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A Dual Control Strategy for Phase Balancing in Three-Phase Four Wire Distribution Systems by Artificial Neural Network

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Abstract: An electrical power system comprises of large number of large number electrical and electronic equipment. These are also used in much number of commercial and industrial applications. In the present scenario, the usage of AC loads in the industrial sector is improving which in turn leads to reactive power problems. Due to the usage of devices like arc furnaces, welding devices and other such instruments which causes flickering and voltage sag, the power quality gets reduced in the system. In this project, a power quality controller is used to mitigate the voltage sag problem in the network. DSTATCOM is used as a compensator here. The system efficiency is improved by training the network through Artificial Neural Network (ANN) algorithm. The proposed technique mitigates harmonic and reactive current problems and ensures balanced and sinusoidal source of current from the supply mains that are nearly in phase with the supply voltage and it also compensates neutral current under varying source and load conditions. The modified system is superior over conventional methods as it eliminates the sensors needed for sensing load current and coupling inductor current. ANN controllers are implemented to maintain voltage across the capacitor and to act as a compensator to compensate neutral current. The performance of the DSTATCOM is validated for all possible conditions of source and loads by analysing the simulation results obtained through MATLAB software and simulation results prove that the proposed control strategy is more efficient than the conventional control techniques.
***Keywords**: Active filter, dual control strategy, power conditioning, three-phase distribution systems, ANN, DSTATCOM.*

I. INTRODUCTION

Power quality (PQ) improvement studies and its necessity got increased in recent periods, mainly due to the increase in usage of nonlinear loads, connected to the electrical power system. They cause distortions in the utility voltages at the point of common coupling.

Voltage sag/swell and voltage unbalances also cause serious problems in the system. They affect the system performance and reduce system efficiency. The wide application of non-linear loads and diverse electrical loads/power sources connected to the grid increases the harmonic pollution in the utility side of ac mains. The harmonic and reactive current generated by non-linear loads/sources make the utility side to have a low power factor, decreased energy efficiency, low power handling capacity and create vulnerable disturbances to the appliances connected to the distribution system. The conventional method like passive filter is the simplest method for harmonic reduction and power factor improvement, but suffers from drawbacks such as bulky component size, occurrence of resonance, and fixed compensation characteristics. The research and development in the area of power electronics prove that active power filters are superior over the passive filters due to the evident advantages such as less response time, compact size, and better performances. In the distribution system a group of devices denoted by generic name customer power devices (CPDs) is employed for the mitigation of the power quality problems. To solve and suppress the source voltage related problems CPD is connected in series with the load and is termed as Dynamic Voltage Restorer (DVR). The problems related to current can be solved and suppressed with the help of Distributed static compensator (DSTATCOM) which is a CPD connected across the load. The connection of both DSTATCOM and DVR in a grid can solve the power quality problems related to both voltage and current. This CPDs combination is termed as Unified Power Quality Conditioner (UPQC). In the literature survey, it is reported that for mitigation of power quality problems and for compensation of neutral current in three phase four wire (3P4W) distribution system different topologies are under investigation. Most of the researchers prefer the four leg VSC topology as a better choice for the compensation of neutral current compared to other configurations, even though the control is complex and costlier.

Proper selection of mitigating technique decides the performance of power quality compensation. The factors which decide the choice of control strategy are accuracy, filter response time and number of steps involved in the calculation. In order to fulfil these

Volume 5 Issue IV, April 2017
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requirements many control strategies are developed and proposed by various researchers. They are (i) instantaneous reactive power theory (IRP), (ii) space vector pulse width modulation (SVPWM), (iii) power balance theory, (iv) synchronous reference frame theory (SRF), (v) Lyapunov function based control, nonlinear control, etc. The above mentioned conventional control approaches calculate harmonic and reactive current components for the generation of reference currents with the help of sensors and multipliers to sense the load currents and source voltages. To perform with high speed and accuracy the controller requires high speed processor and high performance data converters for the calculation of reference current and this makes the controller to suffer from evident disadvantages such as high cost, low stability and more complexity. The control strategy for 3P active power filter (APF) first reported in the literature without reference current calculation was one cycle control (OCC) The conventional controllers like PI, PID, etc., does poor performance under nonlinear 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 which offers best solution for many power quality problems.

II. POWER QUALITY PROBLEM

Power Quality (PQ) related issues and their effects on system efficiency are of most concern nowadays. The widespread use of electronic equipment, such as information technology equipment, power electronics such as adjustable speed drives (ASD), programmable logic controllers (PLC), energy-efficient lighting, led to a complete change of electric loads nature. These loads are simultaneously the major causers and the major victims of power quality problems. Due to their non-linearity, all these loads cause disturbances in the voltage waveform. Along with technology advance, the organization of the worldwide economy has evolved towards globalisation and the profit margins of many activities tend to decrease.

