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An Effective Technique to reduce Total Harmonic Distortion in Distribution Network by using Neural Network

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ABSTRACT: An advancement in technology encouraging the use of power electronic devices which is made up of non linear loads . These non linear loads have the ability to fulfil the demand of this efficient and increasing energy. The electronic front ends quality of nonlinear loads makes them effective. As these non linear loads are responsible for generation of harmonics in networks , which is harmful for overall performance of the system and decreasing the quality of power .So mitigation of these harmonic is very essential to maintain the present power quality , for optimum performance of the system without any interruption in the system and also for achieving high efficiency from the system. In this paper we focuses a Neural Network based three level cascaded MLI-DSTATCOM in distribution network to mitigate these harmonics which is produced due to non linear loads connected in distribution network and for performance observation of this proposed Neural Network based three level cascaded MLI-DSTATCOM in distribution network a three phase four wire system with nonlinear unbalanced load is designed and simulated in Matlab/Simulink .

KEYWORDS*:* Neural network, SRF (synchronous reference frame), CPD (Custom Powered Devices), MLI(Multi-level inverter), PLL (phase locked loop), THD (total harmonic distortion), Cascaded MLI, D-STATCOM (Distribution Static Compensator).

I. INTRODUCTION

The increased use of solid state devices to fulfil the consumer's increasing energy demand has introduced a power quality issue in the form of harmonic distortion due to their nonlinear nature. The magnitude of this harmonic distortion varies with the nonlinear load distribution at various voltage levels of a system. As these harmonics are responsible for losses in power distribution network and can lead to increased cost . To overcome this harmonic problem and for maintaining the present power quality levels Custom Powered Devices introduced . Custom power is an arrangement , which is planned principally to summon the requirement of industrial and commercial consumers. . The custom power device is used to enhance power quality of supply into power distribution system, demanded by the sensitive users. and to solve and suppress the current related problems CPD is connected in shunt with the load and is termed as D-STATCOM(Distribution Static Compensator).The conventional controllers like PI, PID, etc., perform unsatisfactorily during variation in parameters under non-linear load conditions and require precise linear mathematical models which are hard to derive. In recent era the major effort of the researchers is to replace these conventional controllers with a new unconventional control strategy especially like neural network controller. Neural Network techniques have proven that they were suitable for parameter identification and control of nonlinear systems which offers best solution for many power quality problems. The neural network control algorithm can learn, remember and make decisions. The apparent advantages such as fast dynamic response, better steady state and transient stability, robustness, improved tracking and adaptive ability, accuracy and precision under parameter variation make neural network controller superior than other controllers. In this paper, an adaptive Neural network based three level cascaded MLI-DSTATCOM is proposed for eliminating these current harmonics present in the distribution system due to nonlinear nature of solid state devices. It is achieved by reducing the total harmonic distortion (THD) present in the

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distribution system. One of the primary objectives of Neural Networks is an area of Artificial Intelligence (AI) where, by inspiration from the human brain, find data structures and algorithms for learning and classification of data. Neural Network is a technique in which a program can learn by examples, and create an internal structure of rules to classify different inputs. Neural Network techniques have proven that they were suitable for parameter identification and control of nonlinear systems.

II. METHODOLOGY

This paper investigates the performance of the distribution network with or without neural network based Three level Cascaded MLI-DSTATCOM configurations in the presence of non linear load under unbalance condition. Experimental results show that good attenuation of supply harmonic currents can be obtained with a neural network based three level cascaded MLI-DSTATCOM.

A. D-STATCOM

When a static synchronous compensator(STATCOM) used in distribution system with a coupling transformer ,an inverter, and energy storage device then it is collectively called as DSTATCOM(Distribution Static Synchronous Compensator). D-STATCOM is an inverter based custom power device (CPD) used to suppress harmonics and improve other power quality issues related to current in distribution systems. In this paper, Neural Network which has a nonlinear and robust structure is proposed for control of D-STATCOM's direct and quadrature axes currents. The article presents the neural network control of the D-STATCOM which tries to improve the damping of a power system. Simulation of Neural Network controlled D-STATCOM is performed by MATLAB/Simulink software. A typical D-STATCOM connected at the point of common coupling (PCC) in distribution system having unbalanced and nonlinear loads as shown in Fig. 1.

