Research Article

Compensate Power Quality Related Problems by Mitigating Source Harmonics with Artificial Neural-Network controller

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Abstract

This paper deals with Unified Power Quality Conditioner (UPQC) which consists of series and shunt active filter sharing a common dc link capacitor. The series active filter reduces voltage source harmonics. Usually, the shunt active filter is designed to reduce harmonic current-components generated by the nonlinear loads. Thus with compensating effectively all the harmonics and reactive power improves power factor. The application of artificial intelligence is growing fast in the area of power electronics and power systems. The artificial neural network (ANN) is considered as a new device for the design of control circuitry for power-quality devices. Thus for optimal mitigation of voltage/current source harmonics, a neural network is proposed to control the UPQC. In this paper, ANN controller is designed for extracting the fundamental frequency components from non-sinusoidal and for controlling the current of the UPQC. An extensive simulation study has been carried out for investigating the performance of the ANN controller and the system performance has been verified by simulation analysis with Matlab/Simulink software.

Keywords: Harmonic compensation, Unified Power Quality Conditioner (UPQC), Power quality , Neural network

Introduction:

Nowadays, Power Quality is an important concern for the Industry. Harmonics produced by nonlinear loads, such as rectifiers, arc furnaces, power electronics converters, controllers for variable-speed motor drives, electronic power supplies, DC motor drives, battery chargers, and electronic ballasts can create high disturbances and problems in the power quality [1], [2].

Harmonic distortion in power distribution systems can be reduced by using two approaches namely, active and passive power filters. The passive filtering is the one simplest conventional solution to suppress the harmonic distortions. Although it is simple and least expensive, the passive filter has several barriers. The filter components have large size, depending on the source impedance, resonance problem, thus it affects on the stability of the power distribution systems [3].

At present, active power filters (APFs) are becoming reasonably affordable due to reduction of cost in power semiconductor devices, their auxiliary parts, and integrated digital control circuits. In addition , APF is acts as a power- conditioning device which provides various functions such as damping ,harmonic filtering, termination and isolation , load balancing ,controlling reactive-power for improving the power factor and voltage regulation, voltage flicker reduction and their combinations. Resent research helps presenting applications of the unified power quality conditioner (UPQC) to compensate the power quality related problems [4- 9].

In active power filter (APF) design and control, calculation of compensated voltage/current and reference signal generation is important task. Filtering characteristics strongly depends on the accuracy of reference signal and its speed of computation. The several schemes have been developed and studied for the control of active filters such as Fast Fourier Transform (FFT), Kalman filter and artificial neural network (ANN) [10].

Artificial intelligence is an important area and it has the ability to handle complex problems. Neural network is an important tool for this category, which can be trained for a specific task such as signal extraction or pattern reorganization, etc. At present days, these tools are used for improvement of the power quality related problems effectively and to produce good performance even under the distorted supply voltage conditions by suitable training [11], [12].

In this paper, a three phase- three wire UPQC controlled by neural network method is proposed. This controller requires a low processing time, and allows a fast calculation of the reference voltages/currents and it is simple in architecture. It can be effectively applied for harmonic filtering under various power system operating conditions. The proposed controller has been investigated under different non-sinusoidal for its performance.

System Configuration:

The UPQC is the integration of shunt and series APFs through a common bus DC link capacitor. Fig.1 shows the scheme of installed UPQC in distribution system, which includes nonlinear loads. The load can be either a single phase, two-phase or three-phase which may be unbalanced Or balanced connected to the supply mains via a bridge rectifier which defines load nonlinearity. The series active filter was designed for compensating the harmonic currents produced by nonlinear loads. The shunt active filter consists of a three-phase voltage source converter (VSC) connected in parallel with the power grid[8].

