Simulation of UPQC-IG with Adaptive Neuro Fuzzy Controller (ANFIS) for Power Quality Improvement

L. Dinesh[1] S.Harish[2] V. Manoj[3]

Abstract— This paper describes the simulation of a unified power quality conditioner (UPQC) coupled with Induction generator with ANFIS controller witch improving the power quality. Adaptive neuro fuzzy controller (ANFIS) is used to control the active, reactive powers by injecting proper rotor voltage to the Induction generator. The mathematical model of the machine written in an appropriate d-q reference frame. The results are analyzed and presented using matlab/simulink software.

***Keywords*- Power quality, Induction Generator, UPQC, Adaptive neuro fuzzy controller (ANFIS).**

I. INTRODUCTION

Power quality is the set of limits of electrical properties that allows electrical system to function in proper manner without significant loss of performance. Like flexible ac transmission system, the term custom power use for distribution system. Just as facts improve the reliability and quality of power transmission system, the custom power enhances the quality and reliability of power that is delivered to customers. The main causes of a poor power quality are harmonic currents, poor power factor, supply voltage variations, etc.

In recent years the demand for the quality of electric power has been increased rapidly. Power quality problems have received a great attention nowadays because of their impacts on both utilities and customers. Voltage sag, swell, momentary interruption, under voltages, over voltages, noise and harmonics are the most common power quality disturbances. There are many custom power devices. The devices either connected in shunt or in series or a combination of both. The devices include D-STATCOM, DVR and UPQC etc. One of the most common power quality problems today is voltage transients. A voltage transient is a sudden, non power frequency change in the steady state condition of voltage and current.

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Despite a short duration, a small deviation from the nominal voltage can result in serious disturbances. A voltage transient is caused by a fault in the utility system, a fault within the customer's facility or a large increase of the load current, like starting a motor or transformer energizing.

The most popular system is currently the doubly fed induction generator (DFIG), also called the wound rotor induction generator (WRIG). This provides almost all the benefits of full-range variable speed drives, but only a proportion, perhaps one third, of the power passes through the converter. The power converter thus has approximately a third of the size, cost and losses of a conventional variable-speed drive. In this concept, the stator of the electrical machine is connected directly to the network, and the rotor circuit is connected via the power converter. This is a modern version of the classical Kramer or Scherbius system. The DFIG has a more limited speed range than the conventional variable-speed drive (approximately 1.5-2:1, compared to 2.5:1 or more).

This speed range, however, is sufficient to provide the benefits listed above. The conventional option of a power converter, with the same rating as the generator, is unlikely to compete with the DFIG until the cost of power electronic converters falls substantially and the efficiency improves. There is evidence that this point may have been reached, with some manufacturers moving over to fully rated converters[7]. In this respect, the potential for improved efficiency in avoiding the DFIG route may come to outweigh cost differentials. Also, some of the benefit of a DFIG system has been eroded by more stringent network requirements impacting on DFIG system cost.

Unified power quality conditioner (UPQC) is one of the best custom power device used to compensate both source and load side problems [1]. It consists of shunt and series converters connected back to back to a common dc link. It can perform the functions of both DSTATCOM and DVR. In this paper a Adaptive neuro fuzzy controller is used to compensate voltage transients.

Adaptive neuro fuzzy based controllers develop a control signal from the neural network which yields on the firing of the rule base, which is written on the previous experiences & these rules are fired which is random in nature. As a result of which, the outcome of the controller is also random & optimal results may not be obtained[5].

II. UPQC SYSTEM WITH CONTROL METHODS

UPQC mainly includes three parts: the series active power filters, shunt active power filters and energy storage capacitors.

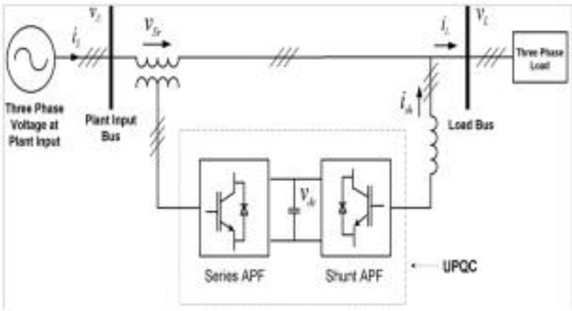

Figure 1. Topology of upqc

The series and shunt active power filter couples together through the DC-link energy storage capacitors. Series APF connected to the grid and load by coupling transformer is mainly used to adjust the load voltage amplitude and compensate the power supply voltage sag in the controlled voltage source mode. Shunt active filter connected to the load is used to compensate load currents.