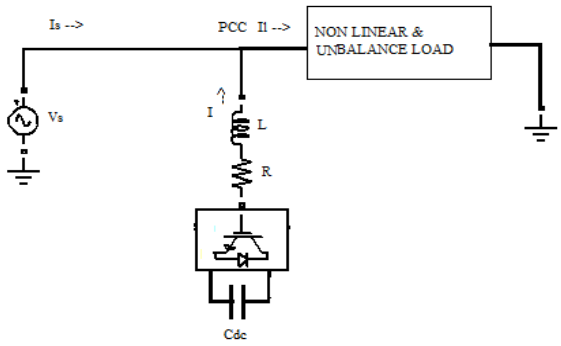
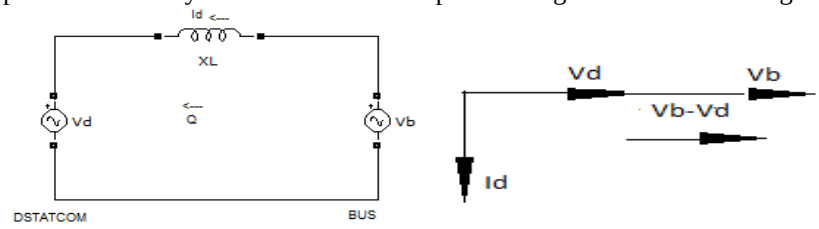


Fig.1- Single line diagram of DSTATCOM

Operating principle of DSTATCOM :-

Inductive Mode of DSTATCOM :

When bus voltage magnitude (Vb) is more than the rated voltage then the D-STATCOM acts as an inductor and absorbing the reactive power from the system. The circuit and phasor diagram are shown in Fig.-2.



(a) Circuit diagram of DSTATCOM (b) Phasor diagram of DSTATCOM

Fig.-2 Inductive mode operation of DSTATCOM

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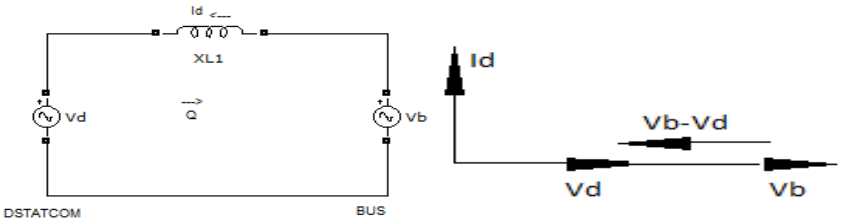
Capacitive Mode of DSTATCOM :
When bus voltage magnitude (Vb) is less than the rated voltage then the D-STATCOM acts as a capacitor generating the reactive power to the system.



(a) Circuit diagram of D-STATCOM (b) Phasor diagram of D-STATCOM

Fig.3-Capacitive mode of D-STATCOM

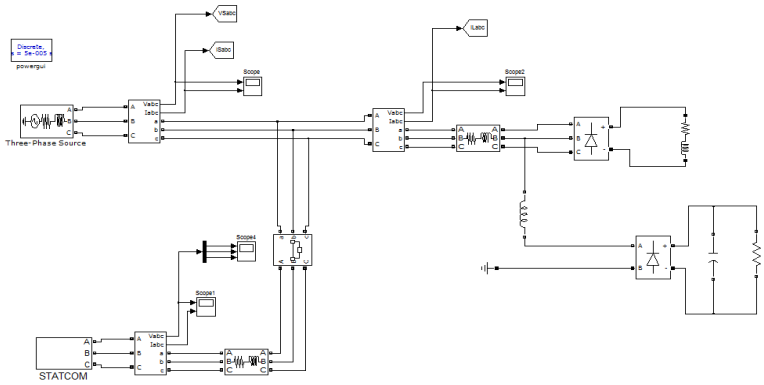


Fig.4-Proposed Neural Network based MLI-DSTATCOM of 3-phase 4 wire system

The above simulation diagram shows a source connected to nonlinear power electronic load which is here diode rectifier connected in parallel with R-L load. compensation is provided to improve power quality by using MLI-DSTATCOM .The diode rectifier with R-L load is used here. By using simulink in the Matlab above diagram is developed.