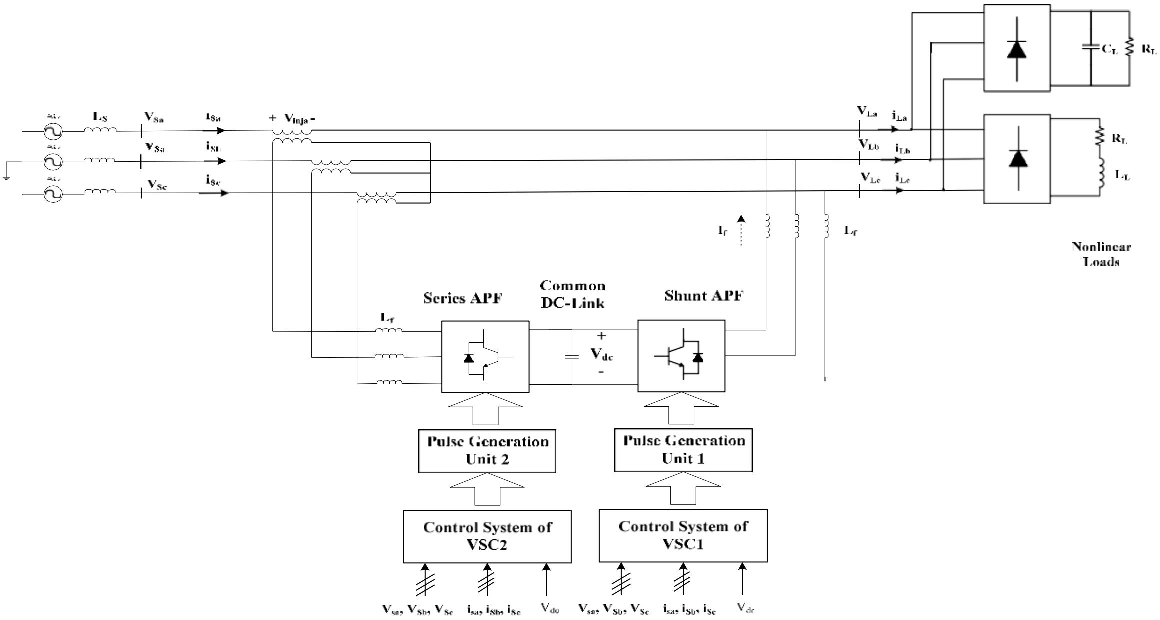

Fig. 1. The scheme of installed UPQC in distribution system[16]

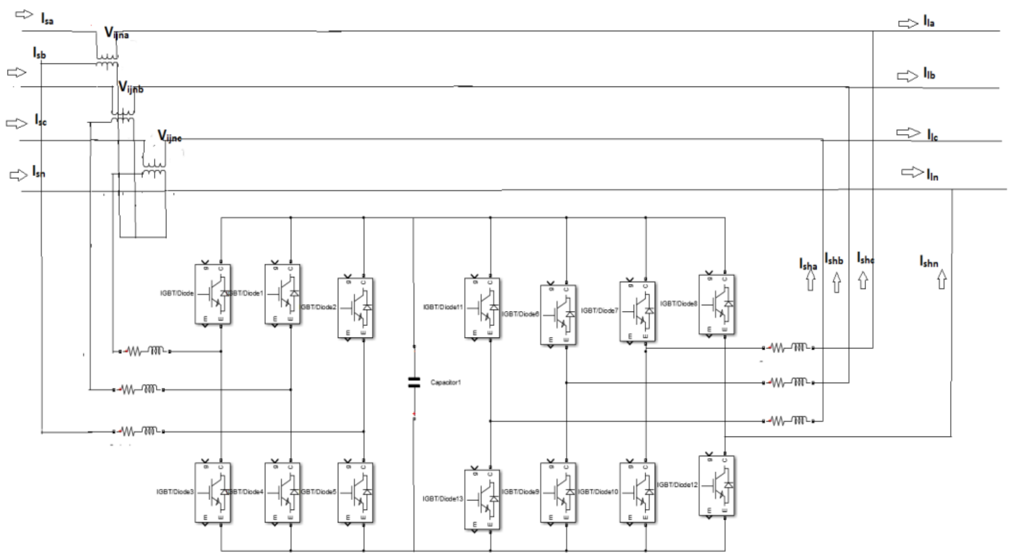

Fig. 2. UPQC carried out by using two VSIs [17]