III.POWER SYSTEM WITH UPQC-IG

Wind turbines use a Unified Power Quality conditioner- induction generator (UPQC-IG) consisting of a wound rotor induction generator and an AC/DC/AC IGBT-based PWM converter. The stator winding is connected directly to the 50 Hz grid while the rotor is fed at variable frequency through the AC/DC/AC converter(UPQC). The UPQC-IG technology allows extracting maximum energy from the wind for low wind speeds by optimizing the turbine speed, while minimizing mechanical stresses on the turbine during gusts of wind. The optimum turbine speed producing maximum mechanical energy for a given wind speed is proportional to the wind speed. Another advantage of the UPQC-IG technology is the ability for power electronic converters to generate or absorb reactive power, thus eliminating the need for installing capacitor banks as in the case of squirrel-cage induction generator.

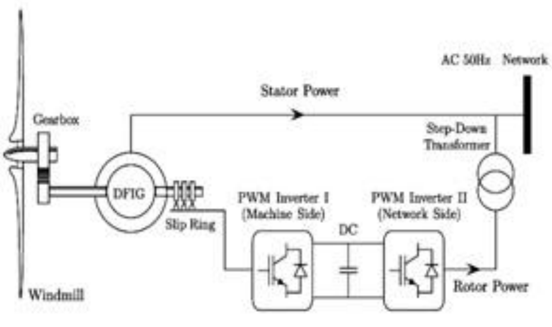

Figure 2 Topology of UPQC-IG

IV. MATHEMATICAL REPRESENTATION OF UPQC-IG

Before going to analyze any motor or generator it is very much important to obtain the machine in terms of its equivalent equations. Traditional per phase equivalent circuit has been widely used in steady state analysis and design of induction motor, but it is not appreciated to predict the dynamic performance of the motor[2]. The dynamics consider the instantaneous effects of varying voltage or currents, stator frequency, and torque disturbance. The dynamic model of the induction motor is derived by using a two phase motor in direct and quadrature axes. This approach is desirable because of the conceptual simplicity obtained with two sets of windings, one on the stator and the other on the rotor. The equivalence between the three phase and two phase machine models is derived from simple observation, and this approach is suitable for extending it to model an n-phase machine by means of two phase machine.

The required transformation in voltages, currents, or flux linkages is derived in a generalized way. The reference frames are chosen to be arbitrary and particular cases, such as stationary, rotor and synchronous reference frames are simple instances of the general case. Although it is somewhat simple, the problem of time-varying parameters still remains. R.H. Park, in the 1920s, proposed a new theory of electric machine analysis to solve this problem. He formulated a change of variables, which, in effect, replaced the variables (voltages, currents and flux linkages) associated with the stator windings of a synchronous machine with variables associated with fictitious windings rotating with the rotor at synchronous speed. Essentially, he transformed or referred, the stator variables to a synchronously rotating reference frame fixed in the rotor. With such a transformation (called Park's transformation), he showed that all the time-varying inductances that occur due to an electric circuit in relative motion and electric circuits with varying magnetic reluctances can be eliminated[8].

Let's define the flux linkage variables as follows:

$$F_{qs} = \omega_b \psi_{qs} \quad \text{--- (1.1)}$$

$$F_{qr} = \omega_b \psi_{qr} \quad \text{--- (1.2)}$$

$$F_{ds} = \omega_b \psi_{ds} \quad \text{--- (1.3)}$$

$$F_{dr} = \omega_b \psi_{dr} \quad \text{--- (1.4)}$$

Where ω_b = base frequency of the machine.

$$v_{qs} = R_s i_{qs} + \frac{1}{\omega_b}\frac{dF_{qs}}{dt} + \frac{\omega_e}{\omega_b} F_{ds} \quad \text{--- (1.5)}$$

$$v_{ds} = R_s i_{ds} + \frac{1}{\omega_b}\frac{dF_{ds}}{dt} - \frac{\omega_e}{\omega_b}F_{qs} \quad \text{--- (1.6)}$$

Electromagnetic torque is the cross product of 2 space vectors such as ψs*is, where as in the complex notation it will appear as Im(ψs is) or in terms of the d-q components as (ψqs ids- ψds iqs).

