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Power Quality Improvement of Unbalanced Distribution System using ANN-LMBNN based D-STATCOM

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ABSTRACT: In power distribution system most of the loads are nonlinear loads, these nonlinear loads causes voltage unbalancing in distribution system lead to major power quality problems in distribution system such as voltage swell, sag and THD, to mitigate these power quality problems a Liebenberg-Marquardt Back propagation(ANN-LMBNN) based D-STATCOM is proposed. The performance of proposed an ANN based D-STATCOM is tested on 13-bus IEEE test feeder, a D-STATCOM is placed at bus no-632.The performance of proposed ANN based D-STATCOM is compared to D- STATCOM with PI control mechanism using MATLAB-simulink .

KEYWORDS: Power Quality (PQ), D-STATCOM, ANN, MATLAB/SIMULINK

I. INTRODUCTION

Now a day's power quality is a more serious problem for consumers and power companies. The detection of power quality problem in power distribution system is more difficult. At consumer premises need to maintain ideal voltage and frequency but supply voltage we are receiving is deviating from normal voltage. In addition to this power quality problems affects more seriously to the end user. There are different types of power quality problems such as impulsive transients, oscillatory transients. Impulsive transients occurs for small duration of time. oscillatory transients occurs for long duration of time, which can damage power line insulators in distribution and transmission systems. Impulsive transients are suppressed by surge arrester. Apart from this there are different types of power quality problems .Short duration power quality problem like voltage sag and voltage swell, which lead to change in magnitude of voltage for small duration of time. Voltage sag causes loss of production in bulk industries; the voltage sag can trip motor and malfunction of its controller. The voltage swell caused more electrical stress on electrical home appliances. Voltage flickers at consumer premises are another power quality problem due to are lamps and arc furnaces. It is well understood that if we are not maintain certain power quality standards at consumer point of view there will be more loss of production, damage of equipment, to mitigate these power quality issues in distribution system the custom power devices are introduced. These custom power devices such as DVR, D-STATCOM effectively improves power quality at consumer side. The distribution system suffers from serious power quality disturbances due to nonlinear loads, which drawing harmonic currents from supply mains.

D-STATCOM is a suitable custom power device to address the power quality issues of an unbalanced distribution system and efficient device to resolve power quality issues, D-STATCOM consisting of a Voltage Source Converter (VSC) and a shunted DC link capacitor [9-10]. A D-STATCOM is reactive source, generating and absorbing reactive power. In this paper a 13-bus unbalanced distribution system is considered to address power quality problem and a D-STATCOM is connected at bus number 632.

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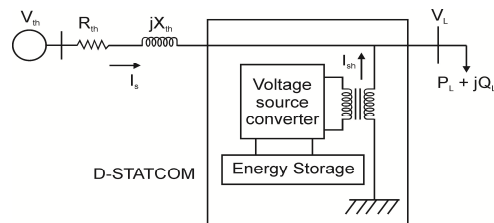


Fig.1: Block diagram of D-STATCOM

This paper is organized as follows the D-STATCOM with PI control mechanism is discussed in section II. The D-STATCOM with ANN control mechanism is discussed in section III. In section IV simulation results are presented where, the performance of D-STATCOM with ANN control technique is compared to PI control mechanism. Finally conclusions are given in section V.