The voltage on the source side is indicated by v_s, v_{inj} is the voltage injected by series active power filter ,, load voltage at the load is indicated by v_L , v_{dc} is the dc link voltage between two inverters . The current at the source side is indicated by i_s, i_{sn} is the neutral current on the source side ,current drawn by the loads is indicated by i_l , i_{ln} is the load neutral current and current injected by the shunt APF is indicated by i_{sh}, as shown in fig. 2.

Following are the assumptions made for the derived model of the system :

1. The voltage at PCC is sinusoidal and balanced.
2. Only the fundamental components of current are considered,since the average power balance expressions cannot be affected by harmonic components.

3. Losses of the system are lumped and represented by an equivalent resistance R_{sh} connected in series wth the filter inductor $L_{sh.}$
4. Ripples in the dc-link current are neglected.

Artificial Neural Network(ANN) Controller:

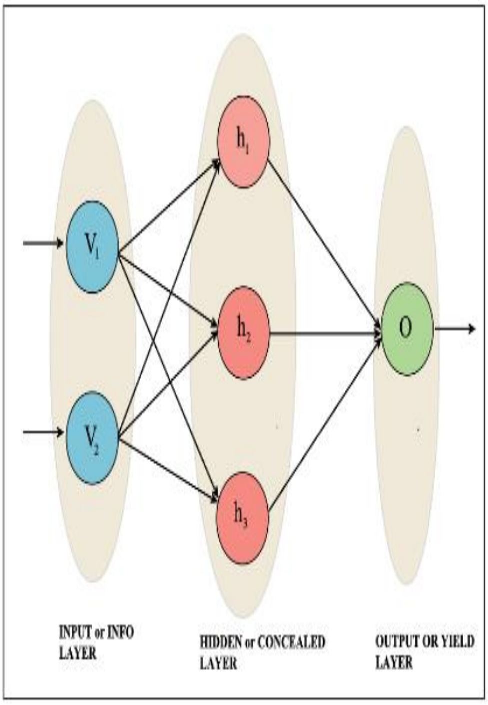

fig. 3.Artificial Neural Network

ANN is being used in various applications such as weather prediction , pattern recognition , robotics, etc. In electrical engineering, ANN is being extensively researched in load forecasting, predicting weather and processing substation alarms for wind farms and solar radiations [15].

In its simplest form, ANN is an imitation of the human
brain. ANN is a collection which is interconnected by nodes, inspires a generalization of neurons in a brain.

As shown in fig. 3. Circular node in the ANN is an artificial neuron and the connection between the nodes is represented by the arrow .

ANN is nothing but a collection of artificial neurons. Each connection in the ANN is like the synapses in a brain ,which transmits a signal from one neuron to another neuron. artificial neuron process the signal received and gives this signal to the other neurons connected to it.

At each connection in the network ,a "signal" is a real number, and non linear functions of sum of inputs computes the output of neuron . These connections in the network are called edges.

These neurons and edges of the network have some mass and this mass changes according to the learning .As the mass increases or decreases ,the strength of the signal changes.

Each Neuron of this network have a threshold and the signal will be sent only when the signal crosses that threshold.Typically, these neurons are aggregated into layers.

Basic ANN architecture has 3 layers and is shown in fig. 3.

1. Input layer- it stores input data and also provides inputs to the system.

2. Hidden layer-inputs provided by input layer are processed in this layer depending on masses of connection between the layers, bias if any and activation functions.

3.Output layer- stores the results of the computations.

Each layers performs different transformations .The Signal travels from the input layer to the the output layer possibly traversing the layers several times.

