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A Neuro-Fuzzy Controller for Compensation of Voltage Disturbance in SMIB System

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Abstract
Since last decade, due to advancement in technology and increasing in the electrical loads and also due to complexity of the devices the quality of power distribution is decreases. A Power quality issue is nothing but distortions in current, voltage and frequency that affect the end user equipment or disoperation; these are main problems of power quality so compensation for these problems by DPFC is presented in this paper. The control circuits for DPFC are designed by using line currents, series reference voltages and these are controlled by conventional Neuro-Fuzzy controllers. The results are observed by MATLAB/SIMULINK model.

Keywords: *power quality, voltage sag, DPFC, voltage Swell*

1. Introduction

The growing demand for power and ageing of networks, makes it is desirable to control the flow of power in a system effectively to produce and maintain the quality of power in a network. By considering the transmission of electrical energy form generating stations to consumer points, the term power quality is used to measure the perfection of power and the grids ability to supply a clear sinusoidal wave shape [1]. Power quality is characterized as the factor in which both the conveyance and utilization of electric power influence on the performance of electrical system [2]. From consumer side, the power quality issue is concentrated about how the transmission line parameters such as voltage, current and others are affected and deviated from their actual values due to occurrence of disturbances.

The power electronics progress, particularly in flexible alternating current transmission system (FACTS) and custom power devices, influenced power quality improvement a lot in recent times [2]. For the most part, custom power devices such as, dynamic voltage restorer (DVR), are utilized to enhance power quality. Most of the dangers stand for sensitive equipment in power grids which arise due to voltage sags and swells. These unsettling interruptions happen because of some events such as flow of inrush currents, short circuits in the grid or due to the switching operations in the grid. The FACTS devices, such as, unified power flow controller (UPFC) and synchronous static compensator (STATCOM), are utilized to mitigate the interruptions and enhance the power quality and reliability [3]. For solving such type of power quality problems, in literature point of view, there are several strategies based on power electronic devices such as dynamic voltage regulators which are used in both transmission and distribution systems. A new converter has been designed consisting of power electronic devices and with the help of Neuro-Fuzzy control; harmonics can be extracted for analysis. This paper follows in the direction of providing a solution for Power Quality problems at the distribution end, by contributing a new FACTS device with a customized control strategy [4-5]. This will as well result in compensation of harmonics in grid voltage and in load currents, controlling real and reactive powers.

For compensating these Power Quality problems, compared to all other devices, the Flexible AC Transmission System provides the efficient work. These are classified as static compensators, series-shunt controllers. There is general accord that the future power grid tends to be smart and mindful, furthermore, statically controllable and energy efficient. FACTS devices, such as SVC, SSSC and UPFC can be embedded in series or shunt or a mix of the

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two, to accomplish control functions, including voltage regulation, system damping and power flow control. Out of all these methods, in this paper we presenting a new controller under series-shunt controller called a distributed power flow controller (DPFC) [6-7]. Basically, this device is a combination of one parallel converter in combination with more number of series converters. This device can compensate the problems in parameters of the transmission line

2. Working Principle of DPFC

A little change in DPFC that compared to UPFC is dc link capacitor is removed.

Like unified power flow controller, the distributed power flow controller is also a combination of series and shunt controllers. Unlike UPFC, in DPFC the series converter is spitted into three individual single phase series converters as shown in Figure 1 [8]. The controlling capacity of the UPFC is back-to-back connection of series and the shunt converters with a DC link, which is used for exchanging the power. In this distributed power flow controller the common dc-link capacitor is eliminated. So, in distributed power flow controller the active power is starts exchanged through the transmission line [9].

