Unified Power Quality Conditioner For Power Quality Improvement Using Ultra-Capacitor Energy Storage

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Abstract—This paper describes the simulation of a unified power quality conditioner(UPQC) coupled with ultra-capacitor energy storage (UCES) for improving the power quality of power systems.A fuzzy logic controller with reference signal generation method is designed for UPQC and compared its performance with artificial neural network based controller. This is used to compensate current and voltage quality problems of sensitive loads. The results are analyzed and presented using matlab/simulink software.

Keywords- ultra-capacitor energy storage (UCES), UPQC, Voltage sag, Fuzzy logic controller, neural networks.

1. 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 dips. A voltage dip is a short time event during which a reduction in R.M.S voltage magnitude occurs. Despite a short duration, a small deviation from the nominal voltage can result in serious disturbances. A voltage dip 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.

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 fuzzy logic controller is used to compensate voltage sag and it is compared with neural network based controller.

The addition of energy storage through an appropriate interface to the power custom device leads to a more flexible integrated controller. The ability of the UPQC-ESS to supply effectively active power allows expanding its compensating actions. Various types of advanced energy storage technologies can be incorporated into the dc bus of the UPQC, namely superconducting magnetic energy storage (SMES), ultra-capacitor energy storage (aka super-capacitor energy storage - UCES/SCES respectively) and flywheel energy storage (FES), among others. However, ultra-capacitors (UC) have distinct potential advantages for energy storage which make them almost unbeatable in many applications.

II. UPQC SYSTEM WITH CONTROL METHODS

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

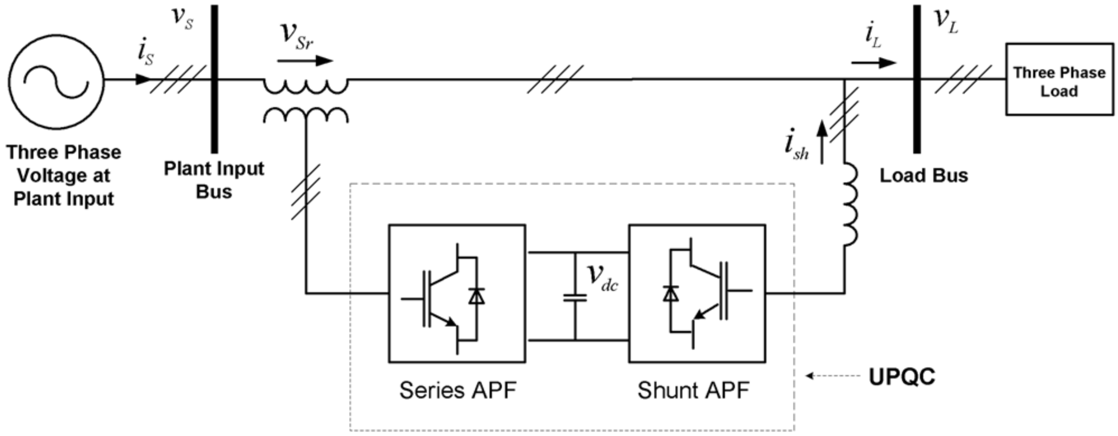


Figure 1. Topology of upqc

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. FUZZY LOGIC CONTROLLERS

The logic of a approximate reasoning continues to grow in importance, as it provides an in expensive solution for controlling know complex systems [2]. Fuzzy logic controllers are already used in appliances washing machine, refrigerator, vaccum cleaner etc. Computer subsystems (disk drive controller, power management) consumer electronics (video, camera, battery charger) C.D.Player etc. and so on In last decade, fuzzy controllers have convert adequate attention in motion control systems [5],[6],[7].The implication was introduced for the evaluation of individual rules.

