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IMPLEMENTATION OF SOFT COMPUTING TECHNIQUES ON COMBINED OPERATION OF SOLAR SYSTEM WITH UNIFIED POWER QUALITY CONDITIONER FOR POWER QUALITY IMPROVEMENT

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A B S T R A C T

Harmonic contamination, non-linear loads, voltage sag-swell and other issues can all have an impact on the quality of electricity. The fluctuation of load side voltage has made it extremely difficult to maintain power quality in recent years. The load side voltage variation solved by optimization technique is suitable for attain good result. The work consist of additional solar system provided with Maximum Power Point Tracking controlled by a Particle Swarm Optimization Technique and fuzzy, Artificial Neural Network based Proportional Integral control technique, which is used in the Unified Power Quality Conditioner, in order to balance and increase to maintain the load side power. Total harmonic distortion has decreased from an average of 2.77 percent for voltage to 1.16 percent, and from an average of 4.48 percent to 2.02 percent for current. Results of the simulation run using MATLAB software.

1. INTRODUCTION

The great benefits in preserving the quality of electricity at fluctuating loads or voltage variations, over the last twenty years, Unified Power Quality Conditioners (UPQC) have garnered a lot of attention. By combining end-to-end parallel and series converters on the dc side, the UPQC, a traditional power device, may correct receiving end current and sending end voltage errors. A few of the power quality issues that can be solved using UPQC such as current and voltage harmonics, voltage sags and swells unbalance, voltage flickers, voltage sags, voltage swells etc. One of the best ways to mitigate serious power quality issues is by active power filtering. UPQC has been created employing no series

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injection transformer for medium voltage applications (Ali et al., 2012; Axente et al., 2010). Clearly explained in the UPQC system is the solar energy fed unified power quality conditioner, which can also send active electricity to the grid (Bhavna et al., 2015). Determining the most effective strategy for active power filters to improve power quality. As a result, the potential difference between two points adds by a series active filter needs to match the voltage difference between an ideal load side and supply side. As a result, the series active filter (S_eAF) serves as a source side of controlled voltage. The shunt active filter (S_hAF) eliminates all current-related problems. The series active filter controls any voltage-related issues and voltage imbalances (Shatshat et al., 2004). The dc link voltage is kept to maintain stable level by using S_hAF.The work, they designed control approaches like PI and fuzzy for 3P4W UPQC systems to cope with the most critical power quality issues (Han et al., 2006; Nishant et al., 2016). Harmonic sag-swell, nonlinear load, and other factors can also have an impact on the quality of power. Recent changes in load side voltage make it extremely difficult to maintain power quality (Peng et al., 2015). For monitoring stability of electronic system neural network controller is employed and control algorithm developed (Senthilkumar et al., 2015). Development of soft computing approaches for UPQC system and proposed fuzzy logic based controller for compensation signal to CSI based system (Sergio et al., 2015; Torabian et al., 2015). Power quality improvements such as total harmonic distortion, voltage sag and swell, load side voltage improvement, and real and reactive power improvement using different controllers are explored during the Unified power quality conditioner design and operation (Arulkumar et al., 2017). In this study, Photo Voltaic (PV) solar system added with MPPT method controlled by PSO technique is presented to correct and enhance the load side power in the distribution network. Moreover, modern techniques like PI controllers, FL controllers, and ANN are used to optimize the UPQC's S_hAF and S_eAF. Total Harmonic Distortion (THD) values reduced from average values of 2.77 percent for voltage to 1.04 percent and from average values of 4.48 percent to 1.55 percent for current, respectively.