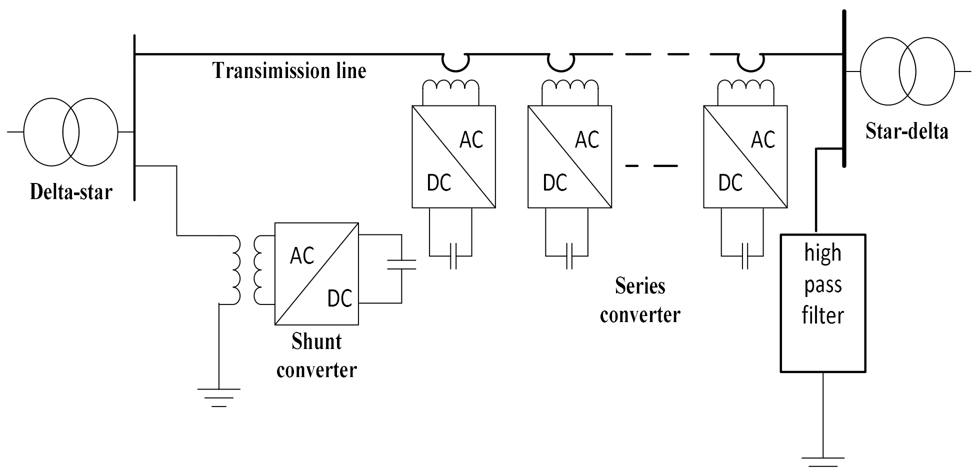

Figure 1. Schematic Diagram for DPFC

Better qualities of DPFC:

The Distributed Power Flow Controller is better than previous devices because of these [10]:

a) High controlling reliability.
b) More efficiency. DPFC is having three series converters which are connected in series so any one of the series converters is fails to work, the total work could not be stopped
c) Economically reliable

3. Control Circuit for DPFC

The control strategies for DPFC is divided into three main categories as shown in Figure 2 i.e A) Central controller, B) series controller and C) shunt controller [11].

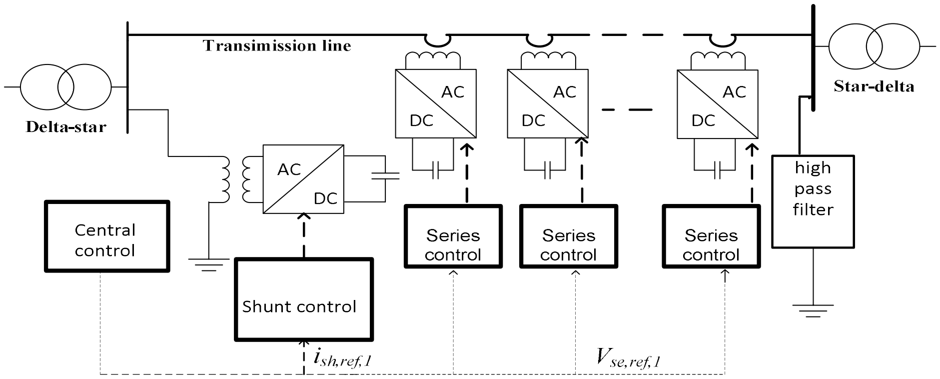

Figure 2. Closed Loop Control Diagram of DPFC

a) Main Controller for DPFC

For controlling series and shunt controllers all the reference signals are generating in this central controller.

b) Series Controller

By maintaining the capacitor voltage to a rated value series controller controls the voltage issues. Capacitor voltages in both quadrature and direct frame generates the reference signals generated and that reference signals are used to operation of this controller. Basically, natural and 3rdorder harmonic currents in these series controllers [12-13] are created by first order low pass and third order band pass filters as shown in Figure 3.

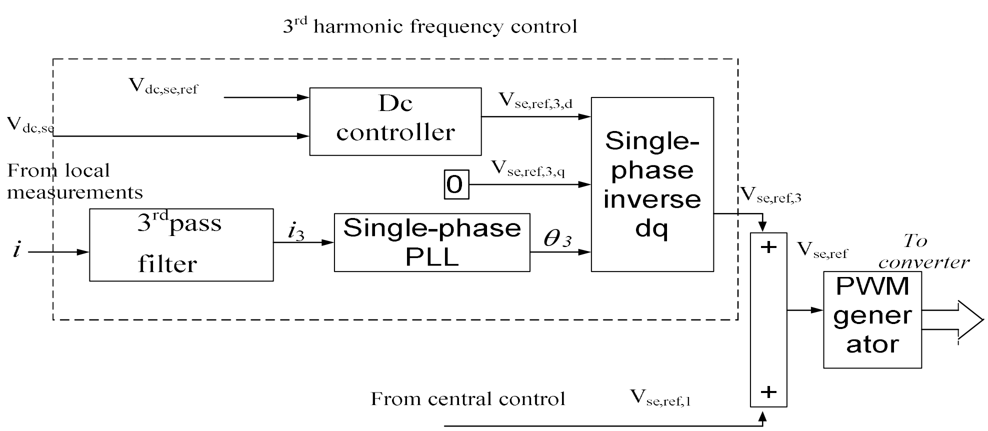

Figure 3. DPFC Series Control Structure

c) Parallel Controller

The control structure for parallel converter is shown in Figure 4. For generating suitable active power to DVR converter a 3rd order harmonic current [14] is inserting into the transmission line it is the basic theme to use this control. The static converter is basically a3ϕ converter and it is connected back to back with another 1ϕ converter.