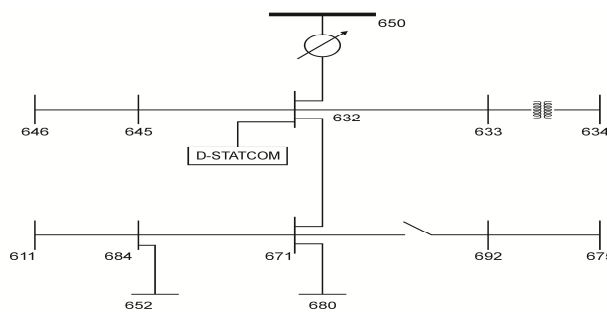


Fig-2: IEEE-13 bus unbalanced distribution system with D-STATCOM

II. CONVENTIONAL CONTROL OF D-STATCOM

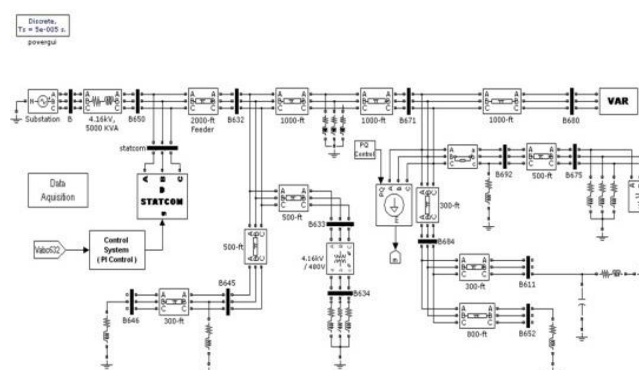


Fig-3: 13-Bus unbalanced Distribution System with D-STATCOM with PI Control Mechanism

III. D-STATCOM WITH ANN CONTROL MECHANISM

The ANN is a mathematical model composed of simple elements operating in parallel. The ANN function is nothing but connection between the elements, by altering the weights we can train a neural network for particular task [17].

In Fig-4 shows an artificial neuron with one input and bias P_i is the scalar input transmitted through connections that multiply with scalar weight W_i to get product of $W_i P_i$. The summation of all weight becomes $\sum W_i P_i$ and

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additionally adding bias input b. The result is the arrangement of transfer function Fig-4, which produces the output. We can get desired output by adjusting weights and bias of the NN [17].

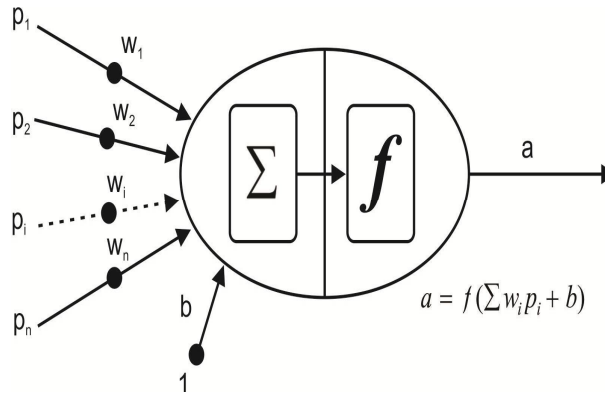


Fig-4: An artificial neuron with one input and biases

Neural networks consisting of different types of architectures. The commonly used ANN models are multi layer perception (MLP) and radial bias function (RBF) networks.

A MLP consisting of input layer, hidden layer and output layer. In Fig-5 suffix-i indicates a neuron. Numbers of input neurons are summed at summer and g is an activation function.

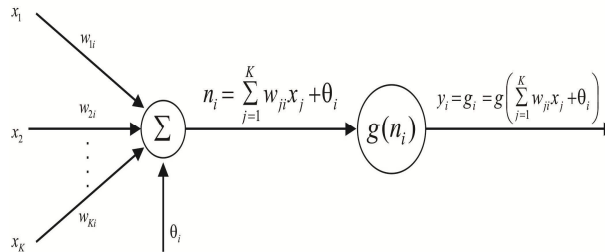


Fig-2 Single node in a Multi Layer Perceptron network

Output of the i^{th} neuron

$$U_i = g_i = g \left[\sum_{j=1}^k w_{ji} x_j + \theta_j \right] \quad (1)$$

The feed forward neural network consisting of input layer, hidden layer and output layer. The training algorithm used is iterative gradient algorithm (trainlm algorithm) to minimize the mean square error between reference signal and actual signal. The input and output at the hidden layer are designated as $y_{\text{net}-j}$ and $y_{\text{out}-j}$ respectively. The suffix j indicate j^{th} hidden layer. The input and output layer are designated as U_{net} and U_{out} respectively.

