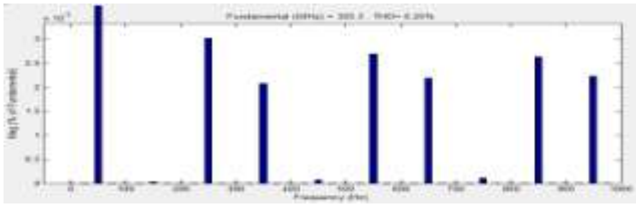

Figure 10: THD without UPQC In load side voltage

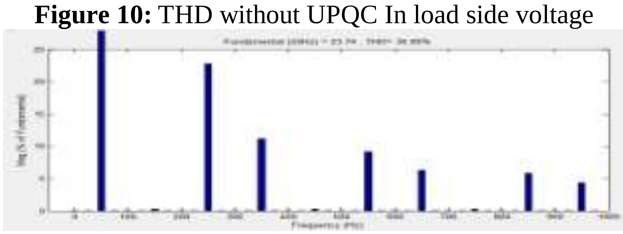

Figure 11: THD without UPQC in load side current

The above fig.10 show THD of load voltage without UPQC in which THD is 0.25 & in fig 11 shows THD of load current without UPQC whose 30.39.

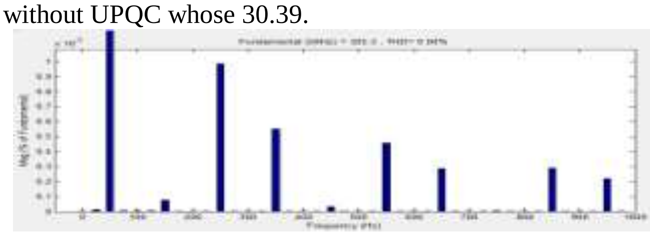

Figure 12: THD with fuzzy UPQC in source side voltage

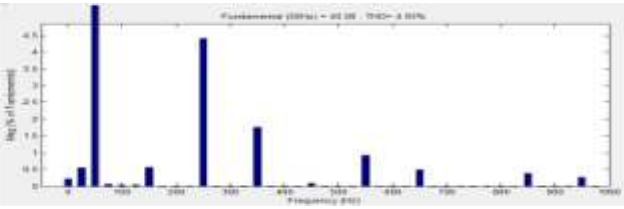

Figure 13: THD with fuzzy UPQC in source side current

The above fig.12 show THD of source voltage with fuzzy UPQC in which THD is 0 & in fig 13 shows THD of source voltage with fuzzy UPQC whose THD is reduced to 4.93.

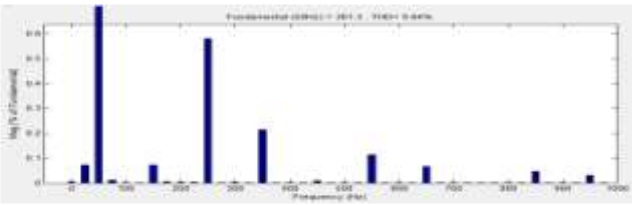

Figure 14: THD with fuzzy UPQC in load side voltage

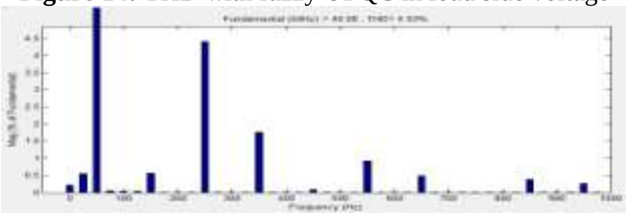

Figure 15: THD with fuzzy UPQC in load side current

The above fig.14 show THD of load voltage with fuzzy UPQC in which THD is 0.64 & in fig 15 shows THD of load current with fuzzy UPQC whose 4.93 which is improved.