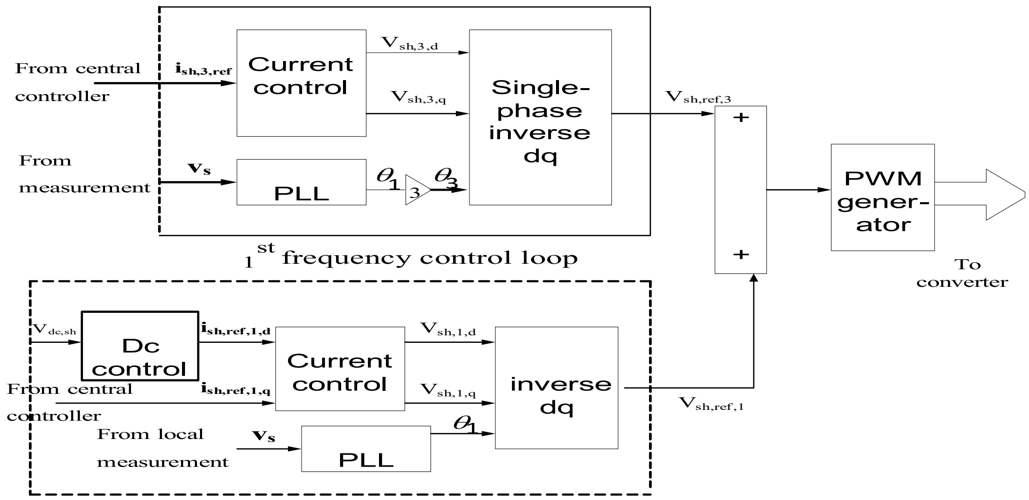

Figure 4. DPFC Shunt Control Structure

4. Adaptive Neuro-Fuzzy Inference System

The ANFIS is one of the important controller in adaptive techniques. This section provides the information regarding the designing of neuro-fuzzy controller. These neural network controller consists of two inputs that are Δe and Δde and it has one output that is f ∈ {Δe, Δde}. Each input consists of 5 membership functions [15]. Figure 5 shows the configuration of ANFIS for a mamdani type and it has two input and one output.

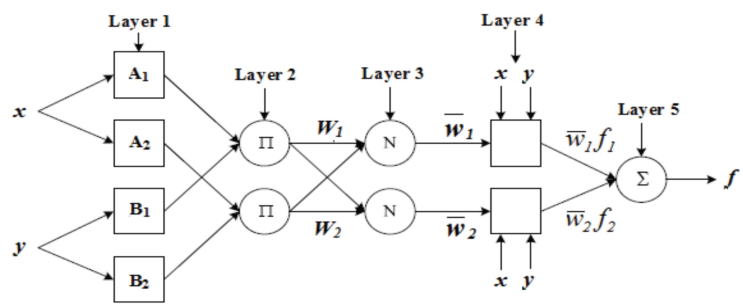

Figure 5. ANFIS Architecture

According to Figure 6, it is a mamdani based fuzzy controller with two inputs and one output and the rules are formed according to if-then statements. μAi and μBi are the membership functions of memberships with the fuzzy sets and these inputs are related with the operator logical AND. The hybrid learning algorithms are implemented for obtaining the values of system parameters [16]. These learning algorithms is a function of linear and non-linear parameters. These explanations are implemented in Matlab/Simulink software.

Algorithm for Neuro Controller:

1. Assume the inputs and outputs in the normalized form with respect to their maximum values and these are in the range of 0-1.
2. Assure the No.of input stages given network.
3. Indicate the No.of hidden layers for the network.
4. Design the new feed forward network based on the system parameters ‘transig’ and ‘poslin’.