$$y_{\text{net}-j} = \sum_{i=1}^n W_{zi} Z_i \quad (2)$$

$$y_{\text{out}-j} = g(y_{\text{net}-j}) \quad (3)$$

$i = 1, 2, 3, \dots n.$

$$U_{\text{net}} = \sum_{i=1}^n W_{yi} Y_{\text{out}-j} U_{\text{out}} = g(U_{\text{net}}) \quad (4)$$

$i = 1, 2, 3, \dots n.$

$$W_{zi,j} = W_{zi,j} + \Delta W_{zi,j} \quad (5)$$

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$$W_{yi} = W_{yi} + \Delta W_{zi} \quad (6)$$

$$g(x) = \frac{2}{1 + e^{-x}} - 1$$

$W_{zi,j}$ = means of the weights between the neurons of input layer and hidden layer.

$\Delta W_{zi,j}$ = weight of i^{th} input layer neuron to the j^{th} hidden layer neuron.

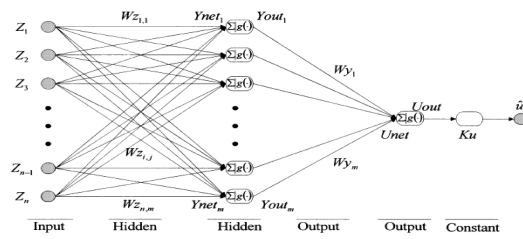


Fig. 7: Structure of ANN

IV. NEURAL NETWORK TRAINING ALGORITHM

Liebenberg-Marquardt ANN Algorithm:

In ANN there are three popular learning algorithms namely Back Propagation Algorithm (BPA), Quasi-newton (trainbpg) and *Liebenberg-Marquardt* (trainlm), the output of the network compared to desired reference target to minimize the error by adjusting the weights and biases [17]. This is the only algorithm which gives best regression accuracy. In this method global error E is defined as [17].

$$E = \frac{1}{2} \sum (t_j - y_i)^2$$

Where t_j is targeted output and y_i is the actual output. This algorithm is a combination of steepest descent method and the Gauss-Newton algorithm.

The weight up gradation can be represented by

$$\Delta w_{yi} = -\mu \cdot \frac{UE}{UW_{yi}}$$

The up gradation of weight between input neurons and hidden layer are updated by the following

$$\Delta w_{zi,j} = -\mu \cdot \frac{UE}{UW_{zi,j}}$$

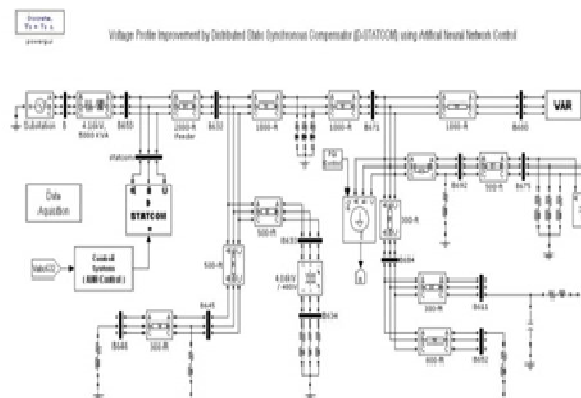


Fig-5:13-Bus unbalanced Distribution System with D-STATCOM with ANN Control Mechanism

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V. SIMULATION RESULTS

In this work a D-STATCOM with ANN control mechanism have been proposed to improve power quality (voltage swell, voltage sag) of 13-bus IEEE distribution system. Simulations are performed using MATLAB SIMULINK. The performance of proposed D-STATCOM with ANN control technique is compared to D-STATCOM with PI control technique.

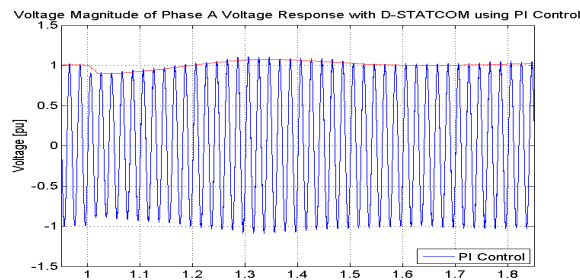


Fig-6: Illustrates mitigation of voltage sag of phase-A from source side using D-STATCOM with PI control mechanism.