B. SYNCHRONOUS REFERENCE FRAME CONTROL

The working of D-STATCOM depends on the control algorithm used for extraction of reference current components and synchronous reference frame (SRF) theory is one of the most widely used control algorithm and made to derive reference currents for a D-STATCOM. In this paper SRF control for a three phase four wire system is developed and analyzed in Matlab/Simulink model and is given in Fig.-5. SRF theory also referred as d-q theory due to transformation of abc to dq-0 frame and now, these signals are filtered and transformed back to abc The load currents of abc coordinates are transformed into d-q-0 coordinates with the help of modified PLL and also with the help of phase-locked loop (PLL) Voltage signals are processed to generate unit voltage templates (sine and cosine signals). These d-q-0 coordinates comprises of an oscillatory component and averaged component resulting to oscillatory in nature. In order to avoid oscillatory response and maintain only averaged components of d-q-0 coordinates, which are stable in nature ,Low Pass Filter is used. These reference source currents or abc coordinates are compared with load currents to generate D-STATCOM reference currents . In order to compensate the supply current harmonics and unbalanced current on phase B, voltage of DC link capacitor should be same or kept constant at rated value i.e., at 1200V, this can be done by proper working of neurons and neurons layers of Neural Network controller . The Neural Network controller is therefore used to compensate the loss component of active current .Now these current signals are fed to a hysteresis-based PWM signal generator and the currents of the D-STATCOM are maintained at reference

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values using this Hysteresis current controller to generate final switching signals which fed to the Three level cascaded Multilevel inverter switching devices (IGBT) of D-STATCOM.

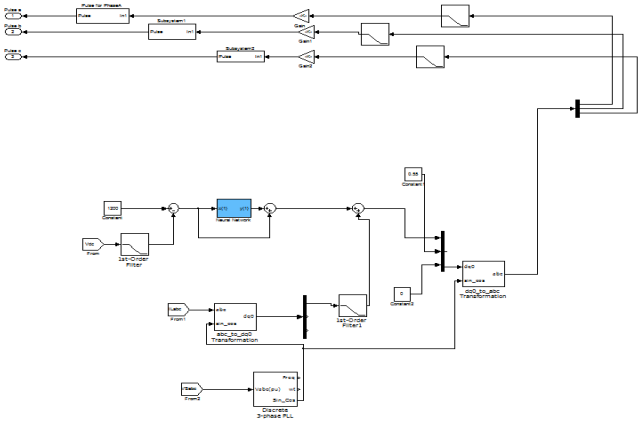

Fig. 5- MATLAB/SIMULINK Diagram of the reference current extraction using Neural Network based SRF theory.

C. NEURAL NETWORK

An artificial neuron network (ANN) or simply neural network is a computing model consist of a number of simple, highly interconnected processing elements, these elements proceed information with the help of their dynamic state response to external inputs.. An artificial neuron network (ANN) or simply neural network is inspired by the structure and functions of biological neural networks. Information that flows through connection of the neural network affects the structure of the ANN because on basis of input and output a neural network changes - or learns. Neural Network reduces the %THD level of uncompensated distribution system. This paper focuses Neural Network based MLI-DSTATCOM which is employed to compensate the uncompensated system shown in Fig. Neural networks have been known to be good function approximators. They are particularly effective in dealing with non-linear relationships between inputs and outputs. This feature is exploited in this paper to propose a new method for the problem of measuring harmonic current injected into a power system network by a non-linear load ,without disconnecting the load from the network. ANNs have three neuron layers that are interconnected. The first layer consists of input neurons. These input neurons are designed to receive various forms of information from the outside world that the network will attempt to learn about, recognize, or otherwise process and send data on to the second layer or hidden layer, which in turn sends the output neurons to the third layer or output layer how it responds to the information it's learned. The ANN is formed by varying the weights and biases. The training criterion is taken as taken as the mean square error of neural network. Commonly one neuron, even with many inputs, is not enough. We might need four, five or…. Ten, operating in parallel, that is called a layer. Similarly one or two hidden layer are sufficient to solve any non linear problem. Also, from accuracy point of you one can adopt the solution of third hidden layer for designing the network, but this will increase overall complexity of the neural network and the total training time will also be increased. There is no need to use four hidden layer in neural network architecture.Here in this paper ANN controller based D-STATCOM is modeled and simulated by using MATLAB/Simulink. With the help of the neural network toolbox in MATLAB the learning process of NN is prepared. The connections between one layer and another are defined by a number called a weight, which can be either positive (if one neuron layer excites another neuron layer) or negative (if one neuron layer suppresses or inhibits another neuron layer).The higher the weight, the more influence one neuron layer on another. A neuron operates by receiving signals from other neurons through connections, called synapses.

