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STATCOM Based Multilevel Inverter Modelling and Simulation

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***Abstract-** The desired reactive power can be provide by exchanging the instantaneous reactive power among the system. A cascaded multilevel inverter type STATCOM is implemented with an isolate DC energy storage. To generate gate pulses for cascaded H-bridge type of multilevel inverter a Level shifted pulse-width modulation technique is employed which reduces harmonics and also the voltage at the output can be maintained. This topology for applying STATCOM together with ANN controller for injecting reactive power gives effective results.*

***Keywords:** Artificial Neural network (ANN), Cascade H-bridge (CHB), phase opposition disposition (POD) and Total Harmonic Distortion (THD).*

I. INTRODUCTION

To increase the efficiency of the power system operation produced by deregulation of the industries, many transformations were carried out in the electrical utilities arrangement [1]. Adapting to patterns and methods of generation need changes, transmission system require greater capacity and flexibility. Additional demands are constantly being made on utilities for supplying increasing loads and improving reliability. FACTS is nothing but a collection of different types of controllers which has the capability to coordinate with other controllers and it can also inter relate to other system parameters they are real and apparent power, impedances like shunt and series.This paper consists of six parts: with the introduction from section – I, section – II provides system description, section – III presents multilevel inverter introduction, Section-IV explains the ANN controller, Section-V discusses the simulation and results and finally in Section VI conclusions are presented.

II. SYSTEM DESCRIPTION

Voltage source inverter is the main part of STATCOM in order to produce VAR.

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Applying multi-pulse inverters to STATCOM has demonstrated and the better output waveform can be obtained by increasing the pulse number with lesser harmonics and filtering requirements, but it requires other components that adds to costs.

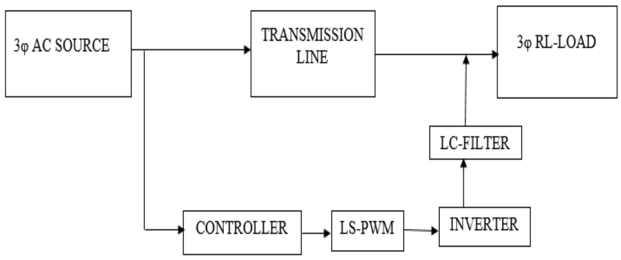


Fig.1. Schematic diagram of proposed system

The power from the source will be transmitted to load from 3-phase source through transmission line. During the transmission of power there may be losses due to faults then the current flowing through the line is lowered therefore STATCOM equipped with voltage source converter is connected in shunt with the system also acts as reactive power compensator.

III. MULTI-LEVEL INVERTER

A MLI is an electrical device which converts dc power to ac power. Available multilevel inverters are classified as follows.

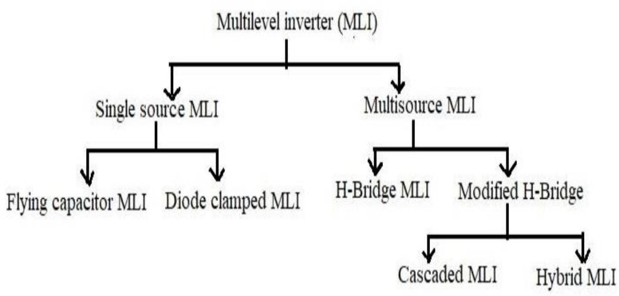


Fig: 2 Classification of MLI

A seven level VSC made of three H-Bridges with three distinct sources is shown in below figure. The no of carrier waveforms to be used depends on the required no of gate pulses. Six different carrier signals will be needed to achieve a seven level output. The available voltage is divided into three distinct sources, thus reducing the voltage to be handled by the switches [2].

Even though the switches required are greater in number but the rating of these switches will be lowered significantly.

