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Enhance Cascaded H-Bridge Multilevel Inverter with Artificial Intelligence Control

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ABSTRACT

This paper proposed a 7-level Cascaded H-Bridge Multilevel Inverter (CHBMI) with two diffenrent controller, ie, PID and Artificial Neural Network (ANN) controller to improve the output voltage performance and achieve a lower Total Harmonic Distortion (THD). A PWM generator is connected to the 7-level CHBMI to provide switching of the MOSFET. The reference signal waveform for the PWM generator is set to be sinusoidal to obtain an ideal AC output voltage waveform from the CHBMI. By tuning the PID controller as well as the self-learning abilities of the ANN controller, switching signals towards the CHBMI can be improved. Simulation results from the general CHBMI together with the proposed PID and ANN controller based 7-level CHBMI models will be compared and discussed to verifyl the proposed ANN controller based 7-level CHBMI achieved a lower output voltage THD value with a better sinusoidal output performance.

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1. INTRODUCTION

Inverters are the power electronic circuit, which converts the DC voltage into AC voltage. It can also say that is transfers or converts power from a DC source to an AC load. Inverters usually gives output in the form of square wave, quasi-square wave or low distorted sine wave. However, the inverter is generally not ideal because the ideal output voltage waveform of an inverter should be a sinusoidal waveform. With the help of drives of the switches in control circuit or smoothing circuit, the output voltage can be controlled [1]. Inverters are widely used in many technologies such as multiple renewable energy applications. There are many kinds of inverter designs and the most common and well-known topology used nowadays is the H-bridge topology [2].

Cascaded H-bridge Multilevel Inverter (CHBMI) is one of the basic and well-known topology among others multilevel inverter and was first proposed in 1975 [3]. It synthesizes a desired AC voltage from several levels of DC voltages. In the past several years, this type of inverter has been the subject of research, where the DC levels were identical by using either batteries, solar cell, etc. [4] It can support both single and three phase conversions and it contain the H-bridge cells. The CHBMI was first proposed in 1975 and it uses multiple units of H-bridge power cells and connected in a series chain to produce high AC voltages from separate DC sources. The series H-bridge was the first topology introduced and more configurations have been developed for this topology and the DC sources can be any natural resource such as sunlight, wind energy or other energies.

The term H Bridge is derived from the typical graphical representation of the circuit which built with four switches and four diodes which more ideal to a sinusoidal output waveform. Also, it does not need any capacitors or diodes for clamping. Different combination of the switch position will determine three different voltages; positive voltage, negative DC and zero. The output of each H-bridge cells will form three discrete levels and by connected several H-bridge inverters in series a staircase waveform which is nearly sinusoidal is provided even without the use of filter [5]. The output voltage generated by this multilevel inverter is the sum of all the voltages generated by each cell. By using the formula 2k+1, where k=number of cell, we can obtain the total output voltage generated.The output AC waveform is more sinusoidal in nature even if no filter is applied. Due to their advantages, they are often used now-a-days. Pulse Width Modulation (PWM) control techniques are most commonly used to control the output voltage of inverters. Whenever the output voltage waveform is not sinusoidal, it means that the inverter contains harmonics. These harmonics can be reduced by using proper control schemes [2],[6]-[7].

PID is a control-loop feedback mechanism and frequently used in industrial control systems. This controller required precise mathematical model of the system, which is difficult to calculate and obtain. A conventional CHBMI is controlled by using a frequency response based linear controller, PID controller has weakness in performing multiple control and has low dynamic response. To overcome the shortage of the PID controller, this research presents an ANN controller which work same as the PID controller, but it solves problems with its self-learning capabilities. The advantages of the ANN controller over the PID controller are; it does not need precise mathematical model and it is more robust than the PID controller. Thus, the weakness of the PID controller can be solved by the proposed AI based controller [8]-[9].