5. Assume the learning rate be 0.02 for the given network.
6. Identify the number of iterations for the system.
7. Enter the goal.
8. Train the network based on the given input and outputs.
9. For the given network Generate simulation with a command ‘genism’

Fuzzy Controller:

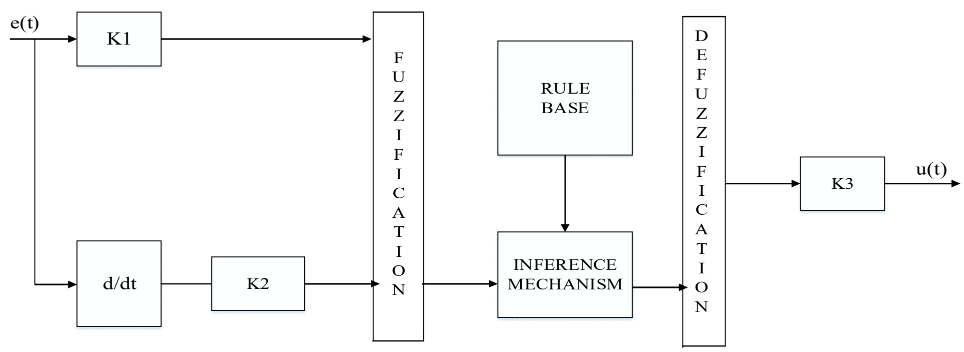

Figure 6. Configuration of Fuzzy Inference System

In this experiment we creating a condition that a system is having voltage sag by connecting a three phase fault to the system and observation analysis is shown in Figure 6 [17].

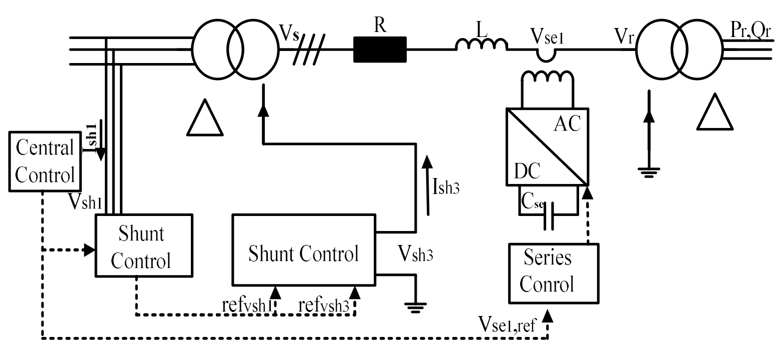

Figure 7. DPFC Control Structure

We consider a case study by creating a voltage sag condition through a three phase fault in a single machine system. The experimental setup is implemented by the basic diagram which is shown in Figure. 2 along with the control circuits by using MATLAB/Simulink based OPAL-RT eMAGAsim Real-Time Simulator, which can provide high speed and real-time simulation for power system. In this system the fault occurred between the time lapse from 500ms to 1500ms. During this fault time the voltage tends to dip as shown in Figure 5. The voltage magnitude is reduced by 0.65 percent of its nominal value during this fault time.

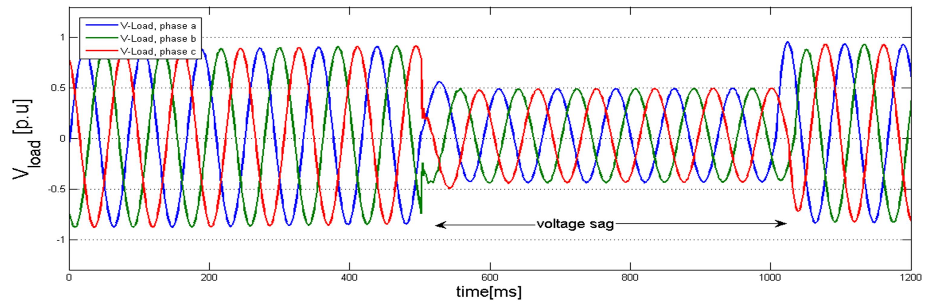

Figure 8. Output Voltage during Fault Condition

Figure 8, shows the simulation result for output voltage during fault condition and in the absence of the proposed controller. In this fault period a sag condition occurs at the output voltage.