2. METHODOLOGY OF UPQC SYSTEM AND MODELING

A power electronic device called a UPQC system has the ability to enhance power quality right where it is installed. It adjusts, respectively, load side current value and sending end side voltage value. Series Active Power Filters (S_eAPF) and Shunt Active Power Filters (S_hAPF) that make up the UPQC system are connected by a DC- link capacitor. While the S_eAPF is utilized to regulate the load side voltage and serves as a voltage control source, the S_hAP fuses a sinusoidal approach to manage supply current. The S_hAPF and the S_eAPF are used here to manage the receiving end voltage and supply side current, respectively. In UPQC, mathematical calculation method is used to compute power flow. The symbols Vl, Vs and Vt, respectively, stand for the load side voltage, source side voltage and terminal voltage. Is and Il respectively, stand for the source current and the load current. Current is injected through a S_hAF, while voltage is injected through a S_eAF. Equation (1) then provides the apparent power that is absorbed by the S_eAPF and the S_hAPF (2).

$$S(c) = P(c) + jQ(c) \quad (1)$$

$$S(f) = V(ch)I(f) \quad (2)$$

Where,

$$P(c) = V(c)I(s)\cos\phi(s)$$

$$Q(c) = V(c)I(s)\sin\phi(s)$$

Where, P(c) and Q(c) are the real and the reactive powers that series APF absorbs.

Figure 1 shows the proposed soft computing controller based UPQC connected system. The system consists of S_hAPF, S_eAPF, solar system and non-linear load connected AC source.

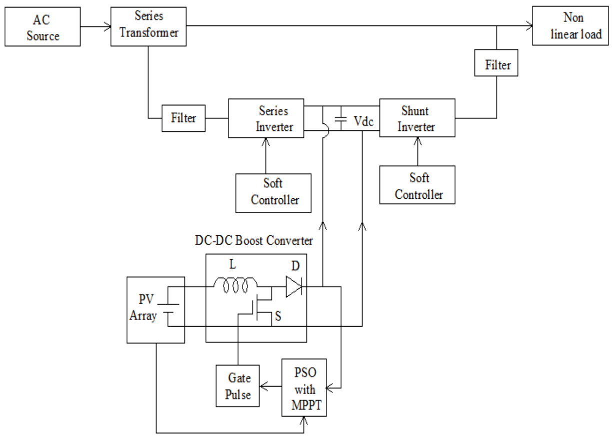

Figure1. Proposed Diagram of Soft Controller based Solar system with UPQC

The DC (Direct Current) link capacitor is combined with the solar system in an effort to raise the level of the power. The series injection transformer served with AC supply source. The filtered output of the transformer is given to the series and shunt inverter. In between these inverters the DC link capacitor is connected. Different controllers are used to control the level of the voltage in this capacitor. Voltage fluctuation may occur due to various types of loads are connected to the system. That fluctuated voltage can maintain with help of DC capacitor link is connected in order to control voltage.

3. PROPORTIONAL INTEGRAL CONTROLLER

Because of its straightforward performance and construction, it is the most popular controller used in industries. Since its introduction, the PI controller has undoubtedly been the best performing industrial controller; it has the most impressive track record in terms of the number of productive industrial applications. It is most frequently employed due to its sturdy construction, simplicity of usage, and successful outcomes for linear systems. PI controllers can be tweaked in a number of ways, such as manually, automatically, using Ziegler-Nichols, analytical approaches, optimization, or pole placement. The Ziegler-Nichols tuning rules are obtained in the following way in this work first set Ti=0 and Td=0. Kp is adjusted from 0 to a critical value Ku at which it exhibits sustained oscillations using simply the proportional control. As a result, the simulation method is used to determine the critical gain Ku and the associated period Pu. The tuning parameters for the PI controller tuning are shown in Figure 2, with the proportional gain being 1.6 and the integral gain being 36. The tuning value is used to determine the best controllable voltage.