The increased sensitivity of the vast majority of processes (industrial, services and even residential) to PQ problems turns the availability of electric power with quality a crucial factor for competitiveness in every activity sector. The most serious and critical areas are the continuously processing industry and the information technology (IT) servicing sectors. When a disturbance occurs, huge financial losses may happen, with the consequent loss of productivity and competitiveness. Although many precautions and steps have been taken by utilities, some consumers require a better level of PQ higher than the level provided by modern electric networks. This implies that some measures must be taken in order to achieve higher levels of Power Quality.

III. CONVENTIONAL VOLTAGE SAG MITIGATION TECHNIQUES

The voltage sag is a major problem that the power system network is facing now-a day. This is a severe problem and affects the functioning of the equipment. Therefore, this problem should be mitigated in order to maintain the efficiency of the power network. The use of custom power devices solves this problem. This chapter presents the basic structure and working principle of different devices like DVR, D-STATCOM, Auto Transformer used to mitigate the voltage sag.

A. Dynamic Voltage Restorer (DVR)

A Dynamic Voltage Restorer is a power electronic converter based gadget intended to ensure the discriminating burdens from all supply-side unsettling influences other than deficiencies. It is connected in arrangement with the distribution feeder for the most part at the purpose of regular coupling.

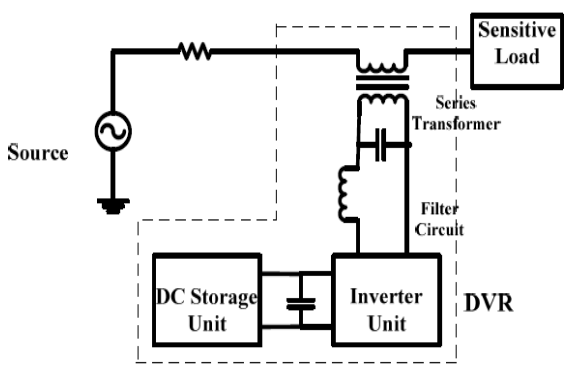

Fig. 1 Basic Structure of A DVR

The DVR is a series connected power electronic device used to inject voltage of required magnitude and frequency. The basic

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structure of a DVR is shown in Fig.1.

B. D-Statcom

A Distribution Static Compensator is in short known as D-STATCOM. It is a power electronic converter based device used to protect the distribution bus from voltage unbalances. It is connected in shunt to the distribution bus generally at the PCC.

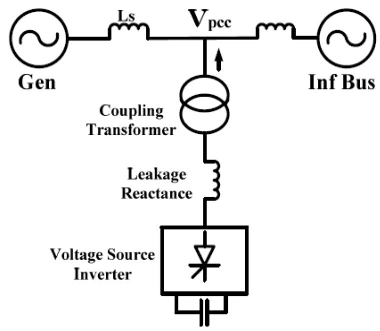

Fig. 2 Basic Structure of D-STATCOM

IV. PROPOSED SYSTEM

This project introduces a new strategy to reduce the phase unbalance of line currents in the three-phase four wire distribution networks and reducing the magnitude of neutral current by flat. The proposed approach executes phase balancing by introducing new winding connections in the ordinary two-winding transformer and therefore it provides switch-less operation. The proposed approach is self-sufficient and robust in itself such that it may relieve to take care about the phase unbalance produced in the distribution systems. The effectiveness of the proposed approach is tested for various load conditions. The simulation results show that the proposed approach is efficient and promising for phase balancing in distribution networks.

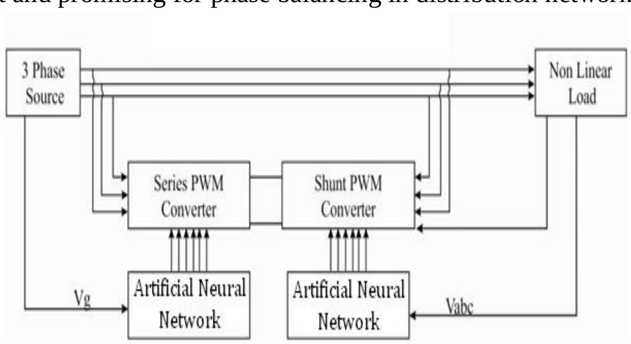

Fig. 3 Block diagram of the proposed system.

A. Artificial Neural Network (ANN)

Fig. 4 shows the structure most commonly used feed forward, multilayer, back propagation type network. The name back propagation comes from its training method. it is also called as a multilayer perception (MLP) type network. The input signals are represented as (x1, x2, x3………xn) and the output signals are represented as (z1, z2, z3………zm). In general these signals may be logical, discrete bi-directional or continuous signals. The links shown always carry the signals in the forward direction. In fact, the circles contains the summing node of the neuron with the activation function and the synaptic weights are shown by dots in the links (often dots are omitted). The network shown has three layers of neurons; input layer, hidden layer, and output layer. The hidden layer functions to associate the input and output layers. The input and output layers have neurons equal to the respective number of signals. The input layer neurons have linear activation functions with unity slope (or no activation function), but there is a scale factor with each input to convert them to per unit (normalization) signals. Similarly, the output signals are converted from per unit signals to actual signals by renormalization. Since the input layer acts as a distributor of signals to the hidden layer, it is often defined as a two layer network. A constant bias source supplies bias signals to the hidden layer and the output layer (not shown) of

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neurons through a weight. The architecture of the neural network makes it evident that basically, it is fast and massive parallel output multidimensional computing system, where computation is done in a distributed manner.