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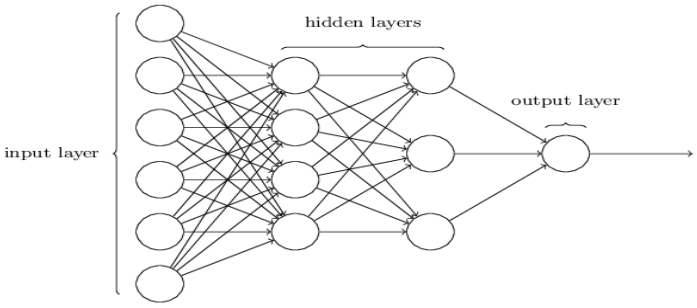

Fig.6-Basic Neural Network diagram

Not all layers "fire" all the time. Each layer receives inputs from the units to its left, and the inputs are multiplied by the weights of the connections they travel along. Every layer adds up all the inputs it receives in this way and if the sum is more than a certain threshold value, the layer "fires" and triggers the layer it's connected to (which is those on its right).

D. CASCADED MULTI LEVEL INVERTER

Multilevel inverter have been attracting increasing interest recently due to the increased Quality Power to bring into being good quality results and for accurate evaluation, improving harmonic performance, In this project, an attempt has been made to improve the quality of power. A three level cascaded multi level inverter with identical dc supply is designed . Multilevel inverters continue to receive more and more attention because it avoid the use of extra clamping diodes and voltage balancing capacitors and thus it requires least number of components with compare to diode-clamped and flying capacitors type multilevel inverters topologies and thus it has modular structure with simple switching strategy and occupies less space and thus switching devices losses and stress is reduced, the output voltage amplitude is increased and improved overall harmonic profile can be achieved. high voltage operation capability, low switching losses, high efficiency. With its modularity and flexibility, the cascaded multilevel inverter shows superiority in high-power applications, because by connecting the H-bridge in series one can get required output voltage as well as power. In cascaded H-bridge multilevel inverter separate DC sources configuration is used to avoid short circuit of DC source. Here in this proposed project consists of three series H-bridge inverter units, each bridge module comprises of four Gate turn-offs Thyristor (GTO).

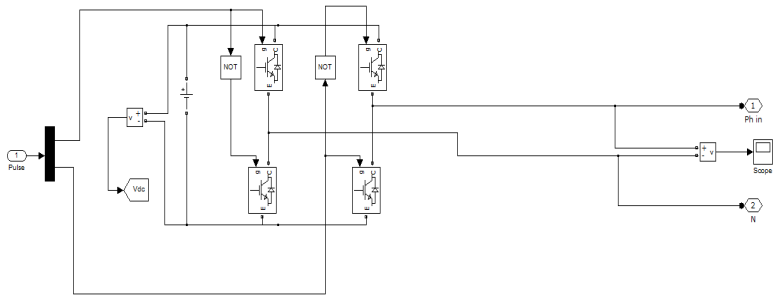

Fig.- Single phase three level H-Bridge Cascaded Multi Level Inverter

III. SIMULATION RESULT AND ANALYSIS

The proposed Three level cascaded MLI-DSTATCOM configuration with SRF control for a three phase four wire system is developed and analysed in Matlab / Simulink model and is given in Fig. 4. The proposed system is analysed in two different cases, i.e., case 1 is a three phase system with nonlinear Load without DSTATCOM (NN) and case 2 is a three phase system with nonlinear Load with DSTATCOM (NN).