Methods:
a) MAMDANI
b) SUGENO

IV. ARTIFICIAL NEURAL NETWORKS

Artificial Neural Networks are relatively electronic models based on the neural structure of the brain. The brain basically learns from experiences [3]. It is natural proof that are beyond the scope of current computers are indeed solvable by small energy efficient packages. This brain modeling also promises a less technical way to develop machine solutions. The ANN is made up of interconnecting artificial neurons. It is essentially a cluster of suitably interconnected nonlinear elements of very simple form that possess the ability to learn.

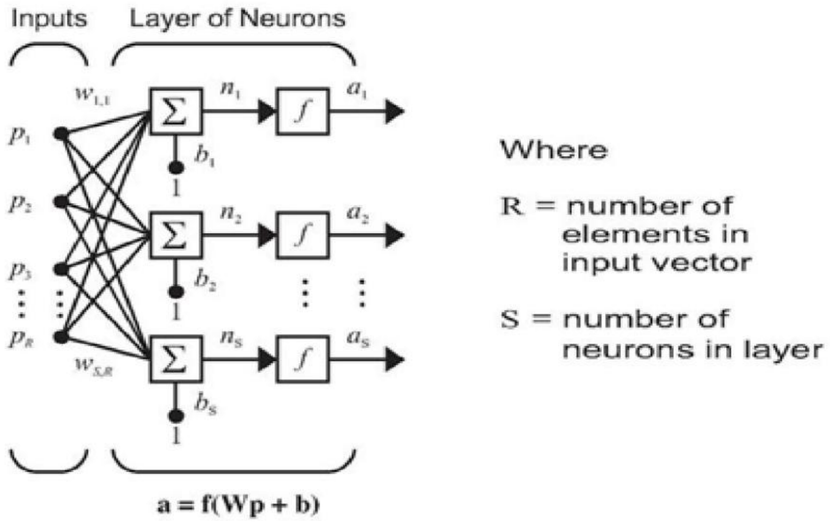


Figure 2. Single layer feed forward network

A one-layer network with *R* input elements and *S* neurons follow. In this network, each element of the input vector p is connected to each neuron input through the weight matrix W. The *i*th neuron has a summer that gathers its weighted inputs and bias to form its own scalar output *n*(*i*). The various *n*(*i*) taken together form an *S*-element net input vector n.

Once a network has been structured for a particular application, that network is ready to be trained. To start this process the initial weights are chosen randomly. Then, the training, or learning, begins. There are two approaches to training – 'SUPERVISED' and 'UNSUPERVISED'. Supervised training involves a mechanism of providing the network with the desired output either by manually "grading" the network's performance or by providing the desired outputs with the inputs. Unsupervised training is where the network has to make sense of the inputs without outside help. The vast bulk of networks utilize supervised training [4]. Unsupervised training is used to perform Some initial Characterization on inputs. Training can also be classified on basis of how the training pairs are presented to the network. They are 'INCREMENTAL TRAINING' and 'BATCH TRAINING'. In incremental training the weights and biases of the network are updated each time an input is presented to the network. In batch training the weights and biases are only updated after all of the inputs have been presented.

V. ULTRA-CAPACITOR ENERGY STORAGE

The ultra-capacitor is a relative recent technology in the field of energy storage systems based on the double layer capacitor (DLC). The construction and theory of operation of a DLC can be understood by examining the schematic view of its internal components presented in Fig. 3 [8]. The elementary structure consists of two activated porous carbon electrodes, which are immersed into an electrolytic solution (typically potassium hydroxide or sulphuric acid), and a separator that prevents physical contact of the electrodes but allows ion transfer between them. Energy is stored in the DLC as a charge separation in the double layer formed at the interface between the solid electrode material surface and the liquid electrolyte in the micropores of the electrodes. This effectively creates two equivalent capacitors connected in series, which gives the name to the structure. The high energy content of ultra-capacitors in comparison to electrolytic capacitors is due to the activated carbon electrode material, which has an extremely high specific surface area and an extremely short distance at the interface between electrode and electrolyte less than 1 µm. Thus, it is possible to obtain a very high capacitance, up to a few thousand Farads.

