# VARIOUS CONTROL STRATEGIES FOR UPQC ENHANCEMENT TO MITIGATE PQ ISSUES

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## Abstract

The improved UPQC device performance can be enhanced by PQ, voltage swell, with the optimal values for converter of UPQC its presentation can be meaningfully enhanced PQ. In contribution of this paper numerous intelligent projected methods have been implemented to enhance UPQC device PQ problems. The numerous intelligent methods are Artificial Neural Network (ANN) controller, Fuzzy Logic Controller (FLC) controller, Neuro Fuzzy Controller (NFC) and Adaptive Neuro Fuzzy Interference System (ANFIS). In addition numerous optimization control methodologies are used to series active power filters and shunt active power filters. The intelligent control methods will be implemented in the MATLAB/Simulink platform and the efficacy of the proposed technique is investigated via the comparison investigation with the conventional methods. The performance of adaptive ANFIS is used for enlightening the performance of PQ of the UPQC device. Lastly, the projected method of simulation is investigated and to mitigate the voltage sag/ swell in UPQC device than the available approaches.

**Keywords:** Active Filters, *P*ower Quality, THD ( Total Harmonic Distortion ), Voltage sag , Fuzzy control , UPQC, ANFIS.

## I. INTRODUCTION

Many control techniques like as, Particle Swarm Optimization (PSO), Neuro Fuzzy Controller, Ant Colony based Fuzzy Control technique, Genetic Algorithm Neuro Fuzzy Controller (GANFC), Fuzzy Logic Controller (FLC), Discrete Firefly Algorithm, Artificial Neural Network (ANN) etc involved to improve the PQ of the UPQC device [7]. In this paper, the various control algorithms are improved to optimize the PQ of SRM drive and also minimize PQ problems such as voltage sag, voltage swell, etc. Many optimization controllers like as Neuro Fuzzy Controller (NFC) based ANN with FLC and Adaptive Neuro Fuzzy Interference System (ANFIS) based hysteresis controller have been proposed. These proposed controllers optimize the two converters of the UPQC, which set the appropriate two voltage source converters are series APF and shunt APF. Further, the control technique goes a long way in optimizing the PQ problems for the UPQC device. Based on the control techniques, the improving PQ performance of the UPQC drive has been enhanced.

## II. LITERATURE REVIEW

To provides the various research works in UPQC drive model for the optimization of the PQ problems minimization. In literature, there has been lot of research progressed for designing new control strategies for enhancing PQ of the UPQC device. Recounted below are some of the modern works which are out of the ordinary.

From the reviewed research works, it shows that, there are various kinds of control techniques for enhancement PQ in UPQC device. The reviewed techniques are ANN controller, FLC, NFC, GANFC, Ant Colony based Fuzzy Controller, Neuro Fuzzy Controller, ANFIS, etc. All these techniques are model free and capable of working with different kind of dynamic nonlinear systems. So, the reviewed methods disadvantages and scope of developing a simple structure of controller for UPQC device have motivated me to do this research work. The proposed controller for enhancement PQ of the UPQC drive system is given in the following section.

## III. AN OVERVIEW PROBLEM FORMULATED WITH PQ

The modem power distribution framework is turning out to be exceptionally defenseless against the diverse PQ issues [11]. To enhance the nature of force provided to the appropriated framework the power electronic based power molding gadgets can be the viable arrangement. The minimization of PQ problems of the UPQC drives is still an important research topic. In existing literatures, many methodologies such as Fuzzy Logic and Neural Networks, PSO, ANN, Ant Colony based Fuzzy Control technique, Discrete Firefly Algorithm, Genetic Algorithm etc are utilized for decreasing the PQ problems performance of the UPQC device under various load conditions. The sole purpose of these controllers is to minimize PQ problems between set point and actual point of the UPQC system. The system can be responses using NFC and ANFIS.

The UPQC is one of the critical power electronic gadgets utilized for remunerating PQ issues. It is intended to remunerate both source current and load voltage flaws since it is a custom power gadget. All sorts of voltage issues, for example, voltage harmonics, unbalance, interruption, sags and swells, or flickers, for example, harmonics, current unbalance and responsive current, and so on can be remunerated. In the UPQC can be taking place to the PQ troubles, which is the amalgamation of series and shunt APF. The expression APF is an extensively utilized expression in the region of electric power eminence development. APFs have completed it probable to moderate a few of the foremost power eminence troubles successfully [16] [17]. Voltage sag is a lessening in the supply voltage extent took after by voltage recuperation after a brief time frame. Under voltage is brought about by excessive system stacking, loss of era, mistakenly set transformer taps and voltage controller breakdowns.