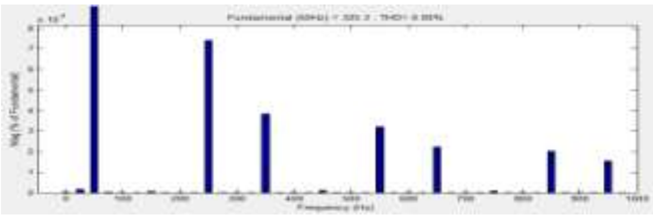

Figure 16: THD with ANFIS UPQC in source side voltage

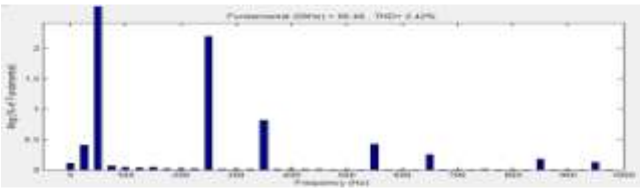

Figure 17: THD with ANFIS UPQC in source side current

The above fig.16 show THD of source voltage with ANFIS UPQC in which THD is 0 & in fig 17 shows THD of source voltage with ANFIS UPQC whose THD is reduced to 2.42.

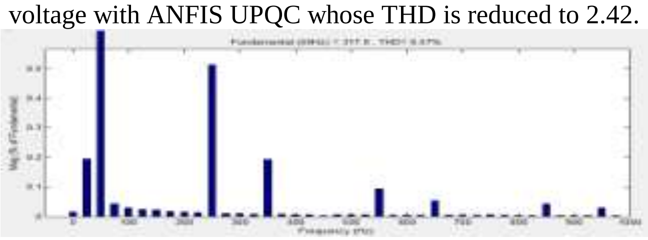

Figure 18: THD with ANFIS UPQC in load side voltage

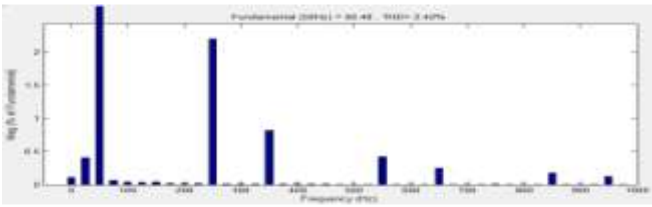

Figure 19: THD with ANFIS UPQC in load side current

The above fig.18 show THD of load voltage with ANFIS UPQC in which THD is 0.64 & in fig 19 shows THD of load current with ANFIS UPQC whose 4.93 which is improved.

Table 1: Result comparison

Location	Without UPQC	With Fuzzy UPQC	With ANFIS UPQC
THD of source side	30.89	4.93	2.42
THD of load side	30.89	4.93	2.42

The above table has shown the results comparison. It clearly noticed that compared to load side the source side THD is low. From the origin place of the harmonics that is in load side the THD content is high. The THD value of the proposed method is low when it is compared with conventional & fuzzy method. The THD value also analyzed with ANFIS method. The better THD is obtained. When comparing to with and without UPQC, with the UPQC better THD value obtained.

6. Conclusion

The Unified power quality conditioner (UPQC) is a device which can be used to solve power quality problems. It takes series and shunt active power filters to compensate both load voltage and load current. In this paper artificial intelligence of adaptive Neuro Fuzzy Inference System (ANFIS) has been used for the control of UPQC DC bus voltage. This paper is based on comparison between a FLC and ANFIS controller to regulate the DC bus voltage. The performance of the system for applications such as voltage sag, harmonics elimination has been successfully examined and analyzed. ANFIS controller presents good results compared with an FLC controller. THD values are minimum for the voltage and the current, which is evident from the results.

System specification

System Input Quantity	3phase Supply voltage Frequency Line Impedance	415V (Ph-Ph) 50 Hz 0.004Ω+ j0.016Ω
LC Filter	Filter inductance(Lf) Filter Capacitor(Cf)	8mH 36 µF
DC link	Capacitor	1100 µF
Non-linear load	Load Impedance	40Ω +j10Ω

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