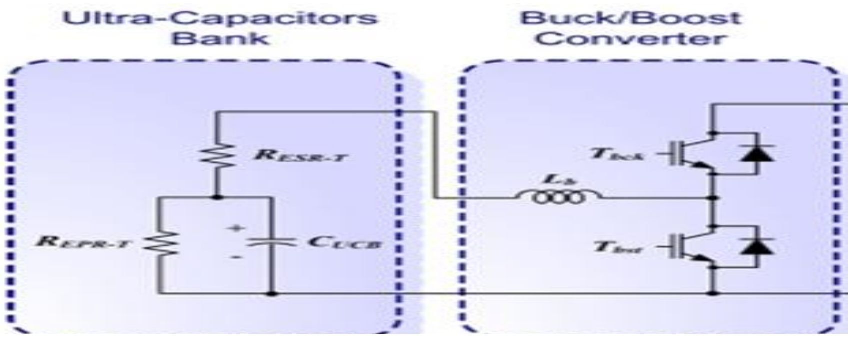


Figure 3. ultra capacitor bank

The equivalent total parameters of the ultra-capacitors bank can be computed from the elemental modules ones, *RESR*, *REPR*,and *CU* respectively as follows:

$$R_{ESR-T} = \frac{N_s}{N_p} R_{ESR} \qquad (1)$$

$$R_{EPR-T} = \frac{N_s}{N_p} R_{EPR} \qquad (2)$$

$$C_{UCB} = \frac{N_p}{N_s} C_{UC} \qquad (3)$$

The amount of energy drawn from the ultra-capacitors bank is directly proportional to the total capacitance and the change in the terminal voltage as given by (4).

$$E_{UCB} = \frac{1}{2} C_{UCB} \left(V_{UCBi}^{\ 2} - V_{UCBf}^{\ 2} \right) \qquad (4)$$

VI. DESIGN OF UPQC USING MATLAB SIMULATION

To verify the operating performance of the proposed UPQC, a 3-phase electrical system, a fuzzy logic controller with reference signal generation method is designed for UPQC and compared its performance with Artificial neural network based controller is simulated using MATLAB software.