**Objective and scope**

- ✰ Different types of controllers are utilized to analyze the PQ problems, such as SAF, DVR, SVC, TCSC and so on.
- ✰ With the utilization of UPQC, the optimal control pulses are needed for filters to achieve the accurate results.
- ✰ The ANFIS technique is used for improving the PQ with controlling the source voltage and load current. The controllers are developed for evaluating the performance of minimizing voltage sags and swells.
- ✰ Source voltage during fault, sag amplitude due to fault, load voltage and THD are analyzed.

## IV. DESCRIPTION OF THE RESEARCH WORK

**(i). Modeling of series APF**

The Phase Locked Loop (PLL) is used for reference voltage calculation. Equation (1) shows that the three phase voltage supply has got transformed into the d-q axes. The equation that is stated below describes about the d-q transformation.

$$\begin{bmatrix} V_0 \\ V_d \\ V_q \end{bmatrix} = \frac{2}{3}\begin{bmatrix} 1/2 & 1/2 & 1/2 \\ \sin(\alpha t) & \sin(\alpha t - \frac{2\pi}{3}) & \sin(\alpha t + \frac{2\pi}{3}) \\ \cos(\alpha t) & \cos(\alpha t - \frac{2\pi}{3}) & \cos(\alpha t + \frac{2\pi}{3}) \end{bmatrix}\begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} \quad (1)$$

Where, $V_d$ and $V_q$ are the voltages of the axes $d$ and $q$, respectively, $V_a, V_b$ and $V_c$ are the three phase voltages. The voltage at the $d$ axis is the combination of the direct voltage and the alternating component voltage. The voltage at the $d$ axis can be determined using the low pass filter (LPF), which is stated in equation (2).

$$V_d(DC) = V_d - V_d(AC) \quad (2)$$

Where, $V_d(DC)$ is the DC component voltage and $V_d(AC)$ is the AC component voltage. The reference voltage is calculated using the inverse $d-q$ transformation block, which is expressed as the following equation (3).

$$\begin{bmatrix} V_{Ra} \\ V_{Rb} \\ V_{Rc} \end{bmatrix} = \frac{2}{3}\begin{bmatrix} \sin(\alpha t) & \cos(\alpha t) & 1 \\ \sin(\alpha t - \frac{2\pi}{3}) & \sin(\alpha t + \frac{2\pi}{3}) & 1 \\ \cos(\alpha t - \frac{2\pi}{3}) & \cos(\alpha t + \frac{2\pi}{3}) & 1 \end{bmatrix}\begin{bmatrix} V_d(DC) \\ V_q \\ V_0 \end{bmatrix} \quad (3)$$

Where, $V_{Ra}, V_{Rb}$ and $V_{Rc}$ are the three phase reference voltages. The hysteresis band of the voltage is controlled using the control pulses that are based on the UPQC controller.

**(ii). Modeling of shunt APF**

Here, the instantaneous three phase currents and voltages $a-b-c$ are transformed into $\alpha-\beta$ as described in equation (4) and equation (5).

$$\begin{bmatrix} V_{s0} \\ V_{s\alpha} \\ V_{s\beta} \end{bmatrix} = \sqrt{\frac{2}{3}}\begin{bmatrix} 1/\sqrt{2} & 1/\sqrt{2} & 1/\sqrt{2} \\ 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix}\begin{bmatrix} V_{sa} \\ V_{sb} \\ V_{sc} \end{bmatrix} \quad (4)$$

$$\begin{bmatrix} I_{L0} \\ I_{L\alpha} \\ I_{L\beta} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1/\sqrt{2} & 1/\sqrt{2} & 1/\sqrt{2} \\ 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} I_{La} \\ I_{Lb} \\ I_{Lc} \end{bmatrix} \tag{5}$$

Where, $V_{sa}, V_{sb}$ and $V_{sc}$ are the three phase supply voltage, $V_{s\alpha}$ and $V_{s\beta}$ are the phase neutral voltages, $I_{La}, I_{Lb}$ and $I_{Lc}$ are the three phase load currents and $I_{L\alpha}$ and $I_{L\beta}$ are the phase neutral currents. The instantaneous values of the real as well as the reactive powers at the load side can be computed with the help of the load currents and the phase neutral voltages. The real and reactive power is given in the following equation (6).