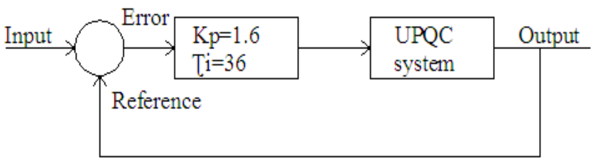

Figure2. PI controller with UPQC system

4. UPQC SYSTEM VOLTAGE CONTROL USING FUZZY LOGIC SYSTEM

The fuzzy control methods used by the UPQC system are shown in Figure 3 and detailed in the section below. Traditional fuzzy controllers never take into account the integral element and always take as two inputs, error difference and error. Integral action is added to the traditional fuzzy control system to get rid of steady state inaccuracy and boost dynamic control results. Advantages of fuzzy control are combined with dependability and ease of usual PI controllers in the fuzzy PI controller (Sayanee et al., 2020). Using the fuzzy logic controller's two inputs, E (Error) and CE (Change in Error), and a single output based on the created rule base, the choice on the execution of action is made. The output is defuzzified when the rules are merged. For this UPQC system, forty nine control rules were created utilizing Error (E) and Changing Error (CE) as input variables., with each variable having 7 membership functions labeled NB (negative big), NM (negative medium), NS (negative small), ZE (zero), PS (positive small), PM (positive medium), and PB (positive big) (Arulkumar & Madhavasarma, 2017). The forty nine sets are finally defuzzified to produce a single value.

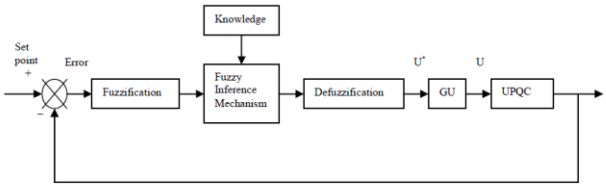

Figure 3. Fuzzy control structures

A program was written in Matlab software with Fuzzy logic toolbox to control the voltage level

The procedures followed are,

1. Sort the data into training data and validation data before storing the measured simulation data for each phase's voltage and current power factor in the workspace.
2. FIS settings Initialized, training data grid partitioning, data matrix generation, and membership function generation for the FIS parameters.
3. Till you reach the target and epoch; perform training using the least squares and gradient descent algorithms.
4. Reduce training in order to maximize the error e (t) difference between the predicted and measured output.
5. Model validation is carried out, and the output response is plotted.

5. UPQC VOLTAGE CONTROL USING NN MODEL

For controlling the UPQC system voltage, a three-layered feed forward neural network trained model utilizing the Levenberg-Marquett (LM) back propagation approach is developed. Figure 4 demonstrates that with this coding, seven neurons were utilized in the input layer and 27 neurons were used hidden layer. The output layer one neuron was employed to maintain a constant level of voltage control for the UPQC system. The method reduces the square sum of the difference between the output value (y_d)and desired output value (t_d) when compared by the net value by adjusting the neural weights and bias values using the gradient descent method.

$$\text{Sum of Square Error} = \frac{1}{2n}\sum(t_d - y_d)^2 \quad (3)$$

The BP algorithm's steps are as follows:

1. Input layer data load training.
2. A comparison of the desired and original outputs.
3. Each neuron does error calculations.
4. The output of every neuron is calculated.
5. Weights are chosen to minimize error.

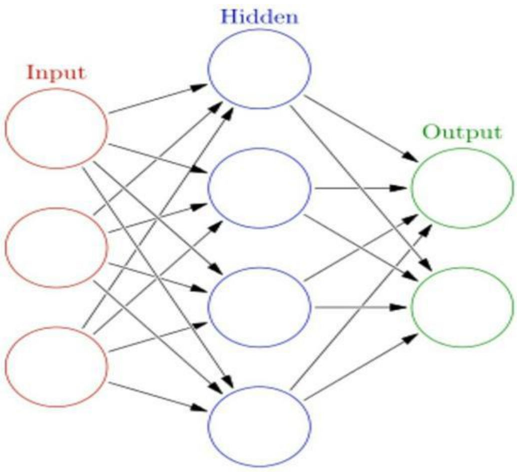

Figure 4. Neural Network layers

The three operational processes in a neural network algorithm are, successively, prediction, correction, and control move determination. The neuron was trained using the UPQC method. Voltage and current are the proposed work's input and output variables, and they were recorded over a range of time periods. For this simulation, a sample period of 10 seconds was used. The 2500 sample is used for validation and training. The neural network model of the non-linear process was created by training the input and output data. The LM back propagation algorithm was utilized for training and validation purposes.