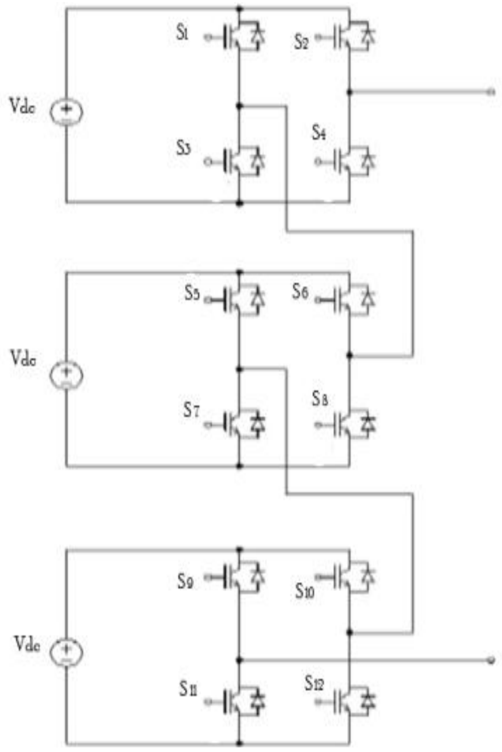


Fig.3 Seven level CHB MLI

In this paper, level-shift PWM is explored among available PWM strategies [3]. The classification of PWM techniques is shown in above figure. Depending on how the carrier waveforms are arranged in relation to each other, it can be further classified into sub types.

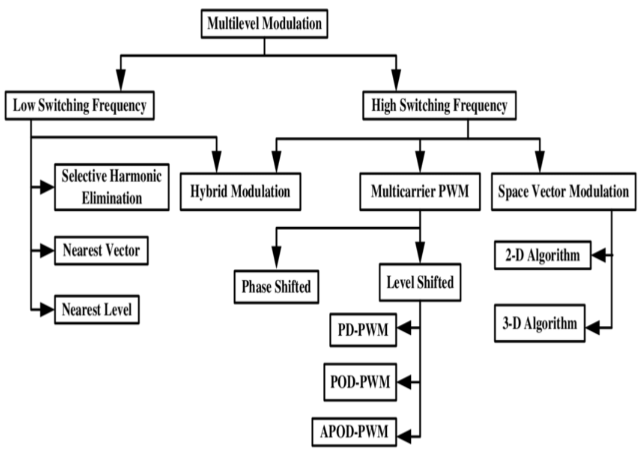
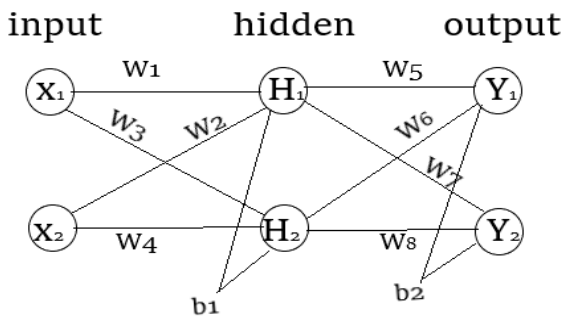


Fig.4 Classification of modulation techniques for MLI

IV. ANN CONTROLLER

A neural network is an interconnection of nodes, similar to the human brain's vast neuron network. An ANN is the mapping that is accomplished by adjusting the data weights of their internal parameters. This process is called the process of training or learning [4]. Back propagation (BP) is an algorithm to adjust the weight of neurons. BP applies a weight correction to the connection weights of the neural network that is proportional to the partial derivative of the error function.

The most commonly used technique for updating neural network weight parameters is the back propagation learning algorithm. While straightforward, it has a slow rate of convergence can sometimes diverge.



Forward:

$$H_1=X_1W_1+X_2W_2+b_1$$

Activation function, Sigmoid $= \frac{1}{1+e^{-x}}$

$$outH_1= \frac{1}{1+e^{-H1}}$$

$$H_2=X_1W_3+X_2W_4+b_1$$

$$outH2= \frac{1}{1+e^{-H2}}$$

$$Y_1=outH_1W_5+outH_2W_6+b_2$$

$$outY_1=\frac{1}{1+e^{-Y1}}$$

$$Y_2=outH_1W_7+outH_2W_8+b_2$$

$$outY_2=\frac{1}{1+e^{-Y2}}$$

Calculating total error, $E_{total}=\sum\frac{1}{2}(\text{target} - \text{output})^2$

$$E_{total}=\frac{1}{2}(T_1 - outY_1)^2+\frac{1}{2}(T_2 - outY_2)^2$$

$$E_1=\frac{1}{2}(T_1 - outY_1)^2 ,$$

$$E_2=\frac{1}{2}(T_2 - outY_2)^2$$

Backward: To update their weights

Consider W_5

Error at W_5, $\frac{\partial E_{total}}{\partial W_5}=\frac{\partial E_{total}}{\partial outY_1} * \frac{\partial outY_1}{\partial Y_1} * \frac{\partial Y_1}{\partial W_5}$

$$\frac{\partial E_{total}}{\partial outY_1} = 2 * [\frac{1}{2}(T_1 - outY_1)^{2-1}]*(-1) + 0$$