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A. Source Current & Voltage with and without using Neural Network based Cascaded MLI-STATCOM

Due to the non-linear load connected to the system, harmonics are produced in load current which affect the supply current and made distorted the supply current waveform as shown in Figure7. In normal condition the source current is sinusoidal but due to nonlinear load there is slight change in the waveform of source current.

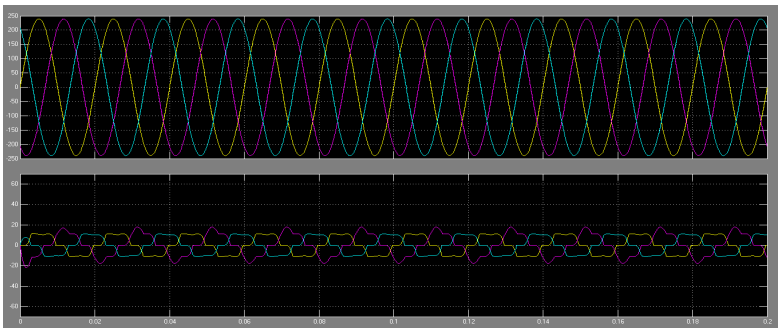

Fig.7- source voltage and current without compensation (NN)

To make the source current distortion free Three level Cascaded MLI-DSTATCOM operate to compensate the current harmonics by injecting the current into the system in phase opposition to the harmonic currents generated by nonlinear load and restricts nonlinear currents to the load end which is depicted in Fig. 8

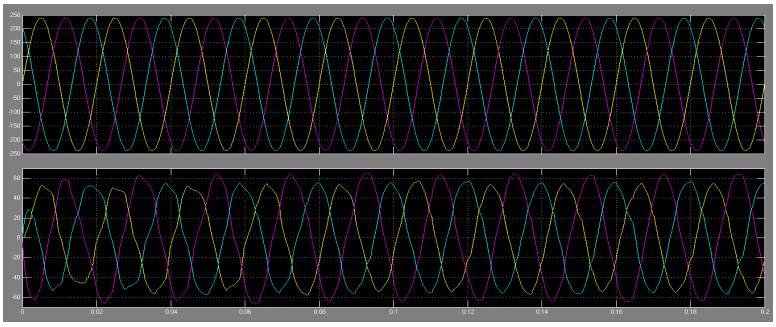

Fig.8- source voltage and current with compensation(neural network)

B. Load Current & Voltage without using Neural Network based Cascaded MLI-STATCOM

The impact of nonlinear and unbalanced load makes the load current to be nonlinear in nature and additional load on phase B draws more current than phase A and phase C, which can be clearly observed in Fig. 9Here in fig.9 load voltage is maintained at value 239.6v which is equal to supply voltage and current is maintained at supply current value which is in without DSTACOM connection equals to 14.7A.

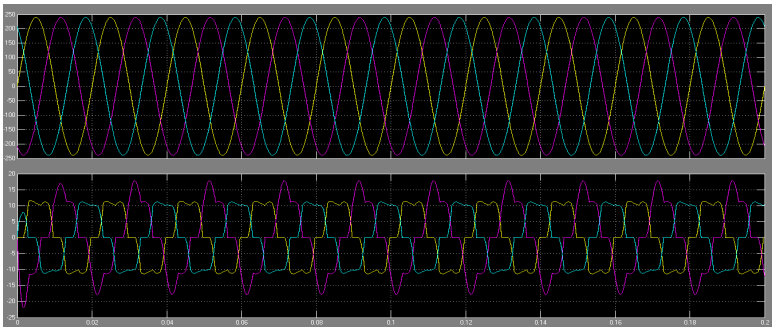

Fig.9- Load voltage and current without compensation (NN)

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The proposed SRF control algorithm Neural Network(NN) based Three level Cascaded Multi Level Inverter-DSTATCOM injects currents into the system in phase opposition to the harmonic currents generated by nonlinear load and restricts nonlinear currents to the load end which can be seen in Fig.10. This makes the system supply current to be sinusoidal i.e. free from harmonics .Here in fig.10 we can see that there is no changes in load current value and that's why there is zero %THD in load current .Here in fig.10 load voltage is maintained at value 239.6v which is equal to supply voltage and current is maintained at supply current value which is in without DSTACOM connection equals to 14.7A.