Te= (3/2) (p/2) (ψs*is)

Te= (3/2) (p/2)M (ψs.is) …. (1.7)

Where M is matrix of order 2*2 whose value is M=[0 -1; 1 0].

Te=(3/2)(p/2)(ψqs.ids-ψdsiqs) … (1.8)

Ψqs, ψds are replaced in terms of Fqs, Fds the electromagnetic torque is modified as

Te= (3/2) (p/2)(1/ωb)(Fqs ids-Fds iqs) …(1.9)

This describes the complete model in state space form where Fqs, Fds, Fqr, Fdr are the state variables.

The matrix M is nothing but equivalent to a unit vector or space rotator which is rotated at an angle 90^0 actually the matrix M is as follows.

$$M=\begin{bmatrix} \cos\theta e & -\sin\theta e \\ \sin\theta e & \cos\theta e \end{bmatrix} \quad \text{…. (1.10)}$$

V. ADAPTIVE NEURO FUZZY INFERENCE SCHEME

ANFIS controller, which becomes an integrated method of approach for the control purposes & yields excellent results, which is the highlight of this paper[1]. In the designed ANFIS scheme, neural network techniques are used to select a proper rule base, which is achieved using the back propagation algorithm. This integrated approach improves the system performance, cost-effectiveness, efficiency, dynamism, reliability of the designed controller.

ANFIS controller is used to reduce the power error to zero. The output of this regulator is the reference rotor current Iqr_ref that must be injected in the rotor by converter Crotor[4]. This is the current component that produces the electromagnetic torque Tem. The actual Iqr component is compared to Iqr_ref and the error is reduced to zero by a controller.

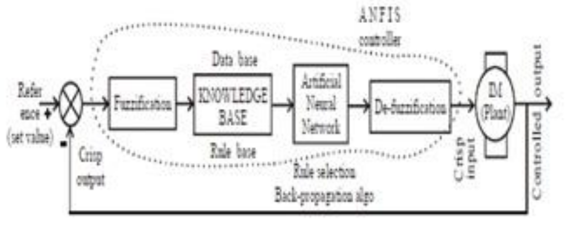

Figure 3. Block diagram of the ANFIS control scheme for the speed control of the IM

VI. SIMULINK IMPLEMENTATION OF UPQC-IG

To verify the operating performance of the proposed UPQC-IG, a Induction generator, fuzzy logic controller and converters are designed and simulated using MATLAB software.

The induction machine is modeled in vectorized form in the synchronous frame associated with the stator voltage space vector. The d-q components of the injected rotor voltage Vr, at slip frequency ω_r are derived from fuzzy controllers. V_{rd} is the output of the cascade arrangement of speed and Ps controllers. V_{rq} is derived from a Qs controller. The mechanical system is modeled as two inertias coupled by means of flexible shaft. The whole system is described by parameters expressed in p.u. The machine representations are based on the motor convention. Consequently in the generator mode of operation, such quantities as Ps, Qs, Tw, Te are negative (with ω_m>0) while Pr is positive for sub-synchronous operation and negative for super-synchronous mode of operation.

The inputs are ω_k (Speed of reference frame in p.u), ω_m (Generated speed), Vs (Stator dq voltage), Vr (Controlled rotor dq voltage). It is modeled in flux linkages. The outputs are Te (electromagnetic torque), is (Stator dq current), ir (Rotor dq current).

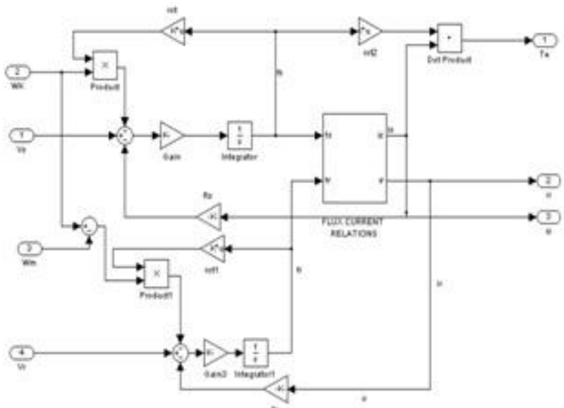

Figure 4. Dynamic Model of Induction Machine in Arbitrary Reference Frame

This block is used for transforming synchronously rotating quantities into stationary quantities by taking dq quantities and phase angle as inputs and giving stationary quantities.