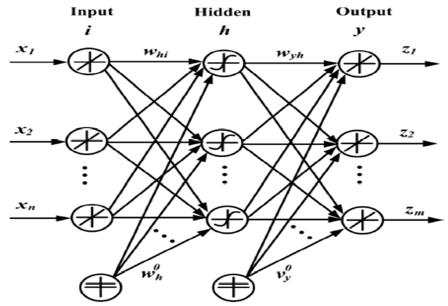

Fig. 4 Structure of Feed- forward three layer neural network

B. The Backward Propagation Algorithm

We will discuss the backdrop algorithm for classification problems. In that situation we change the activation function for output layer neurons to the identity function that has output value=input value. (An alternative is to rescale and recenter the logistic function to permit the outputs to be approximately linear in the range of dependent variable values). The backdrop algorithm cycles through two distinct passes, a forward pass followed by a backward pass through the layers of the network. The algorithm alternates between these passes several times as it scans the training data. Typically, the training data has to be scanned several times before the networks learn to make good classifications. Forward Pass: Computation of outputs of all the neurons in the network The algorithm starts with the first hidden layer using as input values the independent variables of a case (often called an exemplar in the machine learning community) from the training data set. The neuron outputs are computed for all neurons in the first hidden layer by performing.

V. SIMULATION RESULTS AND DISCUSSION

By using simulation models we can obtain the performance characteristics of the system very easily and quickly for analysis purpose. Here, we consider the performance analysis of ANN based power quality conditioning device. The output characteristics of the proposed system are shown in fig.4. From the figure, it is seen that the output voltage got sagged during the transmission. This problem is due to the non-linear load which is connected to the system.

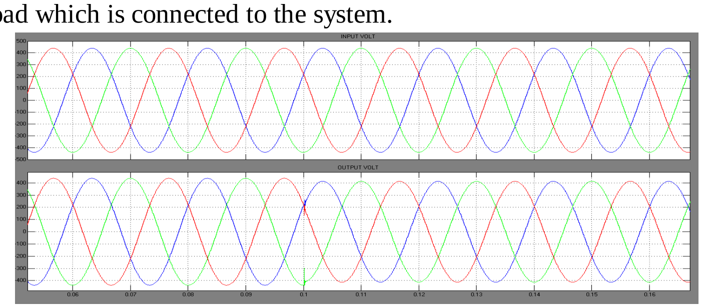

Fig. 4 System without using ANN

From the figure 5, it is seen that the output voltage remains undisturbed during the transmission, while connected with a non-linear load. By implementing UPQC in between the grid and the load, the voltage remains undisturbed.

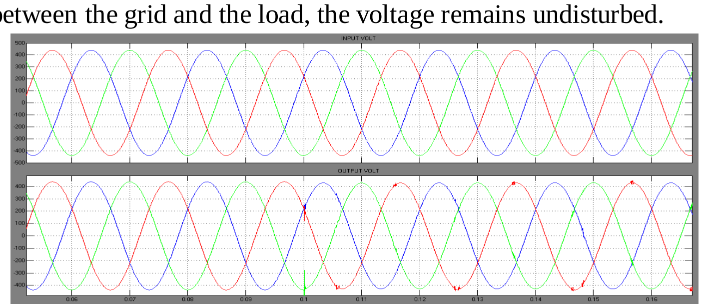

Fig. 5 System with ANN

Load	Operation	
	Without ANN	*With ANN*
Three phase load nominal voltage: 400 Vrms Frequency: 50Hz Active power: 10e3ohm	•Without ANN controller into the system, the voltage got sagged at time t=0.1sec. •voltage sag occurs.	•The voltage remains constant while the network is trained using ANN algorithm. •There is no sag in the load side voltage and amplitude remains same

VI. CONCLUSION

In the present paper two control strategies; current control strategies (id– iq) with PI and ANN with PI have been implemented for the three-phase four-wire distribution system to improve the performance under balanced, un-balanced and non-ideal supply voltage condition. The control scheme using three independent hysteresis current controllers has been implemented. The Real-time implementation and simulation results showed that even if the supply voltage is non-sinusoidal the ANN with PI shows better performance in mitigating the current harmonic than that of id–iq theory with PI controller.

Based on digital signal processing and by means of extensive experimental tests, static and dynamic performances, as well as the effectiveness of the proposed ANN based system were evaluated, validating the theoretical development.

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