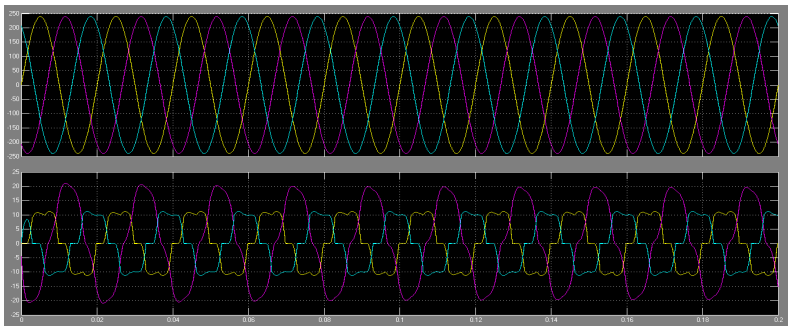

Fig.10- Load voltage and current with compensation (NN)

C. FFT Analysis before using Compensation (Neural Network based Three level Cascaded MLI- DSTATCOM)

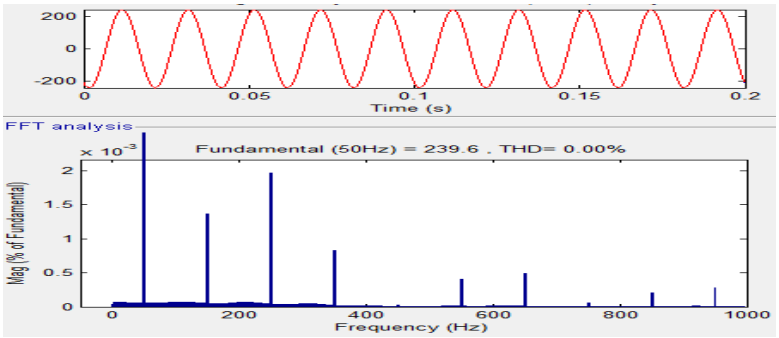

Fig.11- Supply voltage phase-B Waveform & %THD without compensation

Fig.11 shows the Total Harmonic Distortion (THD) and waveform of the phase-B supply voltage using Neural Network based Three level cascaded MLI-DSTATCOM. Where the fundamental component of the supply voltage is 239.6 V with 0.00% Total Harmonic Distortion at fundamental frequency (50Hz) .

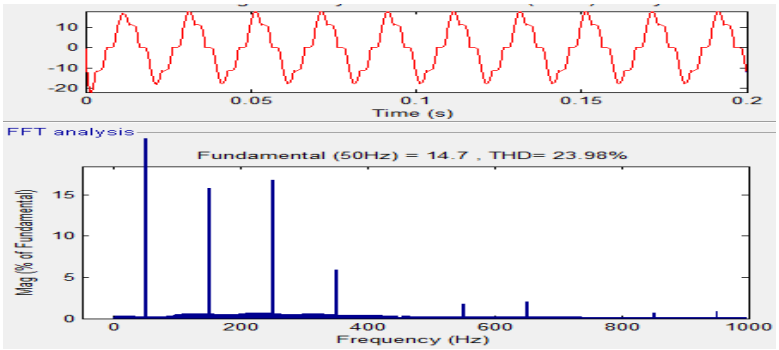

Fig.12- Supply Current phase-B Waveform & %THD without compensation

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Fig.-12 shows the Total Harmonic Distortion (THD) and waveform of the phase-B of supply current without using Neural Network based Three level cascaded MLI-DSTATCOM. Where the fundamental component of the supply current is 14.7 A with 23.98% Total Harmonic Distortion at fundamental frequency (50Hz) .

D. FFT Analysis before using Compensation (Neural Network based Three level Cascaded MLI- DSTATCOM)

The waveforms and %THD of supply voltage and supply current of phase B of distribution network using Neural Network based Three level Cascaded MLI-DSTATCOM are shown in below figures.