6. SOLAR SYSTEM MAXIMUM POWER POINT TRACKING ALGORITHM BASED ON PSO

Schematic diagram 5 shows the PSO technique is used in the solar system. In this work, PV system generates the output value of voltage Vpv and current Ipv. Similarly converter output values are VL and IL.After comparing the two, an output error signal was generated and provided to the MPPT algorithm utilizing PSO techniques. The proposed algorithm on MPPT is utilized to increase power stability. The MPPT algorithm receives feedback from the output voltage and current. The PSO approach calculates the value and provides it to the switch's pulse generation according to the duty cycle.

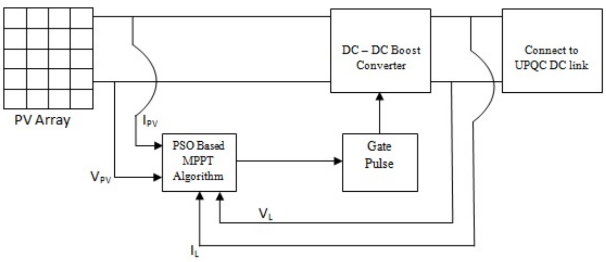

Figure 5. PV connected to UPQC DC link terminals

Particle Swarm Optimization is the best method to optimize the multi variable function. The DC link input terminals are connected to the boost chopper (DC-DC cconverter) output. The optimized method is used to optimize the multi variable function in to single one. In this method variables are randomly assigned and initialized and number of variable are determined the dimension of space.

The PSO Implementation Algorithm:

Step 1: Limit assigned for velocity and position.

Step 2: Set the position and velocity initial values.

Step 3: Find out each particle's fitness value.

Step 4: Identifying of best fitness.

Step 5: Current position of G-best position

Step 6: Continue with Steps 3 and 4 until the ideal answer is found.

Step 7: The optimized best value is provided by G-best at the end of the most recent iteration.

Step 8: The duty-cycle calculation is complete.

7. RESULTS AND DISCUSSION

The proposed work includes a UPQC and solar system model MPPT based PSO with the performance of various controllers used for maintaining power quality on the distribution side.

Switching scheme for the UPQC system's shunt and series inverters, various controllers including PI controller, Fuzzy controller, and Neural Network controller were developed.

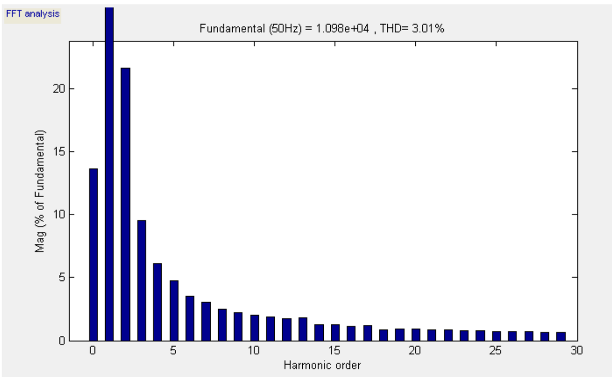

Figure 6. Phase a voltage harmonics (THD %)

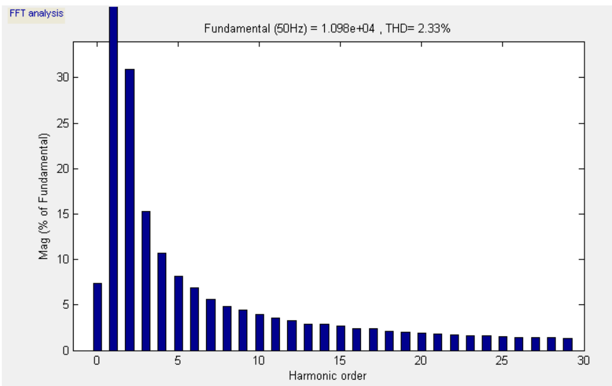

Figure 7. Phase b voltage harmonics (THD %)