The study is design to simulate the 7-level CHBMI using MATLAB Simulink and to develop a proposed ANN controller algorithm for the 7-level CHBMI to achieve lower output voltage THD and improve the output voltage performance. The output finding has been investigate and verified the performance of the proposed ANN CHBMI by simulation testing. The performance of both PID and ANN controllers are compared and analyzed based on the output voltage performance and THD value. Results verified the effectiveness of the proposed ANN controller thus the proposed idea.

2. 7- LEVEL CHBMI WITH PROPOSED ANN CONTROLLER

The different type of 7-level CHBMI models proposed in this research is developed by using MATLAB programming tool. The PWM generator model is built to achieve a better switching towards the CHBMI and causes a better output quality and waveform to be formed. The block diagram of the open-loop general 7-level CHBMI is shown in Figure 1.

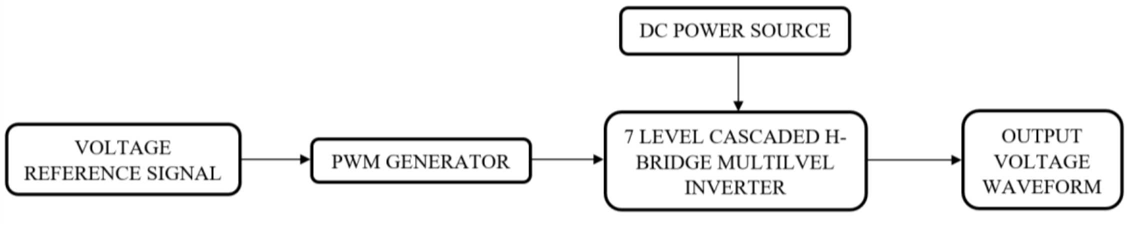

Figure 1. General 7-level CHBMI Block Diagram

The block diagram of a complete closed-loop 7-level CHBMI with the proposed controller either PID or ANN is shown in Figure 2. The output signal of PID/ANN controller provide the modulating signals to the PWM generator and thus a better output is then produced. In addition, the output of the 7-level CHBMI is given to a load through RLC filter to obtain a sinusoidal output waveform.

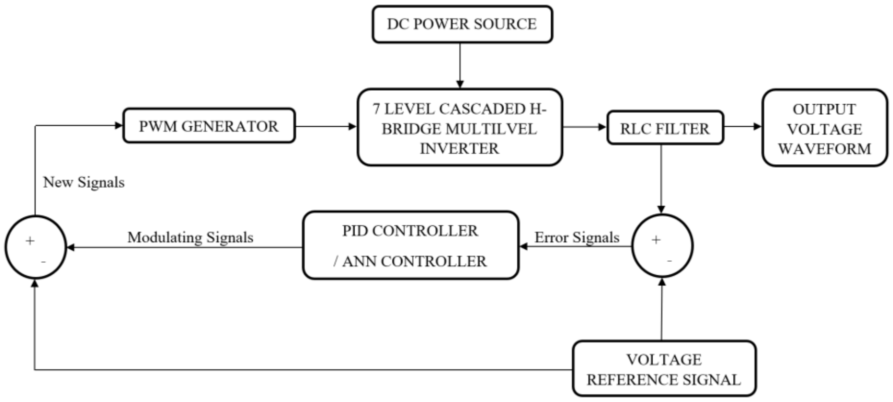

Figure 2. 7-level CHBMI with PID/ANN Controller Block Diagram

2.1. Structure of ANN Controller

The input and output of the ANN controller in the system is design to have same number of input and output neuron at each layer. To design the ANN controller, the numbers of input and output neuron at each layer must equal to the number of input and output signals of the system respectively. To achive a harmonic minimization of 7-level CHBMI, a multilayer perceptrons neural network control is developed to deal with the complexity of the system and the ANN training accuracy. Based on the type of the task to be performed, the structure of the proposed 7-level CHBMI is as shown in Figure 3 [10].