$$\begin{bmatrix} p \\ q \end{bmatrix} = \begin{bmatrix} V_{s\alpha} & V_{s\beta} \\ -V_{s\beta} & V_{s\alpha} \end{bmatrix} \begin{bmatrix} I_{L\alpha} \\ I_{L\beta} \end{bmatrix} \tag{6}$$

The reference current can be determined by using the $\alpha - \beta$ reference current, it is described in the following equation (7).

$$\begin{bmatrix} I_{Ra} \\ I_{Rb} \\ I_{Rc} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 \\ -1/2 & \sqrt{3}/2 \\ -1/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} I_{R\alpha} \\ I_{R\beta} \end{bmatrix} \tag{7}$$

$I_{Ra}, I_{Rb}$ and $I_{Rc}$ are the reference three phase shunt active power filters current. The hysteresis band of the voltage is controlled using the control pulses that are based on the UPQC controller. From that comparison analysis, output performance of the proposed ANFIS based UPQC device has been competent over the other methodologies. Now, the determination of generation switching pulses to decide on the optimization with using the proposed controller is given in the following section.

## V. PROPOSED CONTROL TECHNIQUE BASED UPQC

The proposed control techniques are examines to determine the PQ problems of the UPQC device. Also the section describes the optimization of the PQ problems by using the various techniques.

***(a)Neuro-Fuzzy Controller***

NFC is the mixture of Fuzzy Logic Controller and ANN. The optimization of the NFC output using the following equation (8)

$$Z^{NN}{}_{out} = \sum_{i=1}^{n} W_{2i1} Z^{NN}(i) \tag{8}$$

***(b) Adaptive Neuro Fuzzy Interference System***

ANFIS is a structural plan, which joins the well improved expert's knowledge and the learning ability of the neural networks (Gonzalez and Valla, 2015) or one optimized FIS. The performance of ANFIS is tested by giving more number of signals. The proposed controller of the UPQC based on the result and discussions are described in the following section 6.

## VI. RESULTS AND DISCUSSION

Implementation of the proposed methodology is carried out in the MATLAB/Simulink 8.5.0.197613 (R2015a) platform, 4GB RAM and Intel(R) core(TM) i5. In the section, the various controller based NFC and ANFIS is implemented in MATLAB/Simulink platform. Here, the control method is used to PQ problems mitigation of the UPQC. The controllers are control in the control signals, for evaluating the performance of improving PQ of the UPQC. The proposed controller produces the optimal control signals for the UPQC. The PQ problems are evaluated using the proposed method according to their ANFIS with help of the control signals. The different control algorithms like back propagation algorithm based ANN controller, FLC, ANFIS controller. These control methods are performance to compare them and find the best THD value for reduction of PQ problems.

### A. Analysis of Back Propagation Algorithm based on the NFC

The optimization process is carried out by using the Back Propagation Algorithm based on the NFC. The simulated results are shown in below,