Design of Artificial Neural Network (ANN) controller:

The main requirement for the design of UPQC for desired compensation is the rapid detection of distorted signal with high accuracy and high dynamic response of the the controller. Recently, Neural network based controllers provide fast dynamic response while maintaining stability of the converter system over wide operating range.ANN is a collection of interconnected artificial neurons. It is essentially a cluster of suitably interconnected non linear elements of very simple form that posses the ability to learn and adapt. It resembles the brain in two aspects:
1) Through learning process, the network acquires knowledge.
2) interneuron connection stores the knowledge acquired.
Topology of the network, the manner in which they are trained,the way they communicate with their environment and their ability to process the information characterizes the network.

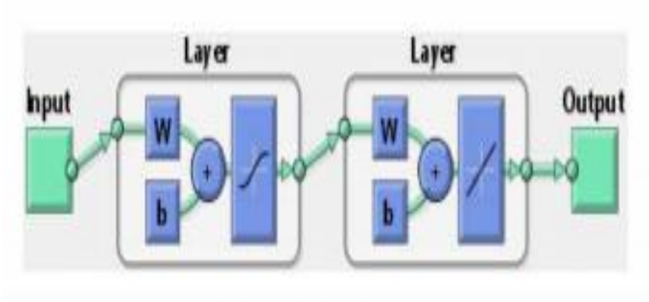

fig. 4.Basic ANN structure[18]

ANNs are being widely for solving the AI problems without creating a real dynamic system model. A multilayer fed forward-type ANN based controller is used for the improvement of the performance of UPQC. This network is intended with three layers, the input layer with 2 neurons, the hidden layer,and the output layer with 1 neuron. Workspace of matlab stores the data related to dc link current taken from the conventional method and is used for training the Neural Network. Tan sigmoidal is taken as activation function for input and hidden layers ,and pure linear function is chosen for output layer . This network works as a compensation signal generator. The network topology of the ANN is as shown in fig. 4. The compensator output depends on the input and its evolution. The NN is trained for outputting fundamental reference currents. Hysteresis band current controller compares the signal obtained and provides switching signals.

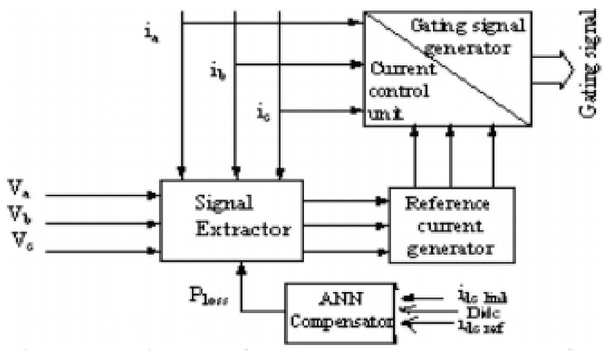

fig. 5.block diagram of the ANN-based compensator[17]

Design of ANN controller using Matlab/Simulink:
"nftool" command is used in workspace of Matlab ,for the Neural Network training tool to be opened.
To operate the APFs, ANN Trainer tool is given the input and target data. Then the data is stored in workspace and later imported for the development of network as desired.
3. From the provided inputs and targets data, training uses 70% of data, validating uses 15% of data and the remaining 15% of data is used for testing the network.
ANN tool with specified number of hidden layers
develops an artificial neural network.
Now the network will be trained by using the train command(trainlm) and target data will be trained using Levenberg- Marquardt back propagation. which validates and tests the network with given data [13].
After completion of the training, the simulink network is generated by the tool itself on command.