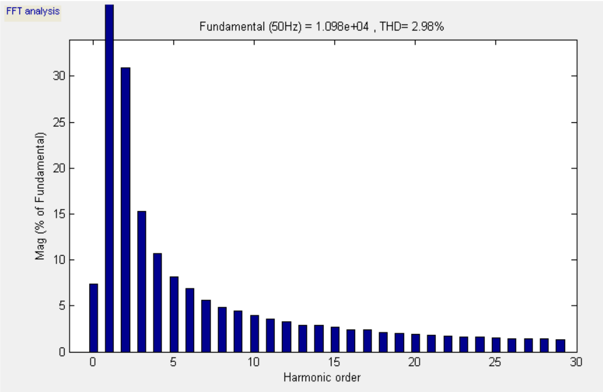

Figure 8. Phase c voltage harmonics (THD %)

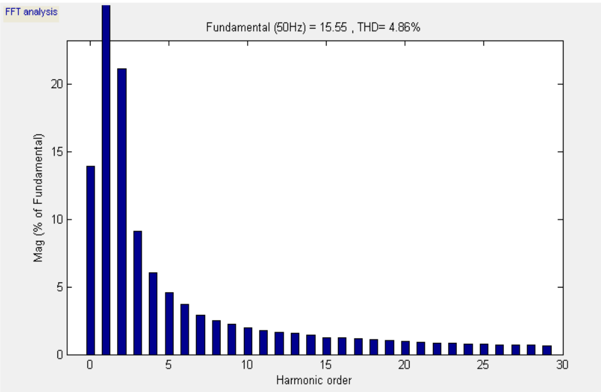

Figure 9. Phase a current harmonics (THD %)

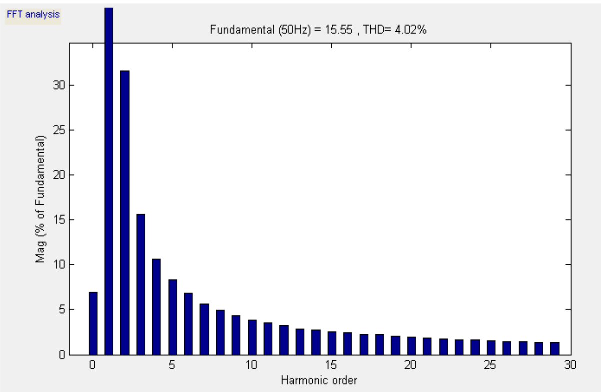

Figure 10. Phase b current harmonics (THD %)

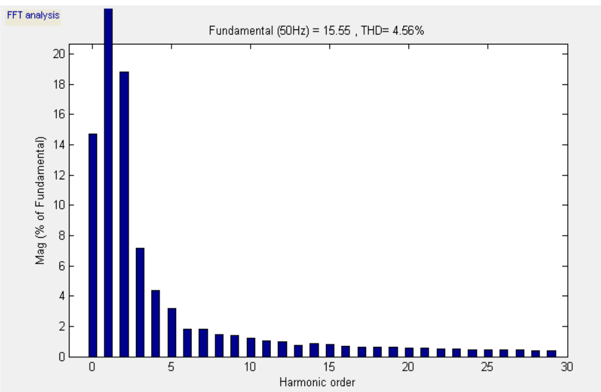

Figure 11. Phase c current harmonics (THD %)

The controller performance were tested with input voltage Vrms11kv, PI controller was able to provide Total Harmonic Distortion (THD) for the various phases of voltage is 3.01%, 2.33% and 2.98% from figure6 to 8 and similarly current is 4.86%, 4.02% and 4.56% from figure9 to 11. From this value, Total Harmonic Distortion (THD) averages 2.77% for voltage and 4.48% for current.