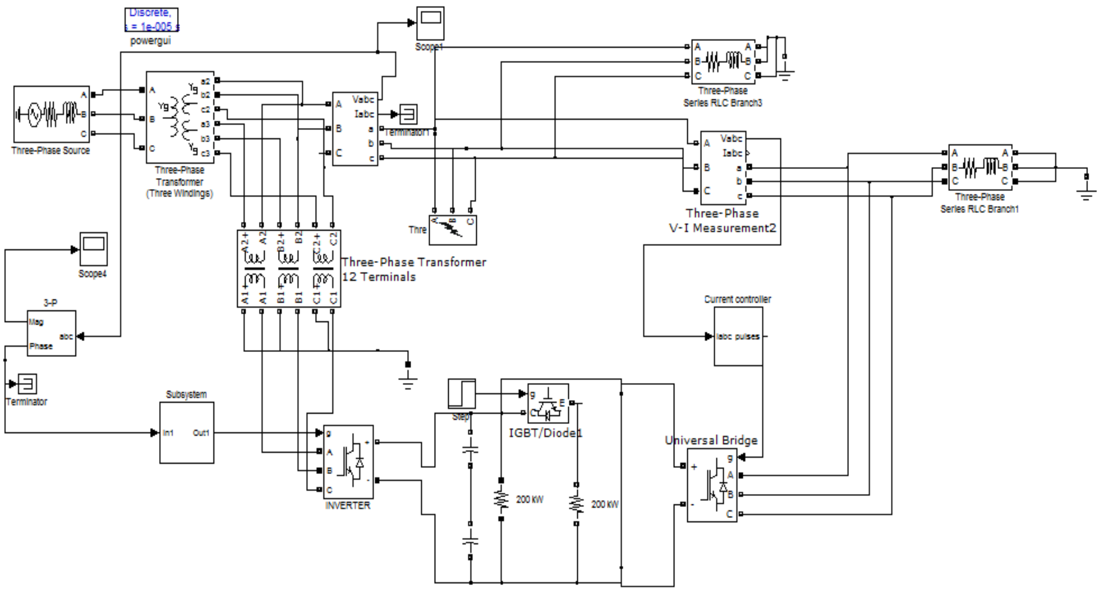


Figure 4. Matlab simulation model of UPQC with UCES

A. Fuzzy logic and neural network controllers design

The aim of the control scheme is to maintain constant voltage magnitude at a point where a fault is connected. The controller input is an erroe signal obtained from the reference voltage and the value rms of the terminal voltage is measured. Such error is processed by a fuzzy logic and neural network based controllers where the output is the angle δ, which is provided to the PWM signal generator.