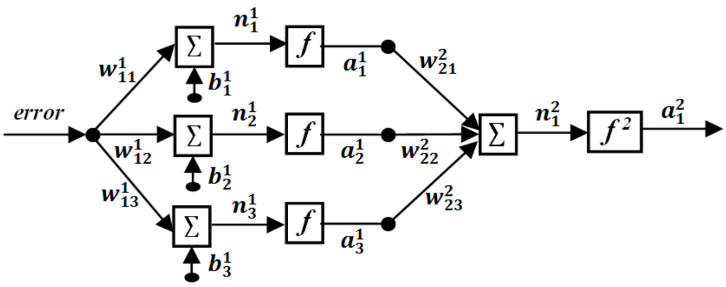

Figure 3. ANN Controller Block Diagram

A 1-3-1 ANN controller network structure is defined based on the number of neuron in the input layer, hidden layer and output layer respectively. The first neuron of the output layer is used as input to feed the PWM generator to generate switching signal for the proposed CHBMI. The connections weight parameter between jth and ith neuron at mth layer is given by wmij, while bias parameter of this layer at ith neuron is given by bmi. Transfer function of the network at ith neuron in mth layer is defined by:

$$n_i^m = \sum_{j=1}^{S^{m-1}} w_{ij}^m a_j^{m-1} + b_i^m$$

The output function of neuron at mth layer is given by:

$$a_i^m = f^m(n_i^m)$$

where f is activation function of the neuron. In this design the activation function of the output layer is unity and for the hidden layer is a tangent hyperbolic function given by:

$$f^m(n_i^m) = \frac{2}{1+e^{-2n_i^m}} - 1$$

3. RESULTS AND ANALYSIS

The general 7-level CHBMI model is shown in Figure 4. In the 7-level CHBMI model, there are four MOSFETs and separate DC sources that designed in the H-bridge cell. Due to the open loop in general 7-level CHBMI, a reference signal is feed directly to the PWM generator to generate the switching signal to feed the MOSFET.

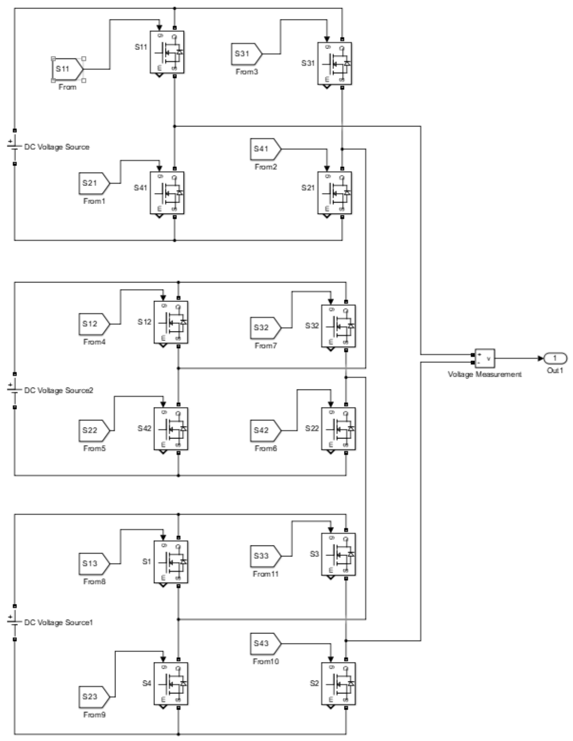

Figure 4. General 7-level CHBMI Model

The overall output voltage waveform obtained is shown in Figure 5. The FFT analysis from powergui block analyzed the THD at the 23rd cycle with 1500 Hz as the maximum frequency. FFT parameters remains the same for all the analysis. It is observed that the output voltage THD value is 13.87% for the general 7-level CHBMI which shown in Figure 6.