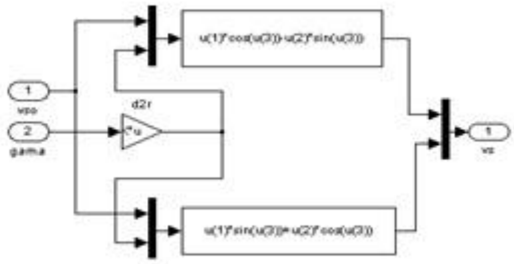

Figure 5. dq-ab Conversion

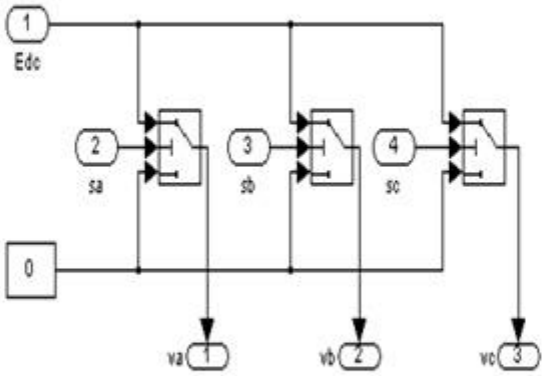

Figure 6. Simulink Diagram for Rotor Side Converter

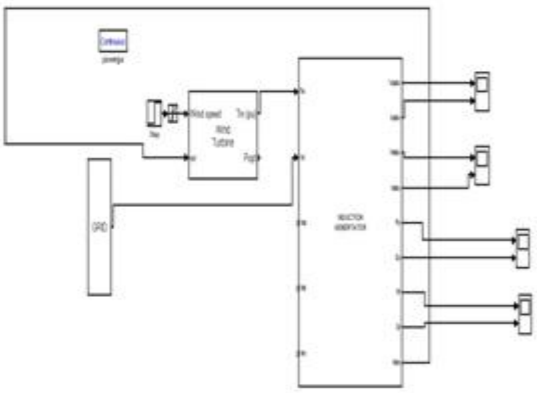

Figure 7. simulation diagram for induction machine connected to grid

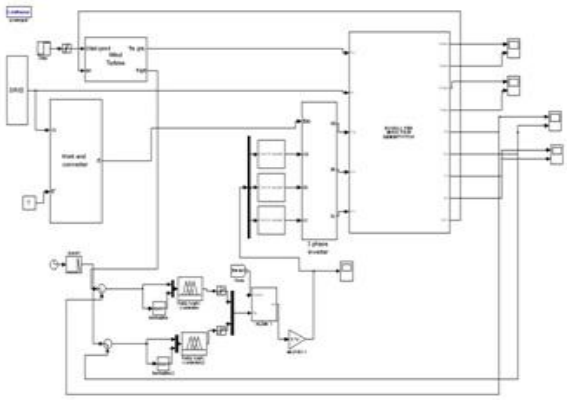

Figure 8. Simulation diagram for UPQC-IG with ANFIS controller

In this we edit the rules, ranges of each membership functions for inputs and outputs.

Figure 9. Membership figures for input.