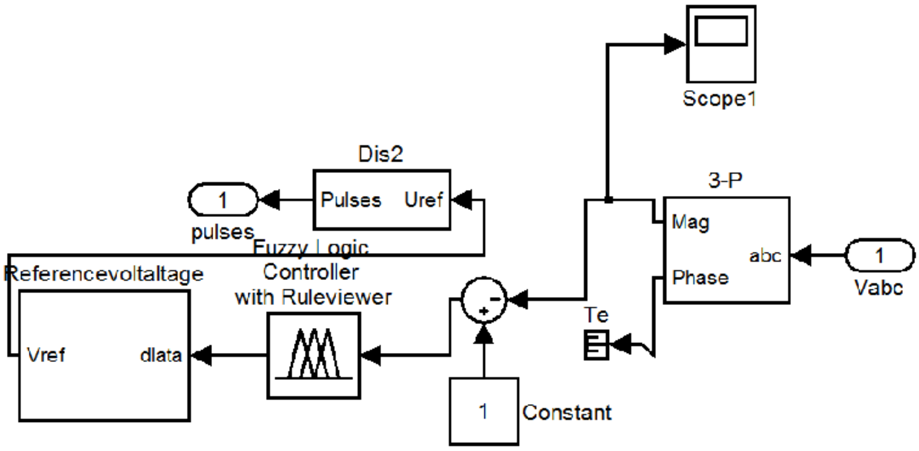


Figure 5. Voltage controller using fuzzy

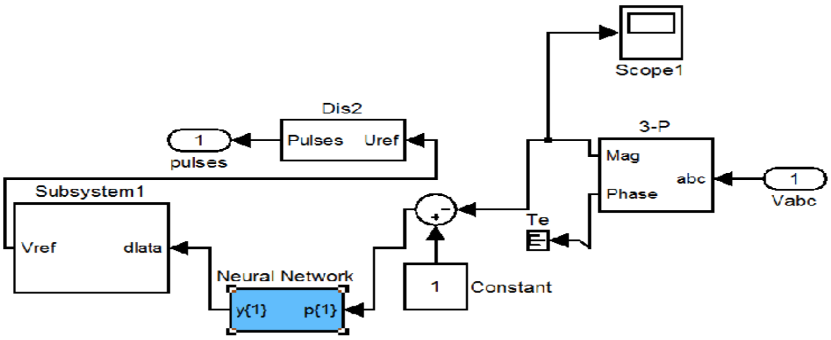


Figure 6. Voltage controller using neural networks

B. Editing Of Fuzzy Interface System

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

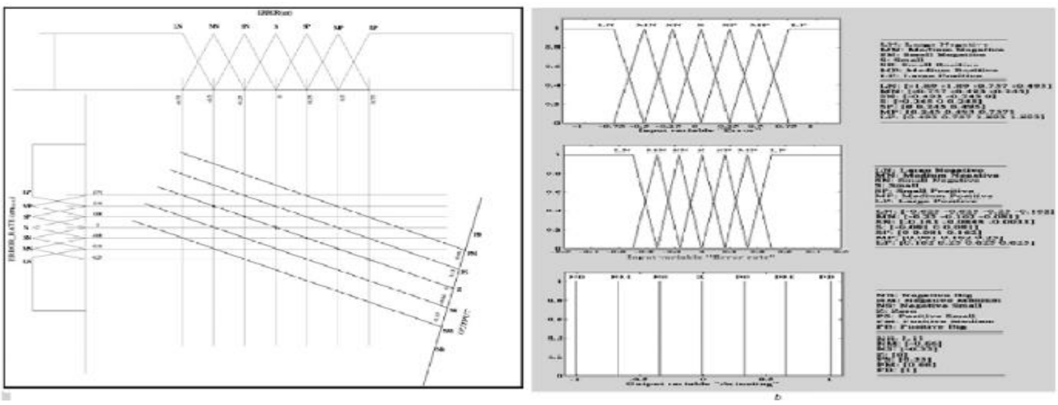


Figure 7. Membership figures for input and output

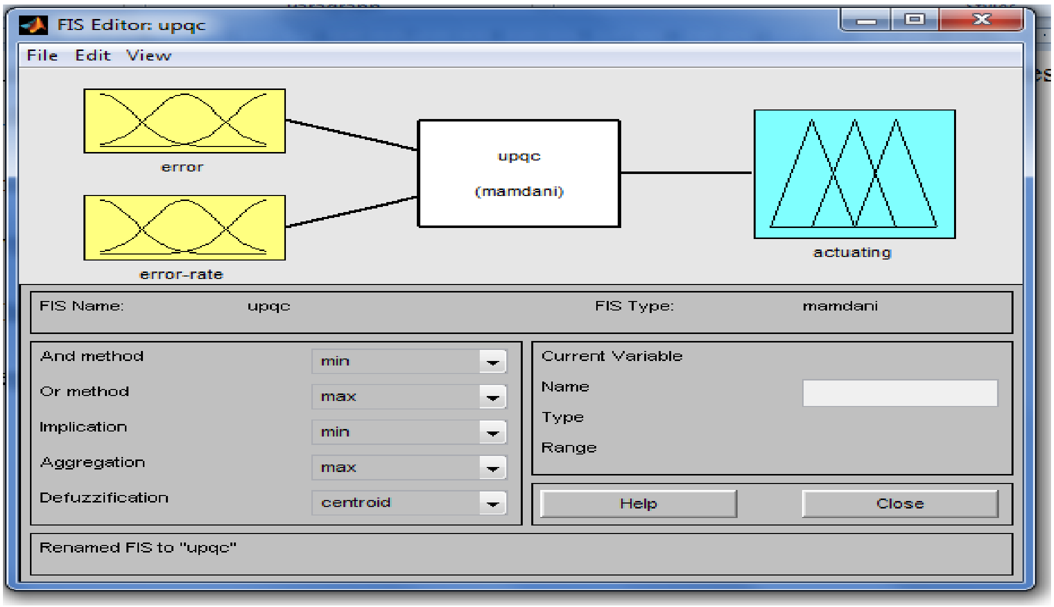