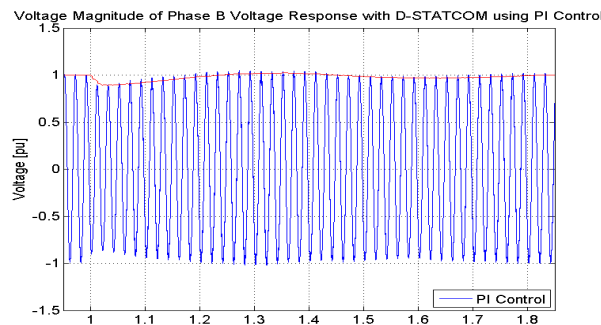


Fig-7: Illustrates mitigation of voltage sag of phase-B from source side using D-STATCOM with PI control mechanism.

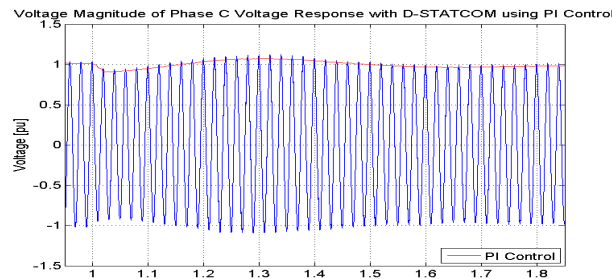


Fig-8: Illustrates mitigation of voltage sag of phase-C from source side using D-STATCOM with PI control mechanism.

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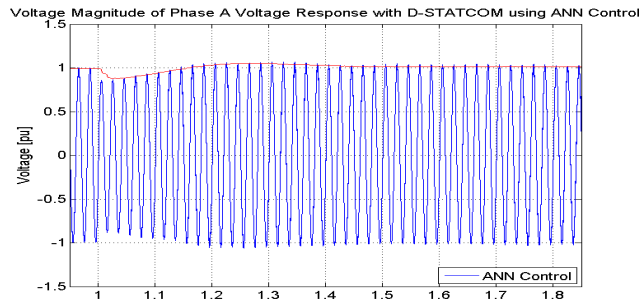


Fig-9: Illustrates mitigation of voltage sag of phase-A from source side using D-STATCOM with ANN control mechanism

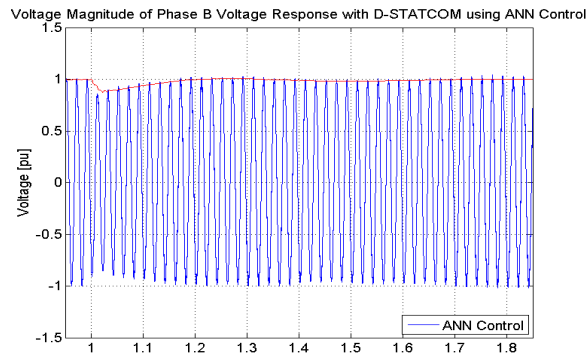


Fig-10: Illustrates mitigation of voltage sag of phase-B from source side using D-STATCOM with ANN control mechanism

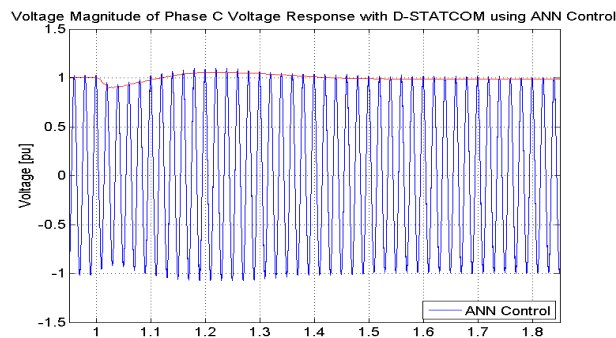


Fig-11: Illustrates mitigation of voltage sag of phase-C from source side using D-STATCOM with ANN control mechanism