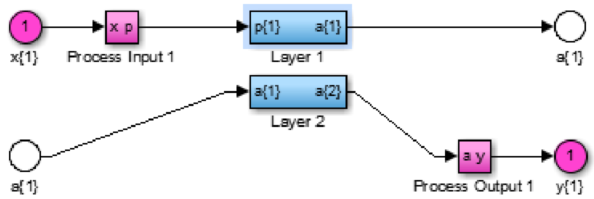

fig. 6. ANN used in shunt controller

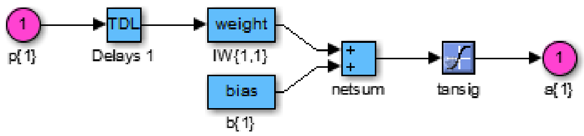

fig. 6a. layer 1 in detail

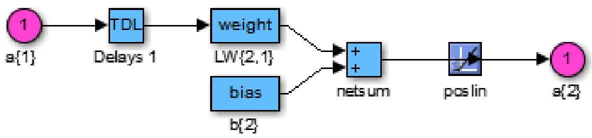

fig.6b.layer2 in detail

Simulation:

The Unified Power Quality Conditioner (UPQC) shown in fig. 1. is simulated using ANN based control method in Matlab/Simulink software and the simulation diagram is depicted in fig. 7.It consists of three phase source, Series controller, shunt controller based on ANN, DC link capacitor and three phase unbalanced linear load and non linear load.[5] With the proposed UPQC topology and controller, the aim of simulation study is as follows,

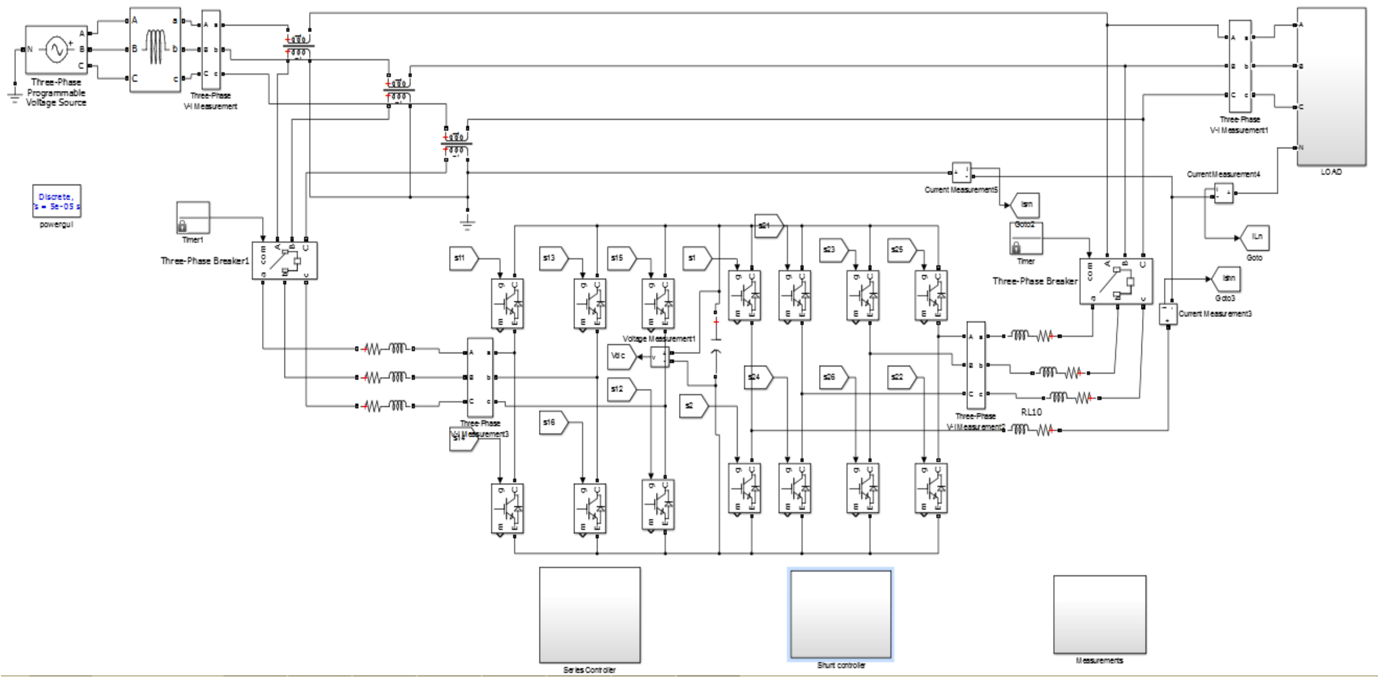

fig. 7.simulation diagram of UPQC with ANN

Simulation Results:

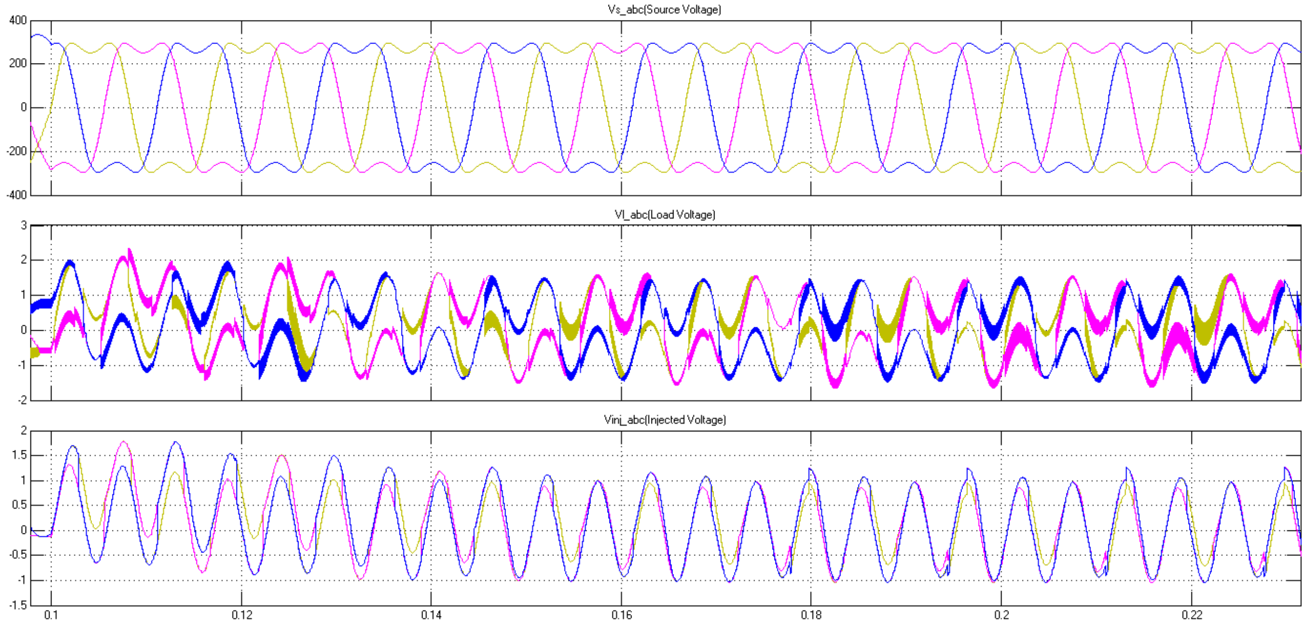

fig. 8a.volatge output with harmonics

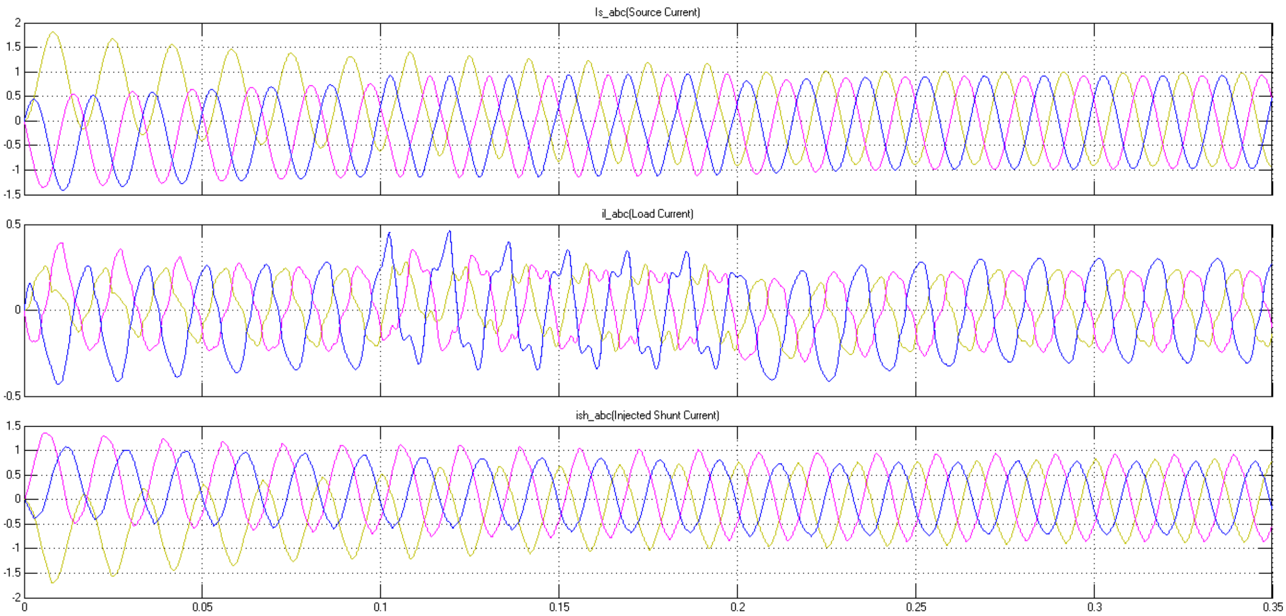

fig. 8b.current output

The simulation results are shown in fig. 8a and 8b.

Initially, the UPQC topology with the ANN controller proposed is tested with non linear and unbalanced load and distorted supply. The severity of voltage harmonics is considered to be 20% of 3rd and 10% of 5th order harmonics as shown in fig. 8a.

From the time t = 0.1 to 0.2 s, the UPQC connected to distribution network, plays an active role in isolating voltage and current harmonics through series and shunt converters.

Both the series and shunt APF's are put into operation at different time instants.During 0.1 sec of simulation, series active power filter is put into operation. shunt APF is put into operation at 0.2 sec of simulation, thus both series and shunt APF's combination is operated as UPQC.

To make the output load voltage harmonic free and sinusoidal ,the voltage harmonics are compensated by injecting voltage from the series convereter of UPQC.

The non linear unbalanced load currents depicted in fig. 8b. when the UPQC is not connected. To make these currents harmonic free,harmonic currents are injected by the shunt convereter at point of common coupling as shown in fig 8b where the UPQC is connected

Conclusion:

Custom power devices like DVR, D - STATCOM, and UPQC are used for improvement of the power quality in the distribution system. From these ,depending on the power quality problems at load or at the distribution system ,there is an option of choosing a particular device.

Unified Power Quality Conditioner (UPQC) is the combination of series and shunt Active Power Filters connected back to back, which compensates supply voltage harmonics and load current imperfections in the distribution system.[6]

A control technique is proposed for UPQC based on ANN . The proposed model has been simulated in MATLAB [14] as shown in fig 7. The simulation results shows that the harmonics in the input voltage and the current caused by non - linear load can be compensated effectively by this proposed control strategy.

The main purpose of developing UPQC is to get rid of the troubles that are associated with crucial load in power systems, to compensate them and to enhance the quality of power and designing UPQC based on ANN is to obtain faster response, can model difficult functions and can be imposed in any application with ease of use.

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