Figure 8.fuzzy interface system

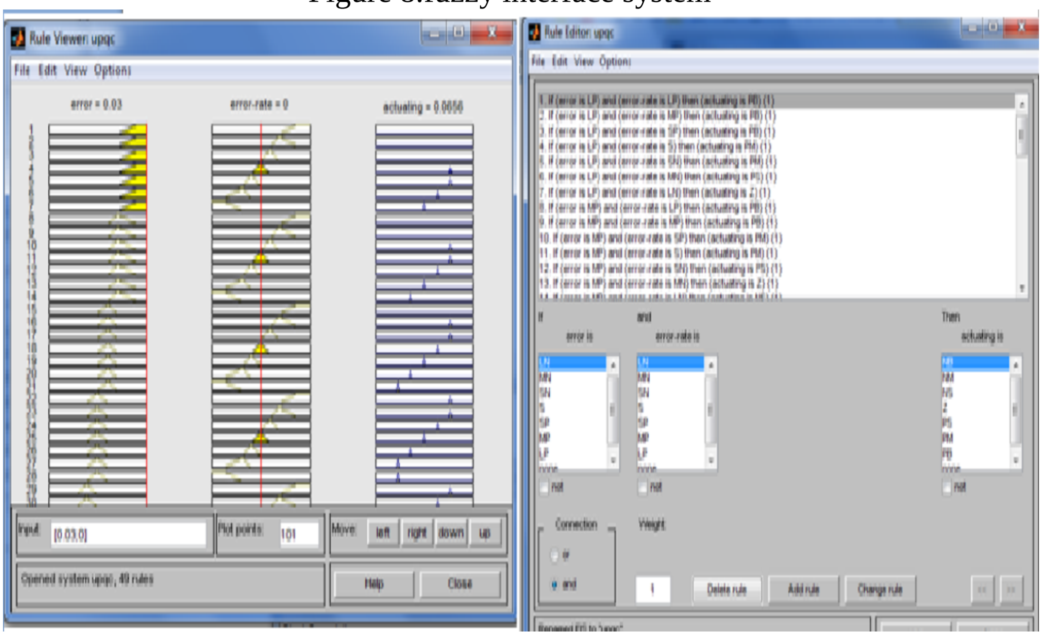


Figure 9. fuzzy Rule Viewer and Fuzzy Rule Editor

TABLE -1

CIRCUIT PARAMETERS FOR UPQC

System quantity	Supply voltage(Vs) Frequency	380Vrms 50Hz
Series converter	Filter inductor(Lf) Filter capacitor(Cf)	8mH 36Uf
Shunt converter	DC link capacitor Reference voltage Smoothing inductor	1100uF 650Vdc 15mH
Non liner load (R+jwL)	40 ohm +j 10 ohm	