$=-(T_1 - outY_1)$

Updating W_5, $W_5 = W_5 - (\eta * \frac{\partial E_{total}}{\partial W_5})$

Now at hidden layer updating W_1, W_2, W_3 and W_4

Consider W_1

Error at W_1, $\frac{\partial E_{total}}{\partial W_1} = \frac{\partial E_{total}}{\partial outH_1} * \frac{\partial outH_1}{\partial H_1} * \frac{\partial H_1}{\partial W_1}$

$$\frac{\partial H_1}{\partial W_1} = \frac{\partial}{\partial W_1}(X_1W_1 + X_2W_2 + b_1) = X_1$$

$$\frac{\partial outH_1}{\partial H_1} = \frac{\partial}{\partial H_1}\left(\frac{1}{1+e^{-H_1}}\right) = outH_1 * (1 - outH_1)$$

Now, $\frac{\partial E_{total}}{\partial outH_1} = \frac{\partial E_1}{\partial outH_1} + \frac{\partial E_2}{\partial outH_2}$

$$\frac{\partial E_1}{\partial outH_1} = \frac{\partial E_1}{\partial Y_1} * \frac{\partial Y_1}{\partial outH_1}$$

$$\frac{\partial E_1}{\partial Y_1} = \frac{\partial E_1}{\partial outY_1} * \frac{\partial outY_1}{\partial Y_1}$$

Updating W_1,

$$W_1 = W_1 - (\eta * \frac{\partial E_{total}}{\partial W_1})$$

Using the Back propagation algorithm (BPA) [5], the network is trained online. The THD can be effectively reduced with an ANN controller than PI controller. MATLAB simulation results tested the STATCOM performance and the results confirm that using ANN controller.

V. SIMULATION AND RESULTS

The proposed concept is designed and it is simulated using MATLAB. Using the VSC MLI type, without employing a coupling transformer the STATCOM can be connected directly to the system. A STATCOM consists mainly of a voltage source converter that is seven-level CHB MLI. For var compensation in STATCOM this selected VSC is employed.

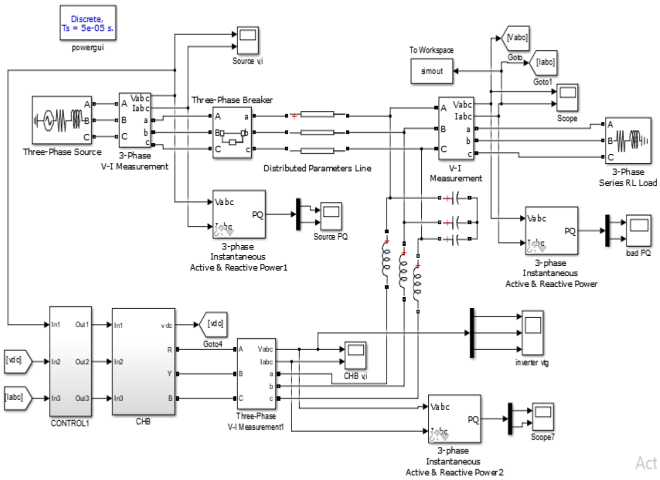


Fig.5 Simulink model of the system

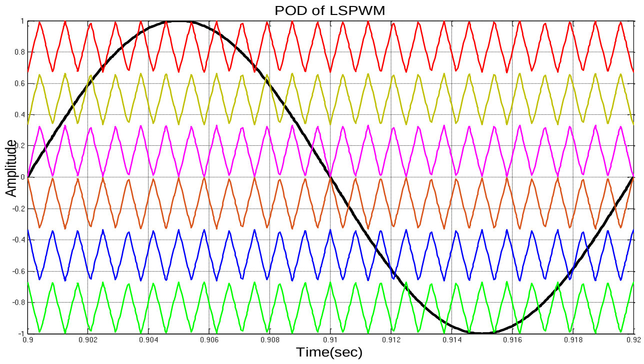


Fig.6 LS-PWM with POD technique

By using POD technique, the PWM output is generated.