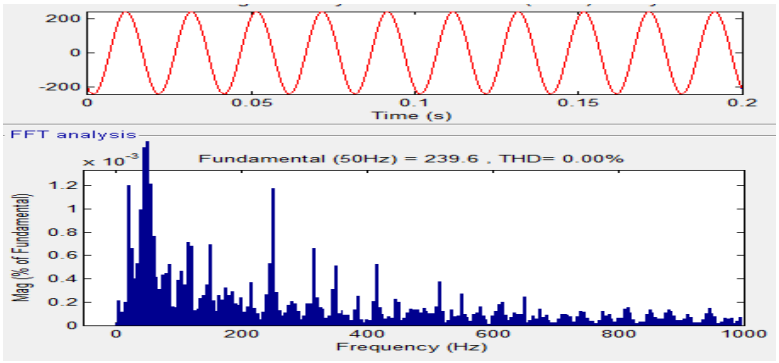

Fig.13- Supply voltage of phase-B Waveform & %THD with NN controller

Fig.-13 shows the Total Harmonic Distortion (THD) and waveform of the phase-B supply voltage using Neural Network based Three level cascaded MLI-DSTATCOM. Where the fundamental component of the supply voltage is 239.6 A with 0.00% Total Harmonic Distortion at fundamental frequency (50Hz) .

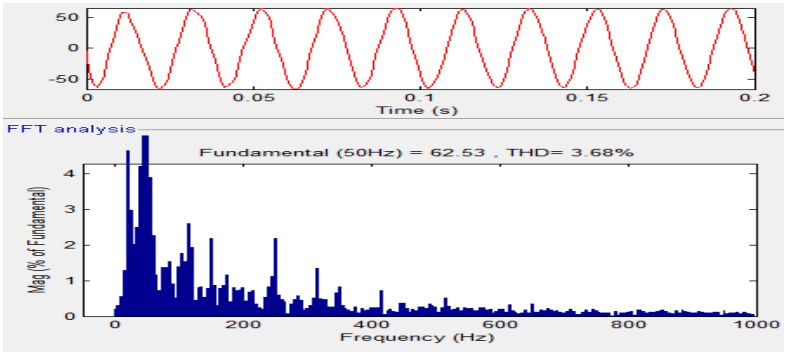

Fig.14- Supply current phase-B Waveform & %THD with compensation

Fig.-14 shows the Total Harmonic Distortion (THD) and waveform of the phase-B supply current using Neural Network based Three level cascaded MLI-DSTATCOM. Where the fundamental component of the supply current is 62.53 A with 3.68% Total Harmonic Distortion at fundamental frequency (50Hz) . Thus the simulation results exhibit that the harmonic currents are restricting at load end and don't enter into source effectively and so there is an increment in current value of supply side, no distortion in voltage of supply and as well as in voltage and current of load side and considerable amount of reduction in %THD of supply current with help of SRF control algorithm Neural network based Three level Cascaded MLI-DSTATCOM in distribution network takes place.

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Comparison of various parameters with and without DSTATCOM (Neural Network)

Parameters	Before Connection of DSTATCOM (NN)	After Connection of DSTATCOM (NN)
Supply current (Amp.)	14.7A	62.53A
Supply voltage (V)	239.6 v	239.6 v
Supply %THD	23.98%	3.68%
Load current (Amp.)	14.7A	14.7A
Load voltage (V)	239.6 v	239.6 v

IV. CONCLUSION

In this paper the performance of a proposed three level cascaded MLI-DSTATCOM is analyzed using Synchronous Reference Frame based control scheme with neural network controller for %THD reduction in distribution network. The operation of proposed system is analyzed using MATLAB/SIMULINK software. It can be concluded that Three level Cascaded Multilevel inverter Distribution Static Compensator using Synchronous Reference Frame Theory control scheme with neural network controller effectively improves the power quality in distribution networks. Using neural network, it improves the trustworthiness of the reduction in Total Harmonic Distortion in Distribution Networks. The simulation results show that current perturbations caused by non-linear load can be compensated effectively by the proposed control strategy and thus the prediction error obtained by Neural Network model is very plausible. So the Neural Network model produces reliable estimates of current THD. The results have also pointed out that Neural Network can implement many other data prediction efforts easily and successfully, the ANN controllers are very effective and efficient compared to the PI and PID controllers, because the steady state error in case of ANN control is less and the stabilization of the system is better in it. In the ANN methodology the time taken for computation is since there is no mathematical model .

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