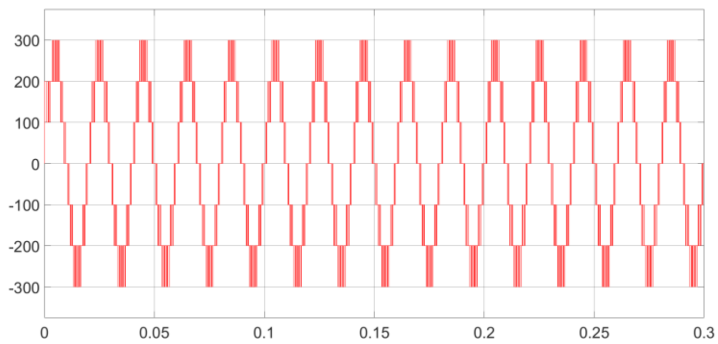

Figure 5. Output Voltage Waveform from General 7-level CHBMI

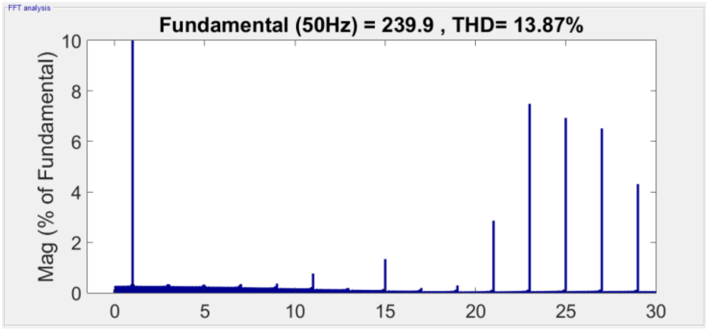

Figure 6. Output Voltage THD from General 7-level CHBMI

A PID controller is added to the general 7-level CHBMI to form a closed-loop system which is shown in Figure 7. The output voltage waveform is shown in Figure 8. One can observed that the output voltage THD value is reduced to 6.91% for the PID based 7-level CHBMI as shown in Figure 9.