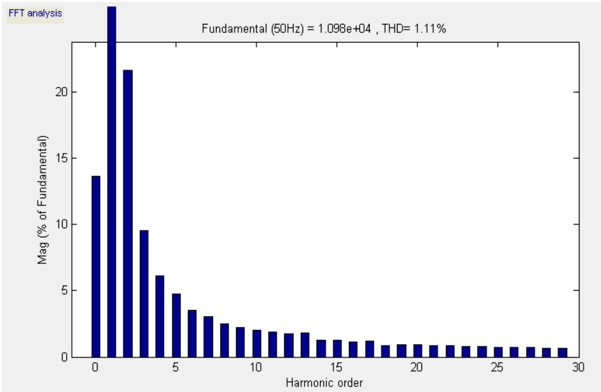

Figure 12. Phase a voltage harmonics (THD %)

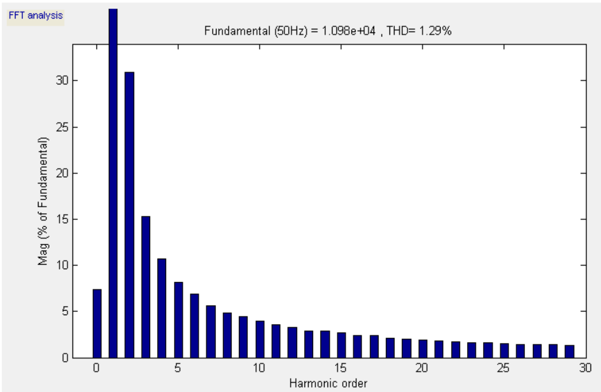

Figure 13. Phase b voltage harmonics (THD %)

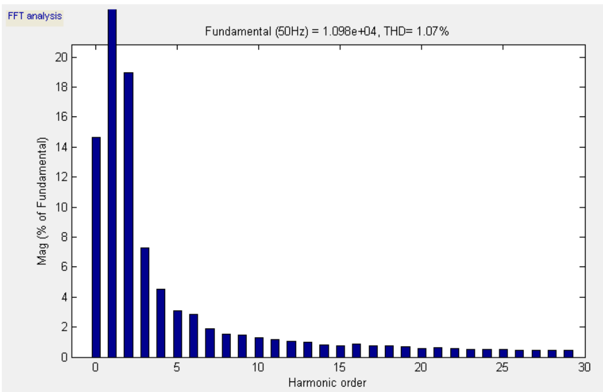

Figure 14. Phase c voltage harmonics (THD %)

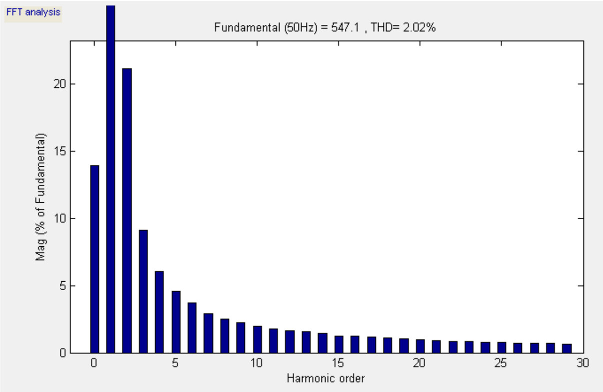

Figure 15. Phase a current harmonics (THD %)

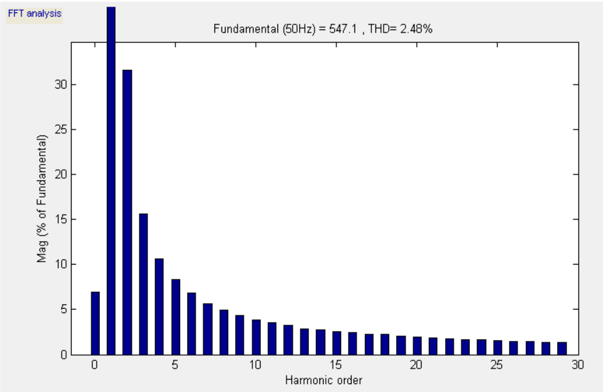

Figure 16. Phase b current harmonics (THD %)