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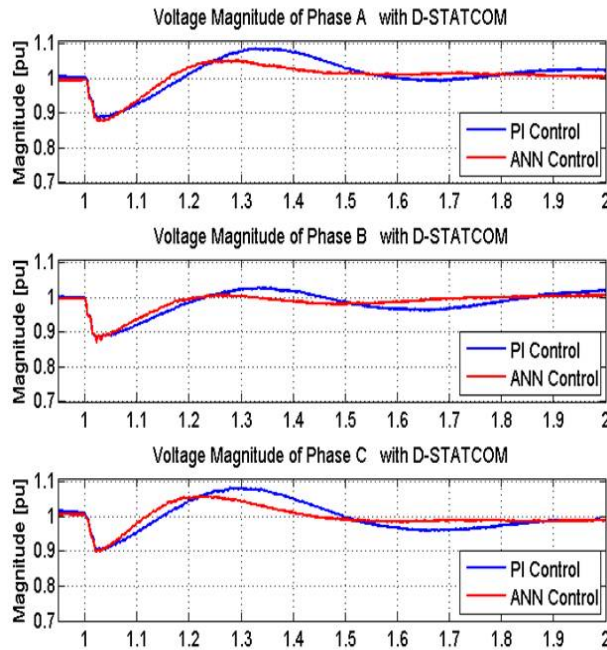


Fig-12: Illustrates mitigation of voltage sag of phase A, B, C from source side using D-STATCOM with PI & ANN control

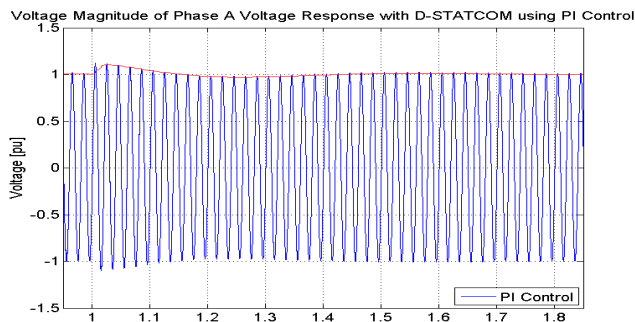


Fig-13: Illustrates mitigation of voltage swell of phase-A from load side using D-STATCOM with PI control mechanism.

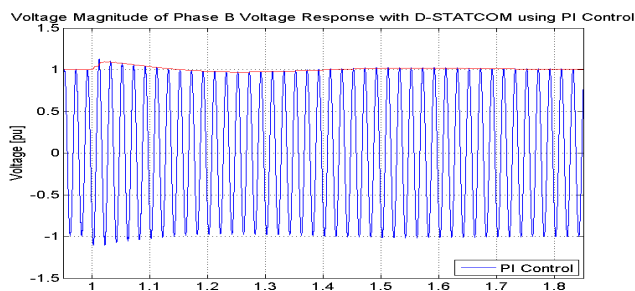


Fig-14: Illustrates mitigation of voltage swell of phase-B from load side using D-STATCOM with PI control mechanism.

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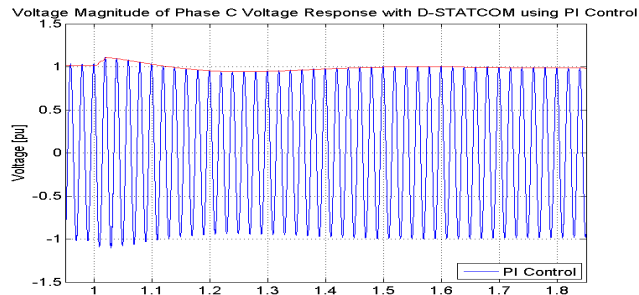


Fig-15: Illustrates mitigation of voltage swell of phase-C from load side using D-STATCOM with PI control mechanism