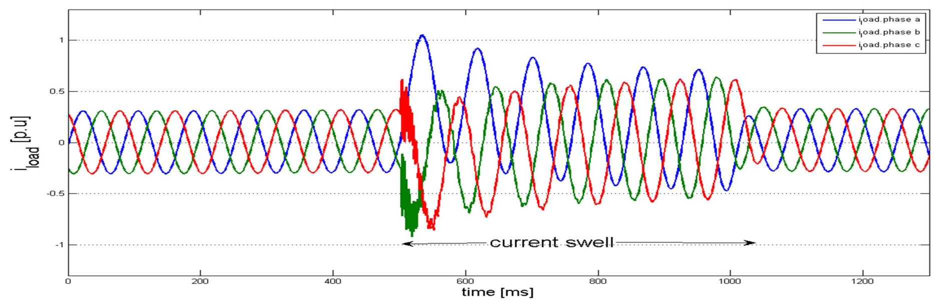

Figure 9. Output Current during Fault Condition

During this fault time the load current raises its magnitude around 1.2% per unit as shown in figure 9. This current swell condition is also due to the fault which we intentionally created in the interest of demonstrating the significance of the absence of proposed controller DPFC. As shown in figure 10, the required voltage is being injected by the series converter component of DPFC.

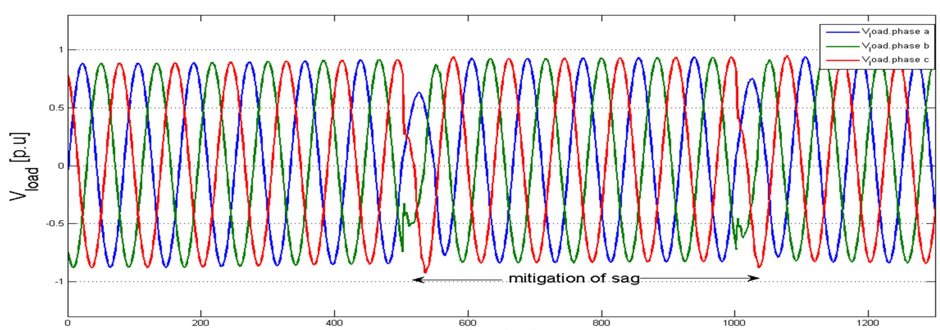

Figure 10. Output Voltage Compensated by DPFC Controller

Figure 11, exhibits the required compensation of currents by the custom designed DPFC, which exhibits its potential presence during current swell condition.

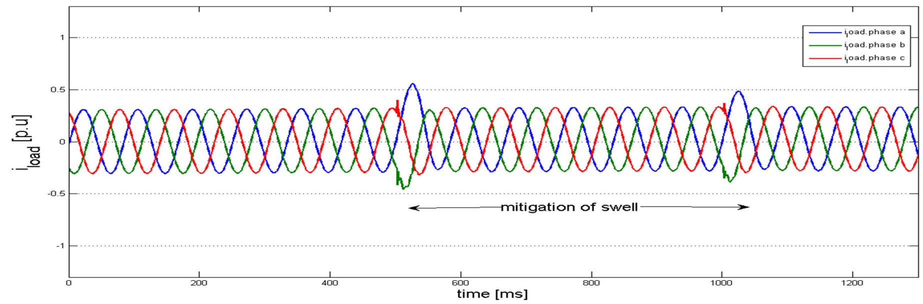

Figure 11. Compensated Output Current by DPFC controller

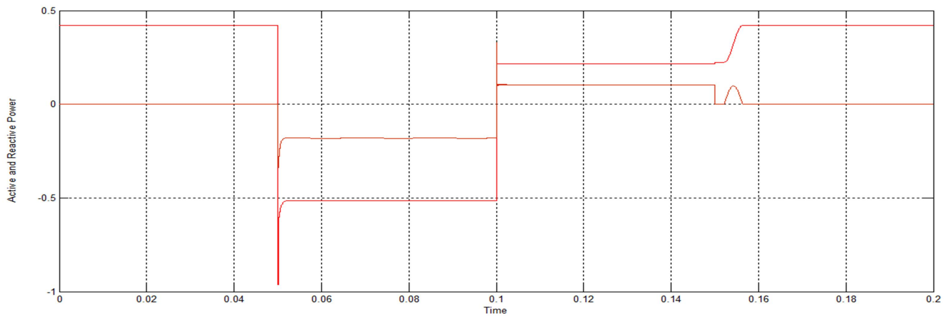

Figure 12. Active and Reactive Power

The flawless desired voltages and harmonic free currents are displayed in the results which demonstrate the capability of the proposed device. By using Fast Fourier Transform (FFT) analysis it is possible to analyze THD content of the system. Fourier analysis of a periodic function implies the extraction of sines and cosines which when superimposed will reproduce the function. The fast Fourier transform is a mathematical procedure for transforming function of time into function of frequency. THD value for a system is 12.36% and it is reduced by using DPFC controller.