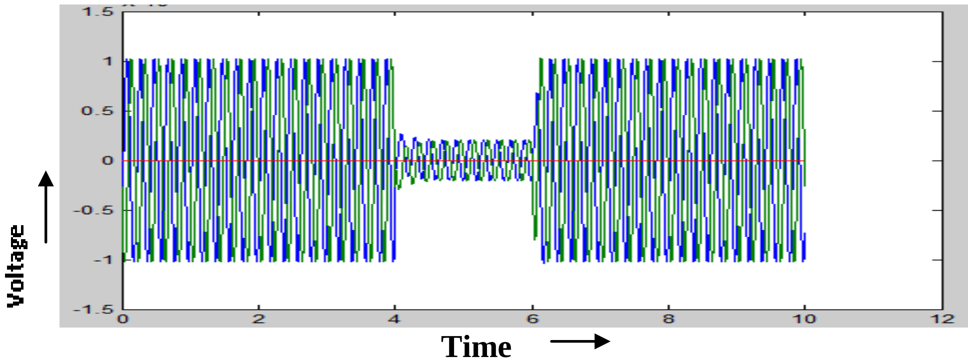


Figure 10. Source voltage due to 3 phase fault

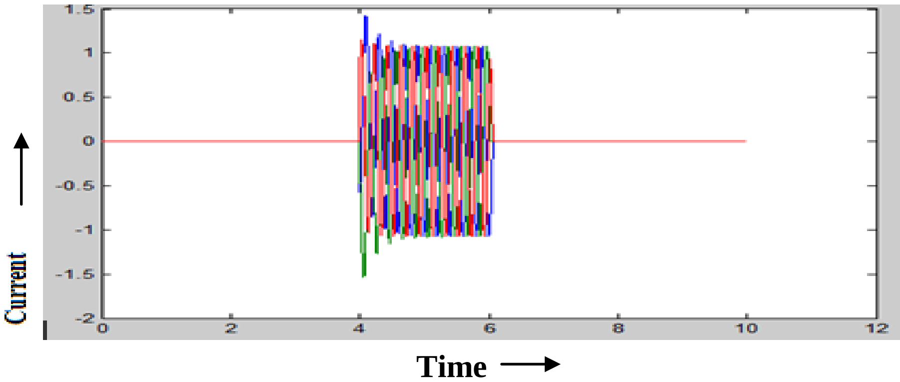


Figure 11. Load current due to 3 phase fault

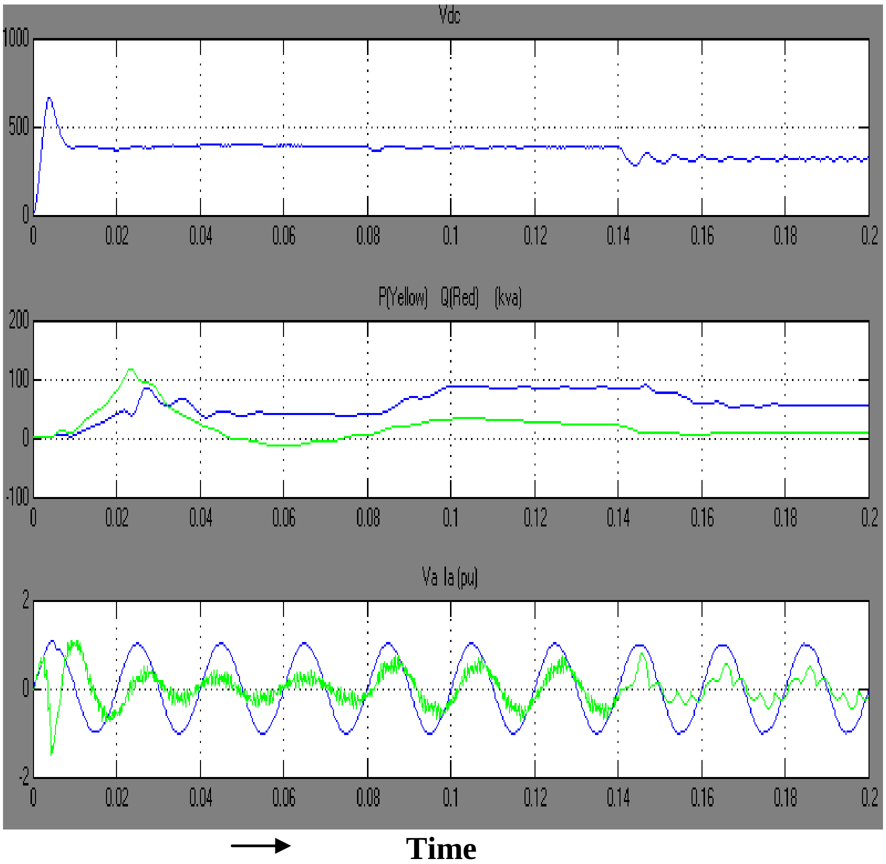
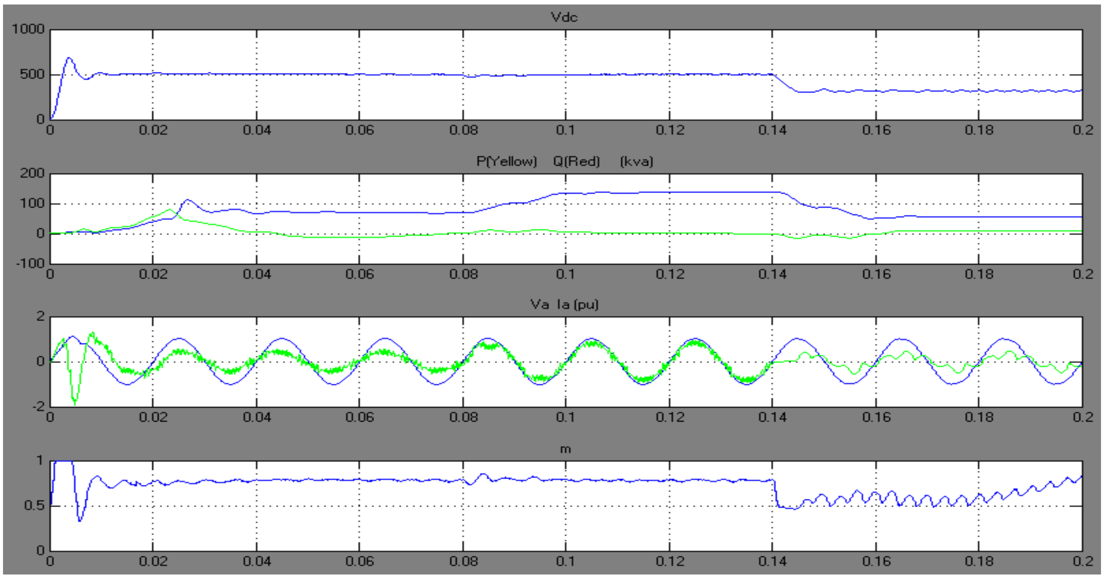
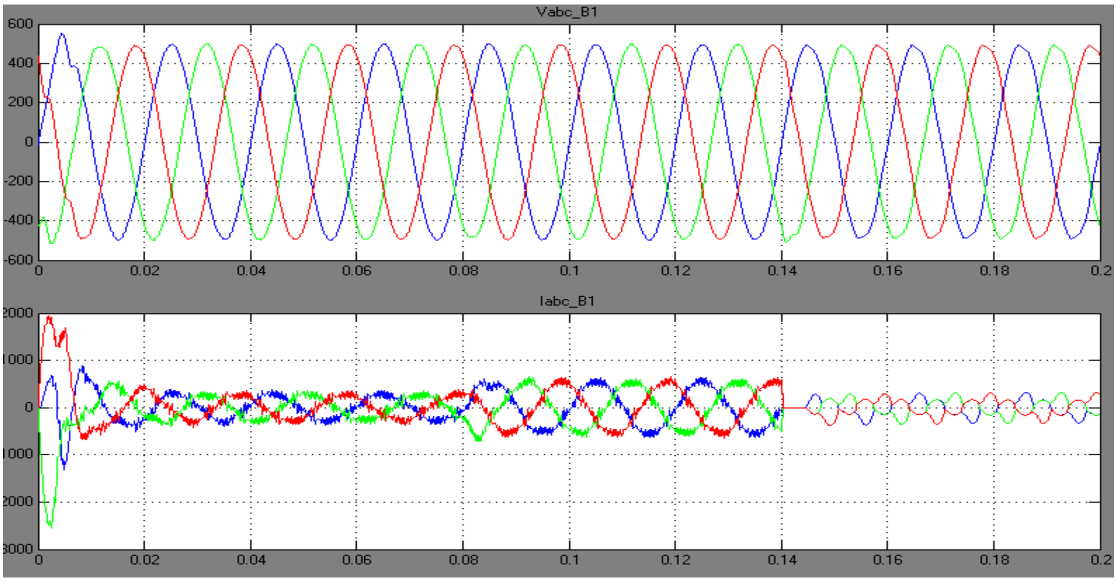


Figure 12. waveforms with FLC



Time ⟶

Figure 13. waveforms with neural networks



Time ⟶

Figure 14. Load voltage and current with artificial neural network

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 behaviour of different controllers used for power quality improvement connected to distribution line. The controllers mainly used for power quality improvement are Fuzzy logic controller and Artificial neural network based controller. Hence as compared to the response obtained with Fuzzy controller, Neural network based controller have great advantage of flexibility. The improved capabilities of the integrated **UPQC-UCES** controller to rapidly control the dc voltage exchange.

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