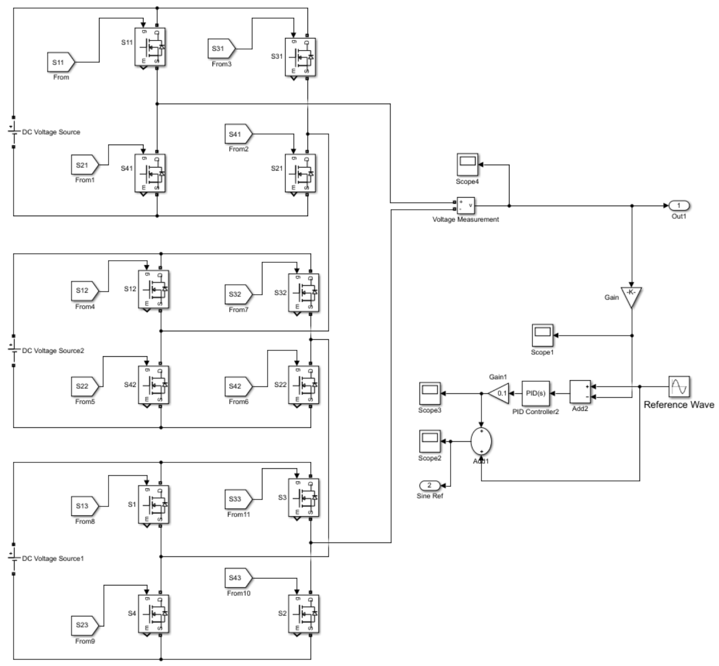

Figure 7. 7-level CHBMI Model with PID Controller

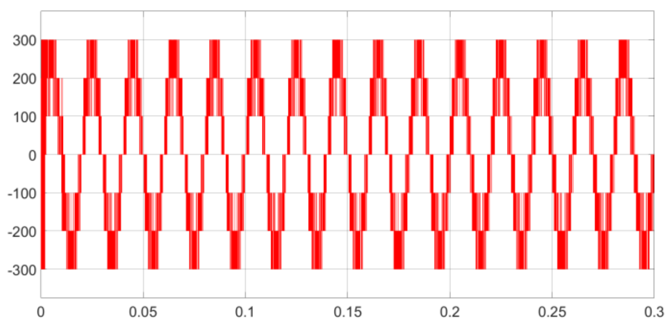

Figure 8. Output Voltage Waveform from 7-level CHBMI with PID Controller

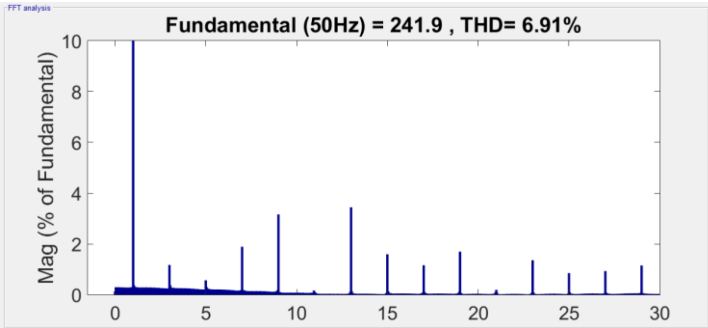

Figure 9. Output Voltage THD from 7-level CHBMI with PID Controller

The proposed ANN based 7-level CHBMI with ANN Controller and RLC Filter is shown in Figure 10. A RLC filter was added to the ANN based 7-level CHBMI where the parameter used is shown in Table 1. The sinusoidal output waveform is then obtained as shown in Figure 11. It can observed that the output voltage THD value is 2.28% for the ANN based 7-level CHBMI with RLC filter as shown in Figure 12.

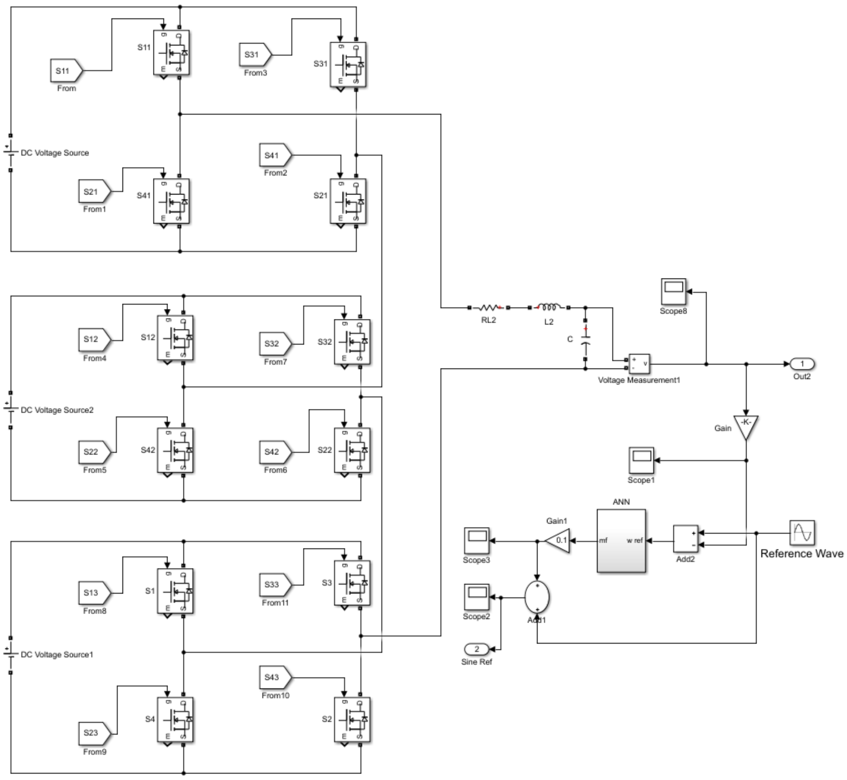

Figure 10. 7-level CHBMI Model with ANN Controller and RLC Filter

Table 1. Parameter in RLC filter.