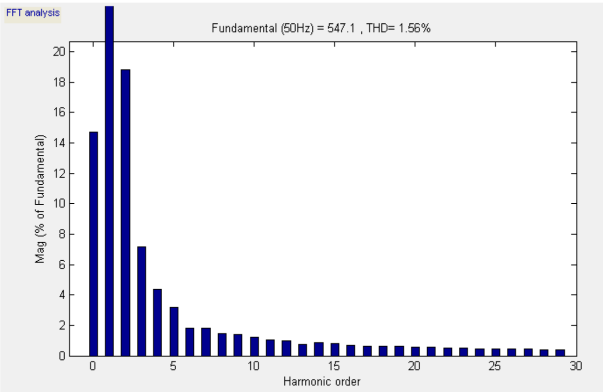

Figure 17. Phase c current harmonics (THD %)

Fuzzy controller was able to provide Total Harmonic Distortion (THD) for the various phases of voltage is 1.11%, 1.29% and 1.07% from figure12 to 14 and similarly current is 2.02%, 2.48% and 1.56% from figure15 to 17. From this value, Total Harmonic Distortion (THD) averages 1.15% for voltage and 2.02% for current.

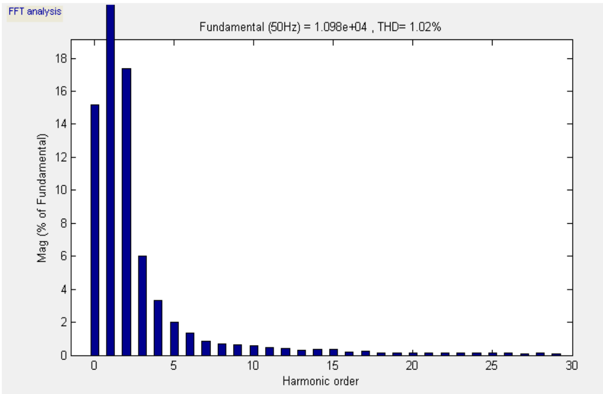

Figure 18. THD % for Phase a voltage

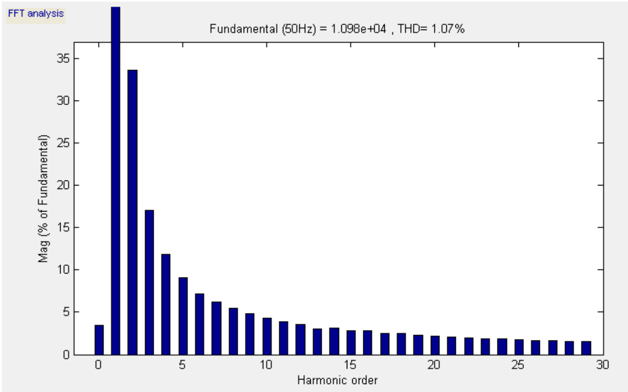

Figure 19. THD % for Phase b voltage

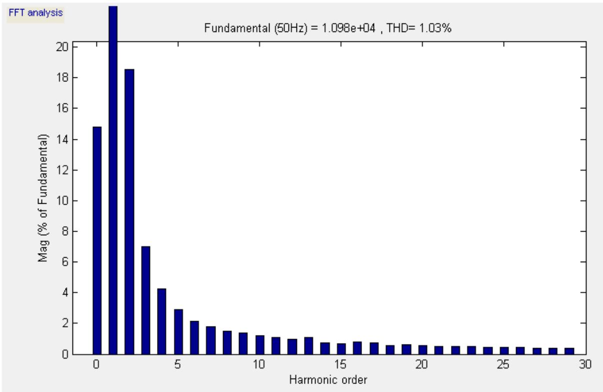

Figure 20. THD % for Phase c voltage

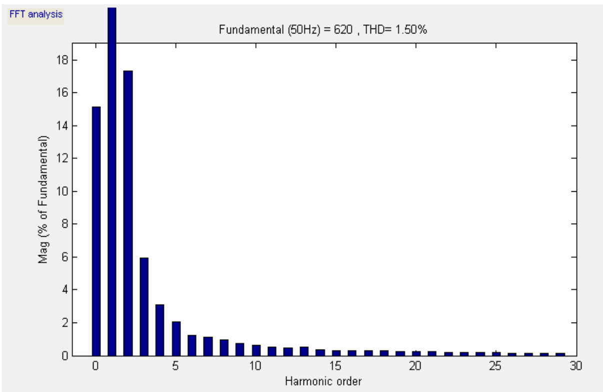

Figure 21. THD % for Phase a current

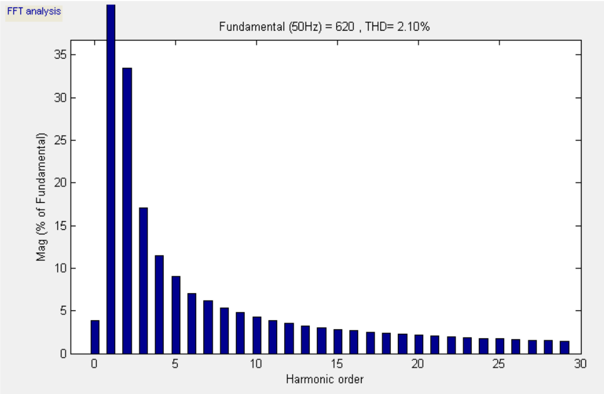

Figure 22. THD % for Phase b current

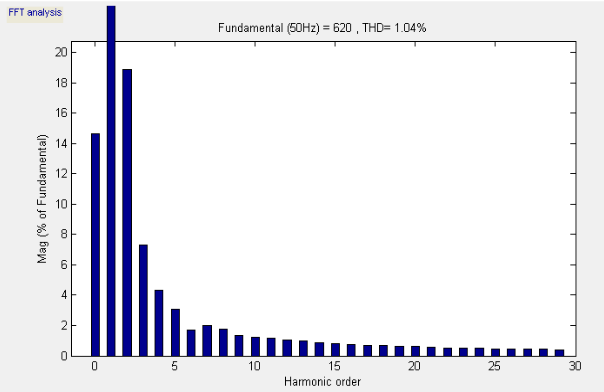

Figure 23. THD % for Phase c current

Neural Network controller was also able to provide Total Harmonic Distortion (THD) for the various phases of voltage is 1.02%, 1.07% and 1.03% from figure18 to 20 and similarly current is 1.50%, 2.10% and 1.04% from figure21 to 23. From this value, Total harmonic distortion (THD) averages 1.04% for voltage and 1.55% for current.

Table 1. Different controller THD Analysis Comparison

S.NO	Controller	THD for Voltage Harmonics (%)			THD for Current Harmonics (%)		
		A	B	C	A	B	C
1	PI Controller	3.01	2.33	2.98	4.86	4.02	4.56
2	Fuzzy Controller	1.11	1.29	1.07	2.02	2.48	1.56
3	Neural Network Controller	1.02	1.07	1.03	1.50	2.10	1.04

The harmonic analysis for several controllers is compared in Table 1. From Table 1, it can be inferred that neural networks are more effective than traditional and fuzzy logic controllers.

8. CONCLUSION

The goal of the neural network-based PI tuned controller is to increase power quality and maintain a constant voltage level in the UPQC system. We can see that from the table.1. The optimal controller for this system is a neural network tuned PI controller. The results show that, in comparison to the traditional controller seen in the table, the suggested system's output voltage and current have relatively low THD. Therefore, the load receives the maximum amount of electricity. For nonlinear systems, the neural controller can offer more skill than the traditional controller.

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