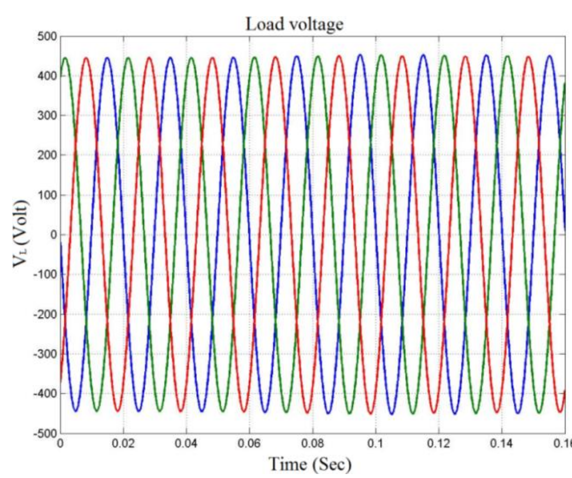


**Figure.1.** nonlinear load voltage with NFC

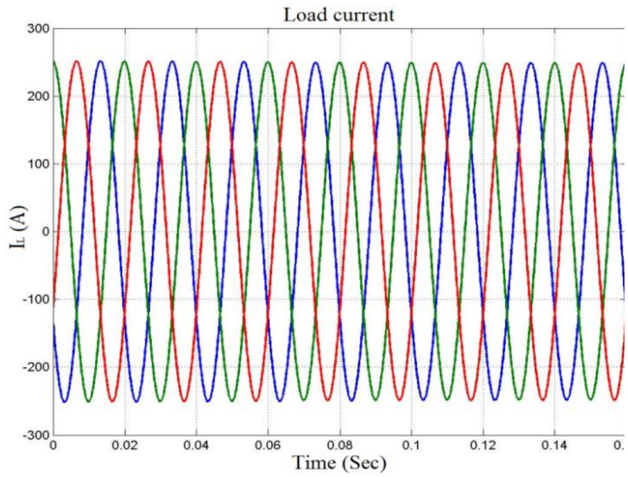


**Figure.2.** nonlinear load current with NFC

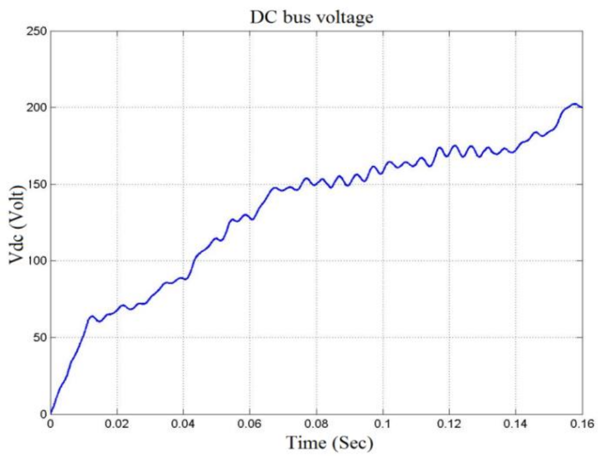


**Figure.3.** DC bus voltage with NFC

In figure 1 illustrates, the performance of the nonlinear voltage with NFC has been analyzed. Here take the voltage as -400 to 400, it's performed the three phase non linear voltage has been evaluated. From the figure 2 and 3 illustrates, the performance of the non linear load current and dc bus voltage with NFC technique. In the figure 3, the rise time at o seconds and settling time 0.16 seconds.

**B. Analysis of Adaptive Neuro Fuzzy Interference system based UPQC**

From the analysis, the adaptive Neuro Fuzzy Interference system is implemented in MATLAB/Simulink platform. Here, the ANFIS is used to achieve the PQ problems detection of the UPQC device. Here, the power quality of the system is analyzed using the proposed control technique. At this point, the proposed technique is really on the basis of UPQC that is supporting the control for producing reference signals of the scheme. With the help of proposed technique, voltage sag issues tend to be revoke out the sag entrance all the way over sensitivity load linked distribution schemes.