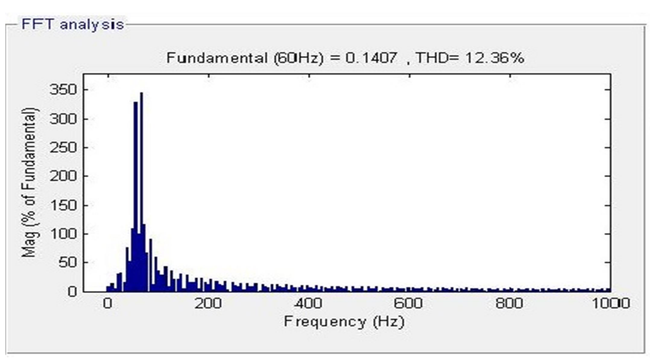

Figure 13. THD Value of System Output Voltage without DPFC

Figure 13, shows the total harmonic distortion (THD) content of load voltage without any controller and can see a drastic change after employing converters with PI and Neuro-Fuzzy controller. According to IEEE 519 standards, harmonic voltage distortion on power systems 161

KV and above is limited to 5% THD. A PI controller based DPFC controller is used for that system and now the THD value is reduced drastically to 3.88%.

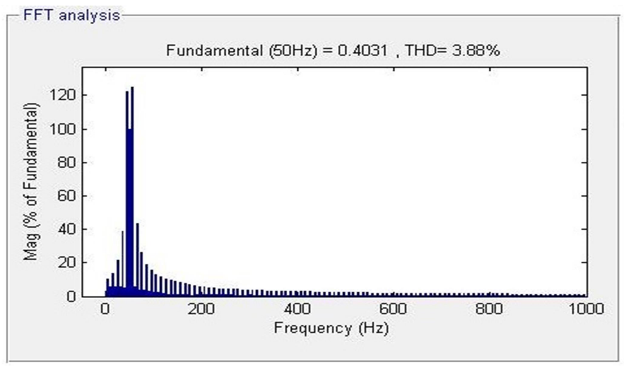

Figure 14. THD Value of DPFC (pi controller) Load Voltage

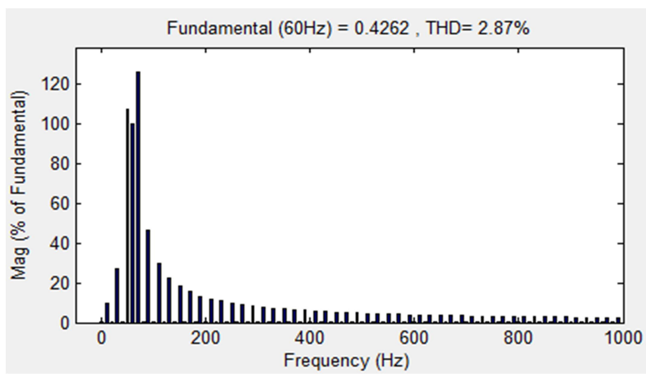

Figure 15. THD for output voltage under Neuro-Fuzzy controller

Simulated results were obtained for the system using series-shunt converter system with Neuro-Fuzzy Controller. And the THD content amounting to 2.87% as shown in figure 15, which is well inside the limits of IEEE 519 standards.

5. Conclusion

In this paper we implemented a concept to controlling the power quality issues i.e. DPFC. The proposed theory of this device is mathematical formulation and analysis of voltage dips and their mitigations for a three phase source with linear load. In this paper we also proposed a concept of Ann controller for better controlling action. As compared to all other facts devices the DPFC based Neuro-Fuzzy has effectively control all power quality problems and with this technique we get the THD as 3.65% and finally the simulation results are shown above.

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