For level Shifted PWM (LS PWM),

$$n_{carriers} = n_{voltage\ levels} - 1$$

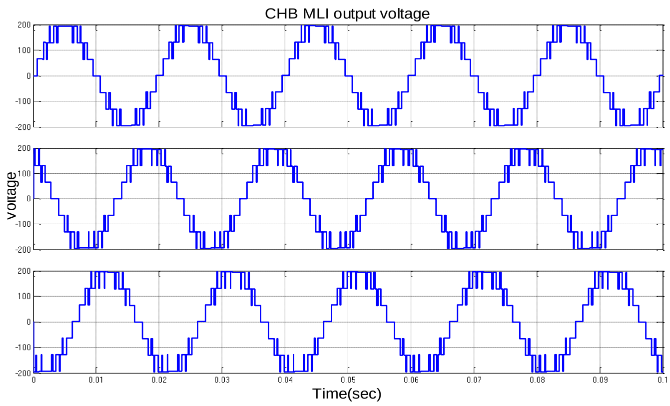


Fig.7 Seven level CHB MLI

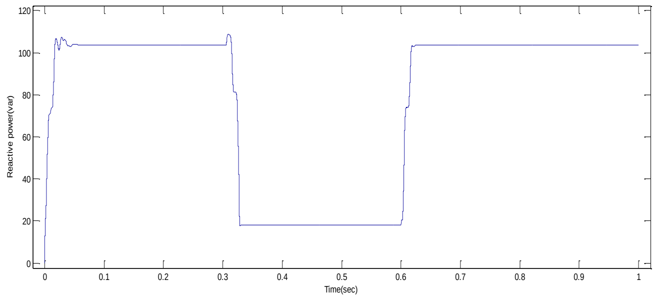


Fig.8 Source side Reactive power plot during fault

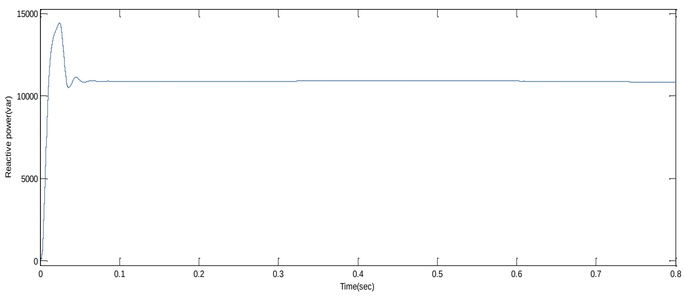


Fig.9 Load side reactive power plot during fault

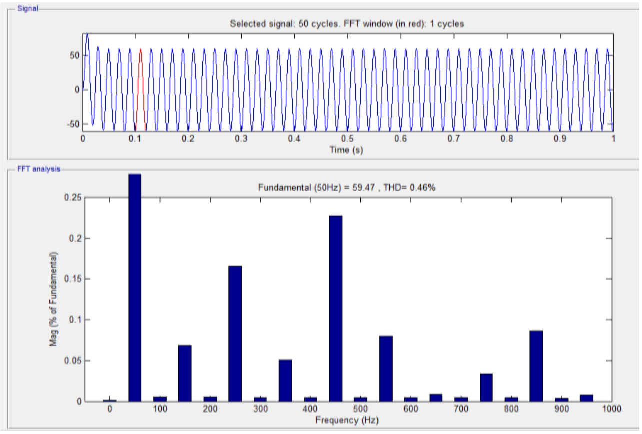


Fig.10 THD analysis of Voltage at load

VI. CONCLUSION

A 3 phase seven level CHB MLI with SPWM phase disposition control was presented in this paper to achieve high quality output signals with very low THD i.e 0.46% due to its design. By using STATCOM which improves the system dynamics by injection of active power and the seven level CHB type MLI performance shows the plot of reactive power at load side is in steady state condition even though the system reactive power changes.

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