Parameters	Values
Load inductor	15mH
Load capacitor	20μF
Load resistor	100Ω

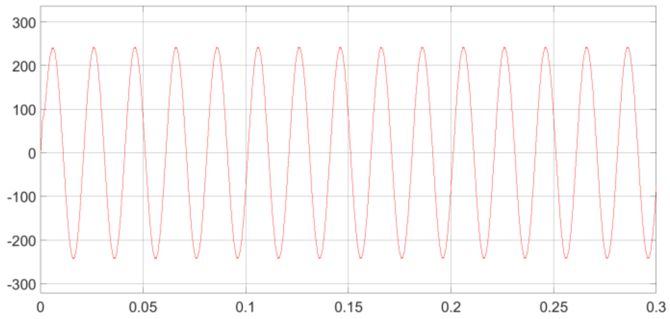

Figure 11. Output Voltage Waveform from 7-level CHBMI with ANN Controller and RLC Filter

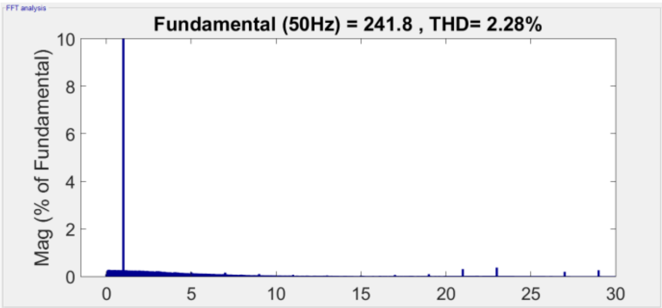

Figure 12. Output Voltage THD from 7-level CHBMI with ANN Controller and RLC Filter

Results of the THD value for general CHBMI, PID based CHBMI and proposed ANN based CHBMI has been compared and summarized in Table 2. The findings clearly show that the THD value is reduced after the implementation of the PID controller from 13.87% to 6.91%. The ANN based CHBMI with RLC filter shows a significant low THD value of 2.28% which is less than 5% that adopted by IEEE 519-1992 standard under voltage distortion limits [11]. In additional, it is observed that a better sinusoidal overall output voltage waveform is obtained as the THD value decreases. Hence, from all the observed results, the output voltage THD value are reduced and a most sinusoidal waveform is obtained by using the proposed ANN controller.

Table 2 . Simulation Summary.

Type of CHBMI	THD %
General CHBMI	13.87
CHBMI + PID Controller	6.91
CHBMI + AI Controller + RLC Filter	2.28

4. CONCLUSION

In this research, the performance of the proposed ANN controller and PID controller based 7-level CHBMI has been studied. Based on the self-learning ability of the ANN controller it overcome the shortage of a PID controller which has weakness in low dynamic response. The simulations test for general 7-level CHBMI together with the proposed PID and ANN controller based 7-level CHBMI have been carried out and the simulation results are compared and analyzed. From the obtained simulation results, it is found that the proposed ANN controller performs better than PID controller. The ANN controller provides output voltage with relatively better sinusoidal waveform and lower THD value. The output voltage THD from both controller with 7-level CHBMI and RLC filter satisfies the IEEE-519 constraints. The ANN controller is more responsive than PID controller in feedback and modulate errors because it learns from experience as it is trained through data set in supervised learning based on back-propagation model of neural networks which also make it more suitable for industrial control applications that facing unknown disturbance and having uncertainties from the environment. Lastly, the objectives of this research had achieved based on the results. The performance and effectiveness of the proposed 7-level CHBMI system is verified as it had produce a lower output voltage THD and better sinusoidal output waveform.

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