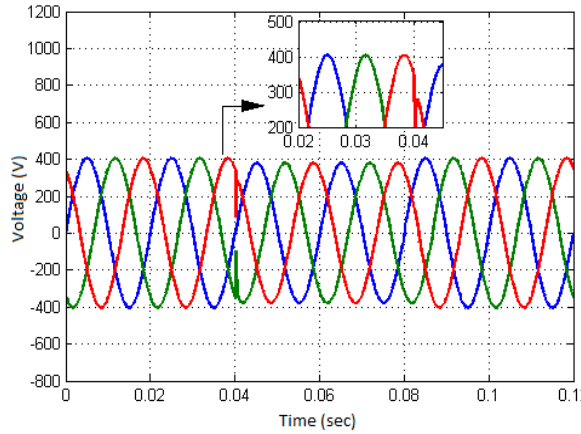


**Figure.4:** Load voltage using proposed technique

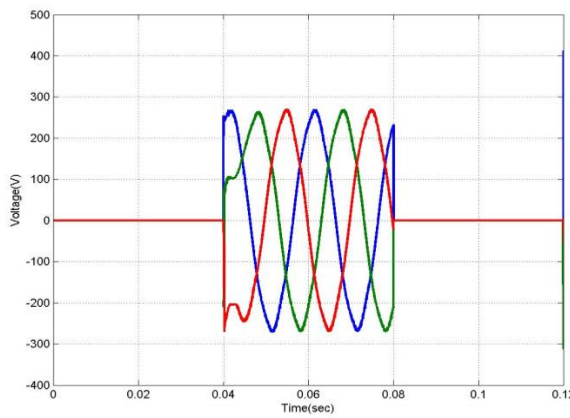


**Figure.5:** UPQC injected voltage using proposed technique

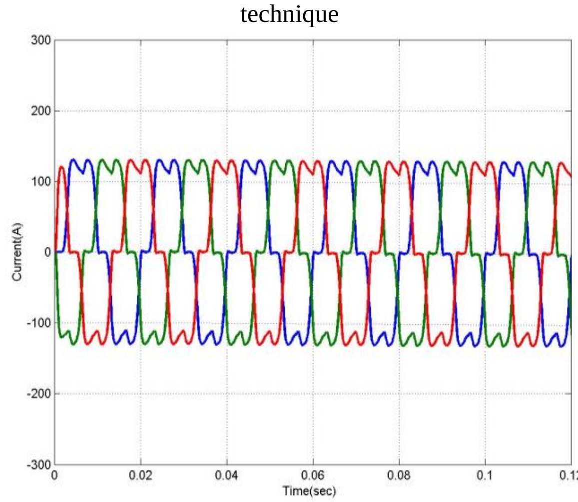


**Figure.6:** Load current using proposed technique

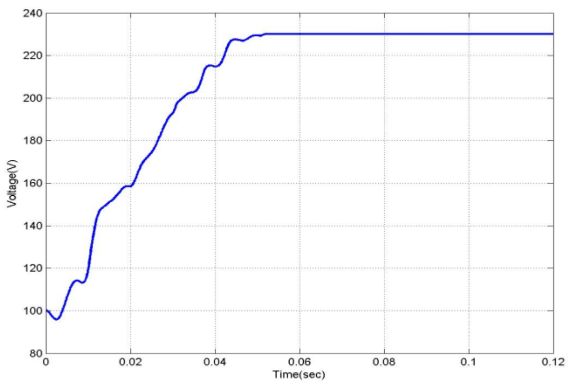


**Figure.7:** DC voltage using proposed technique

The load side voltage that is obtained through the utilization of the ANFIS method is described in figure 4 illustrated. Here, the load side voltage is enhanced from 200V to 390V and the initial peak value has also got reduced effectively. In figure 5 shows that, the performance of the injection of voltage from the UPQC with using ANFIS has been analyzed. During the ANFIS controller effectively handles the UPQC in both the normal as well as the abnormal conditions. The load current that is attained from the proposed method is illustrated in figure 6. It is clearly shown that the ANFIS technique is capable of maintaining the stability in all the operating conditions. The DC voltage of the system that is obtained using the proposed controller is described in figure 7 has been illustrated. Here, the DC voltage waveform illustrates that the voltage value is constantly where as the normal and abnormal conditions has been optimized.

**Table.1: Performance analysis of the different techniques**

| Solution techniques | Fault time (in sec) | Source voltage during fault (in V) | Sag amplitude due to fault (in V) | Load voltage (in V) | THD |
|---|---|---|---|---|---|
| FLC | 0.04-0.08 | 400 | 200 | 360 | 3.5364 |
| NFC | 0.04-0.08 | 400 | 200 | 370 | 2.8239 |
| Proposed | 0.04-0.08 | 400 | 200 | 390 | 2.3519 |

**Table.2: Comparison of %THD of source current with existing and proposed method**

| Source current | Exiting methods | | | | | Proposed method |
|---|---|---|---|---|---|---|
| | SRF [19] | SC | IARCC [19] | FLC | NFC | ANFIS |
| THD % | 5.38 | 3.98 | 3.79 | 3.53 | 2.82 | 2.35 |

The performance of the mentioned controllers in relation to power quality is described in table 1. It shows that the FLC controller achieves a load side voltage THD as 3.5364. On the other hand, the NFC controller has achieved a load side voltage THD of 2.8239. But, the proposed method is found to have the reduced THD than all the controllers and its value is 2.3519. Finalize we can understand that the ANFIS has the ability to maintain the stability in an effective manner, in addition to enhancing the PQ of the UPQC system. The correlation of % THD of the source current with existing and proposed strategy has been enhanced in table 2 separately. The achieved results are depicted in the accompanying.

## VII. CONCLUSIONS

In this paper, proposes a control algorithm for improving the PQ with UPQC device. The optimization based ANFIS controller is efficiently and successfully implemented for solving the PQ problems of the UPQC derive by considering control signals. Here, the minimization of the voltage and currents from the ANFIS controller with UPQC device. The effectiveness of the proposed controller was analyzed, fault time, source voltage during fault, sag amplitude due to fault, load voltage and THD are analyzed.

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