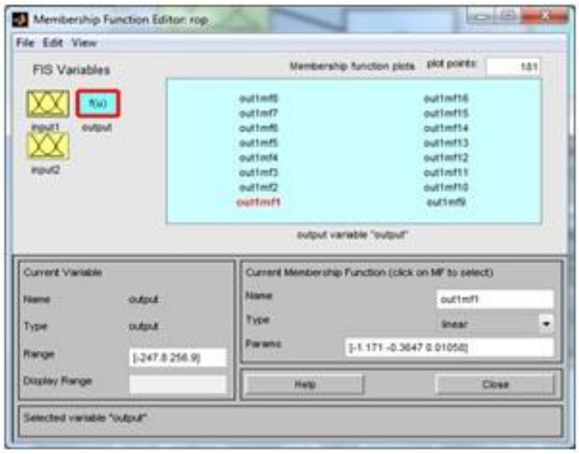

Figure 10. Membership figures for output

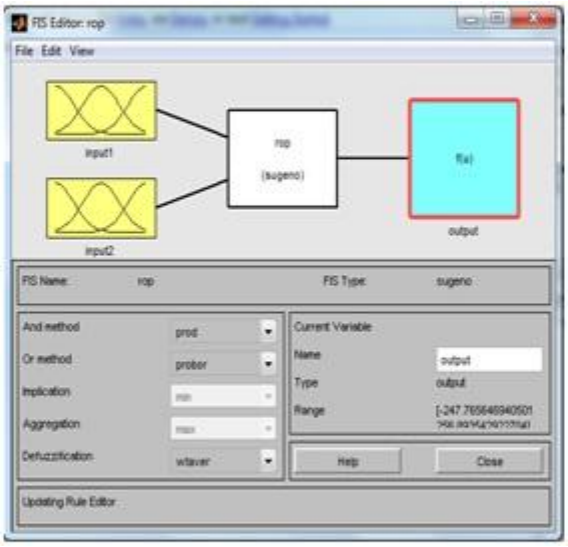

Figure 11.Fuzzy interface system

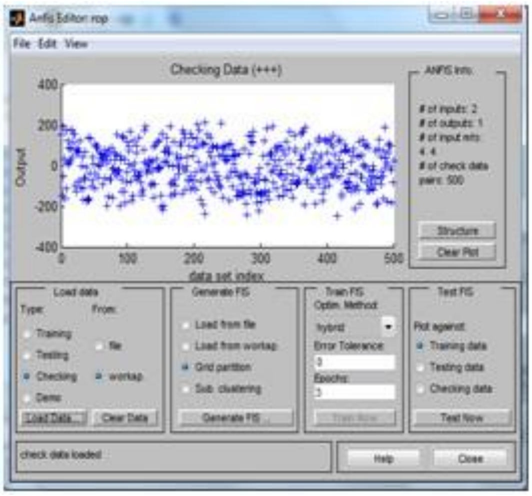

Figure 12. ANFIS Checking data

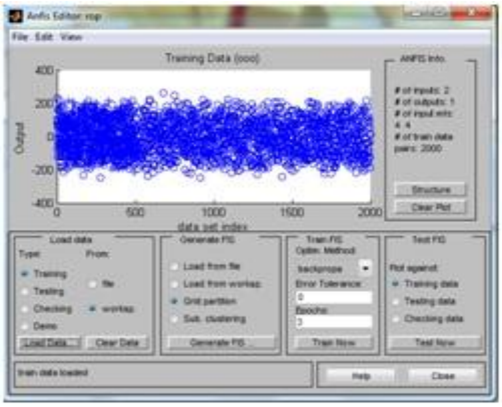

Figure 13. ANFIS training data

VII. RESULTS

The performances of UPQC-IG during steady state operating condition and during occurrence of unbalanced faults are discussed in this section.