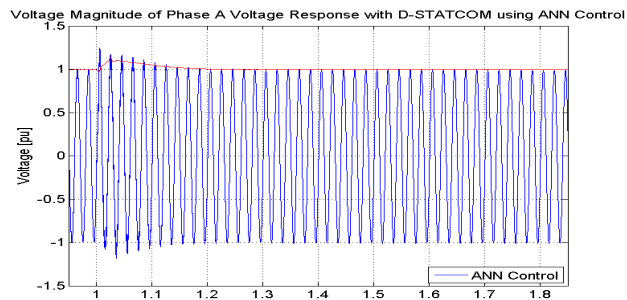


Fig-16: Illustrates mitigation of voltage swell of phase-A from load side using D-STATCOM with ANN control mechanism

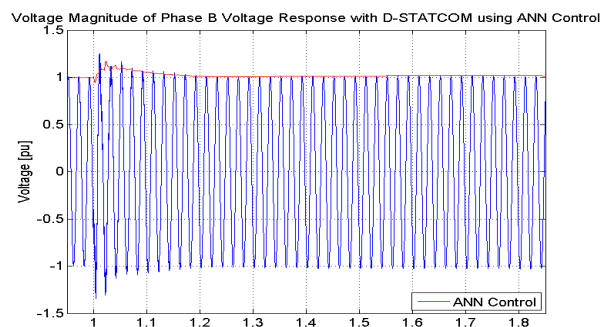


Fig-18: Illustrates mitigation of voltage swell of phase-C from load side using D-STATCOM with ANN control mechanism

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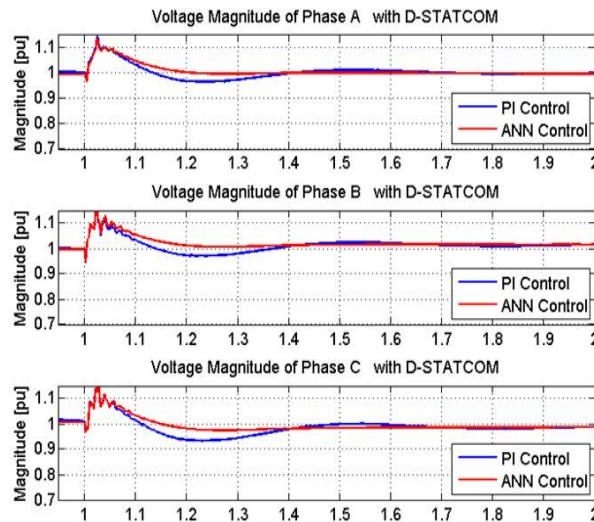


Fig-19: Illustrates mitigation of voltage swell of phase A, B, C from load side using D-STATCOM with PI & ANN control.

Table-1: Comparison of power quality parameters when sag occurs in the distribution system.

Voltage sag with different controllers	Phase- A		Phase- B		Phase- C	
	Overshoot(sec)	%THD	Overshoot(sec)	%THD	Overshoot(sec)	%THD
PI controller	18.38	3.02	20.14	5.23	16	5.04
LMBNN-ANN Controller	0.699	1.35	1.8264	1.24	1.84	1.69

Table-2: Comparison of power quality parameters when swell occurs in the distribution system.

Voltage Swell with different controllers	Phase A		Phase B		Phase C	
	Over shoot	%THD	Over shoot	%THD	Over shoot	%THD
PI controller	18.3	6.38	20.1	6.02	16	3.28
LMBNN-ANN Controller	13.5	1.19	17.3	1.07	14.6	0.4

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VI.CONCLUSION

In this paper for enhancement of power quality of distribution system a 13- bus system is considered. An ANN control based D-STATCOM is introduced at bus number-632 of 13-bus IEEE test feeder system. The performance of proposed method is compared with PI based D-STATCOM. Simulation results revealed that the proposed intelligent control methodology based D-STATCOM can tackle power quality issues such as voltage sag, voltage swell at all bus considerably. An ANN based D-STATCOM is quite capable of suppressing voltage swell and voltage sag compared to PI based D-STATCOM.

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