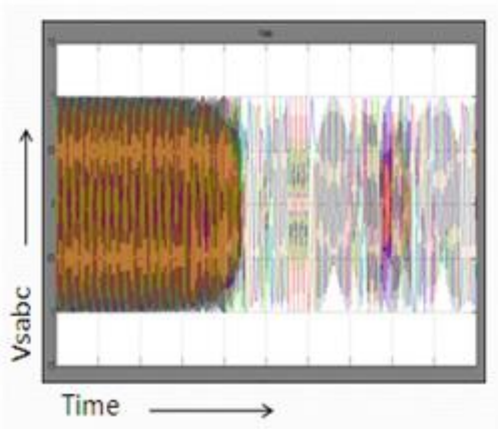

Figure 14. Rotor voltage when induction machine connected to grid

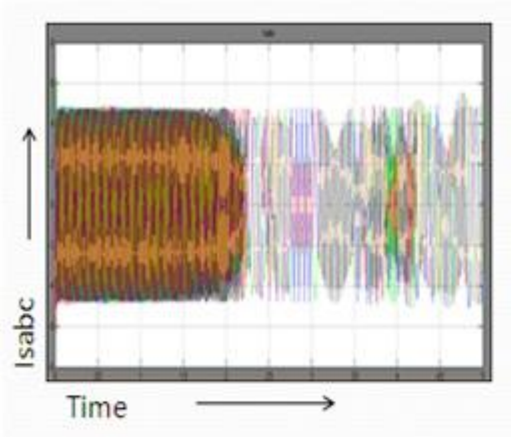

Figure 15. Rotor current when induction machine connected to grid

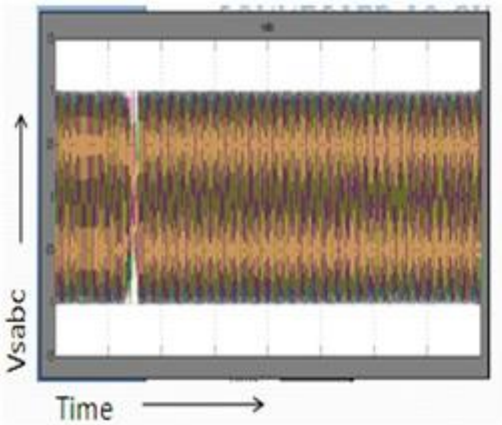

Figure 16. Rotor voltage when UPQC-IG connected to grid (PI Controller)

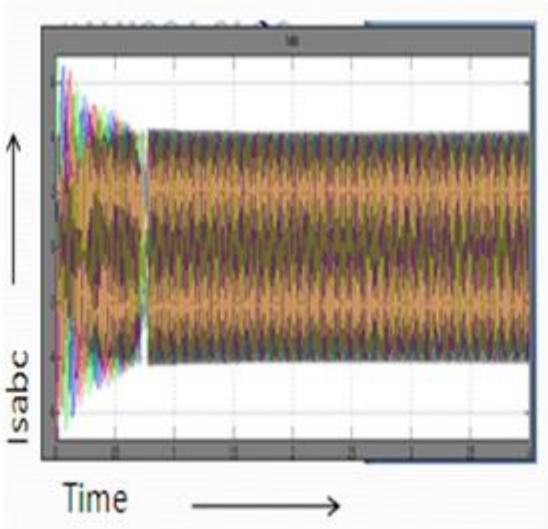

Figure 17. Rotor current when UPQC-IG connected to grid (PI Controller)

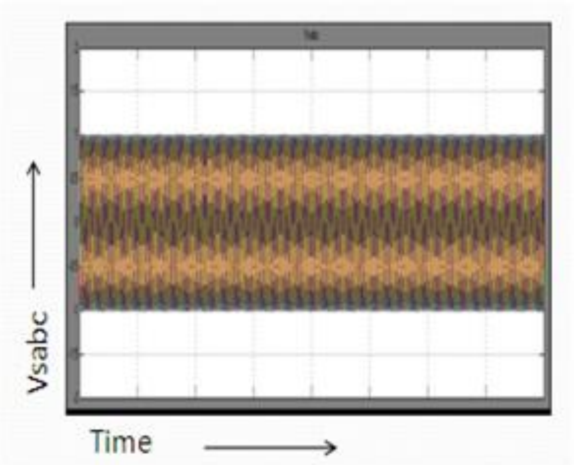

Figure 18. Rotor voltage when UPQC-IG connected to grid (ANFIS Controller)

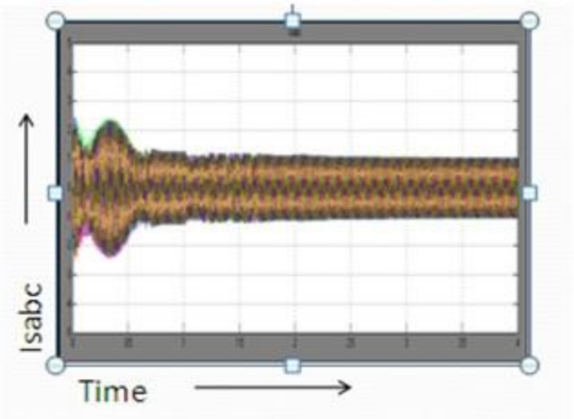

Figure 19. Rotor current when UPQC-IG connected to grid (ANFIS Controller)

VII. CONCLUSION

This paper is mainly devoted to the study of Power Quality problems and its compensation with Unified power quality conditioner (UPQC). Results obtained from this study provide useful information regarding the behavior of different controllers used for power quality improvement connected to grid. The controllers mainly used for power quality improvement are PI and Adaptive neuro fuzzy controller (ANFIS). The simulation results show that the UPQC with PI Controller Compensates **85%** of voltage transients during fault condition. While UPQC with Adaptive neuro fuzzy controller (ANFIS) Compensates **98%** of voltage transients. Hence as compared to the response obtained with PI Controller, Adaptive neuro fuzzy controller (ANFIS) based controller have great advantage of flexibility.

VIII. REFERENCES

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BIBILOGRAPHY

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