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Development of Artificial Intelligence Based Multilevel Inverter Using MATLAB/Simulink

Chamarthi Savitri
Department of Electrical Engineering
Tulsiramji Gaikwad College Of Engineering and Technology
Mohagaon, Wardha Rd, Nagpur, Maharashtra 441108

Prof. Chetan Jambhulkar
Assistant Professor, Electrical Engineering, TGPCET, Nagpur, India.

Abstract - The research focuses on the development and evaluation of a multilevel inverter. Multilevel inverters have certain advantages but also face challenges such as harmonic injection and low output voltage, which limits their suitability for certain projects. To overcome these limitations, the proposed inverter design reduces the number of switches and incorporates a robust controller. Two control approaches, a conventional Proportional-Integral (PI) controller and an Artificial Intelligence-based Artificial Neural Network (ANN) with a feed-forward architecture, are developed and implemented. The goal is to address the drawbacks of traditional multilevel inverters through the suggested inverter design coupled with the controller-based system. The study identifies renewable energy applications, specifically solar photovoltaic systems, as potential markets for the newly proposed inverter. The performance of the novel inverter design is demonstrated and verified through experimentation using hardware or MATLAB/Simulink simulations with various input parameters.

Keywords - Artificial Intelligent (AI); neural network; feed-forward architecture controller; MATLAB/SIMULINK.

INTRODUCTION

This advancement in inverter technology has paved the way for the development of multilevel inverters, which have become increasingly popular due to their ability to generate high-quality output waveforms and their compatibility with renewable energy sources. However, these multilevel inverters still face challenges such as switching losses and lower reliability compared to single-level inverters. To address these challenges, researchers have proposed various strategies to mitigate harmonics in multilevel inverter circuits. One approach is to develop innovative theories for selecting optimal switching patterns that filter out specific harmonics, such as the fifth, seventh, eleventh, and thirteenth harmonics. By carefully selecting these switching patterns, it is possible to reduce the total harmonic distortion of the converter circuit's output voltage within the tolerance limits set by IEEE 519. Furthermore, the topology of multilevel inverters has evolved from initially supporting only two levels to now supporting more than two levels. This multilevel inverter topology enables the generation of a pure sinusoidal waveform at the output voltage while simultaneously reducing output noise and operating frequency. Overall, the literature highlights the importance of addressing harmonics in multilevel inverter circuits to improve power quality and system efficiency. The advancements in inverter technology, particularly in the development of multilevel inverters, offer significant potential for applications in renewable energy sources and industrial process control.

A. Proposed artificial intelligence controller-based multilevel harmonic filter.

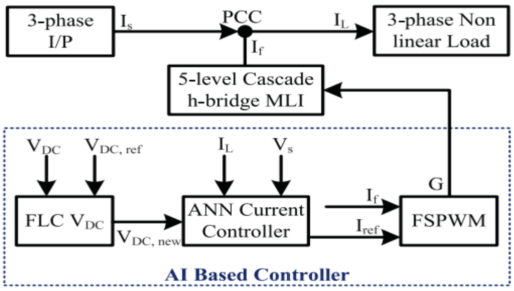

Fig. 1 Block diagram of Artificial Intelligence (AI) based controller for the multilevel harmonic filter.

Figure 1 illustrates the Cascade H-bridge inverter (CHB) filter and the AI-based control mechanism for the proposed harmonic filter. By increasing voltage and switching frequency, this method enhances compensation performance compared to a 2-level filter while reducing switching stress at higher frequencies and the number of required filter inductors. However, due to the increased number of inverter-switching states, filters based on Multilevel Inverters (MLIs) can be more costly and challenging to maintain. Nevertheless, the cost-effectiveness and performance justify their use in medium and high-voltage, high-power applications. To enhance reference extraction and compensation, this approach combines Artificial Neural Networks (ANNs) with Fuzzy Logic Controllers (FLCs). One FLC regulates the DC voltage, while another generates gate pulses for the IGBTs in the inverter. The Cascaded H-bridge Multilevel Inverter (CHBMLI) architecture simplifies control by eliminating clamping diodes. Harmonic cancellation is applied at the Point of Common Coupling (PCC) to improve current quality and power factor. The ANN is a suitable choice due to its adaptability and ability to manage harmonics. It continuously analyses load current and dynamically adjusts parameters. ANNs can adapt rapidly to changing conditions and estimate Fourier coefficients without relying on a mathematical model. Uncertainties are addressed using fuzzy logic-based controllers. FLCs receive linguistic input from ANNs trained with data from PI controllers. The integrated approach, which includes ANN-based harmonic extraction and FLCs for voltage and current management in Multilevel Inverter-based Active Power Filters (MLI-APF), proves efficient, flexible, and quicker due to reduced voltage controller count through batch control techniques.

In this approach, the CHB filter is used in combination with an artificial intelligence (AI) based control mechanism to enhance compensation performance and reduce switching stress. The CHB filter is capable of increasing voltage and switching frequency, which improves compensation performance compared to a 2-level filter. This also reduces the number of required filter inductors and switching stress at higher frequencies. However, it should be noted that the increased number of inverter-switching states in filters based on Multilevel Inverters (MLIs) can make them more costly and challenging to maintain. Despite this, the cost-effectiveness and performance of MLIs justify their use in medium and high-voltage, high-power applications. To enhance reference extraction and compensation, this approach combines Artificial Neural Networks (ANNs) with Fuzzy Logic Controllers (FLCs). The FLCs are responsible for regulating the DC voltage and generating gate pulses for the IGBTs in the inverter. This simplifies control by eliminating clamping diodes. Harmonic cancellation is applied at the Point of Common Coupling (PCC) to improve current quality and power factor. The ANN is chosen for its adaptability and ability to manage harmonics. It continuously analyzes the load current and dynamically adjusts parameters. ANNs can adapt rapidly to changing conditions and estimate Fourier coefficients without relying on a mathematical model. Fuzzy logic-based controllers are used to address uncertainties. The FLCs receive linguistic input from ANNs that are trained with data from PI controllers.

The integrated approach, which includes ANN-based harmonic extraction and FLCs for voltage and current management in Multilevel Inverter-based Active Power Filters (MLI-APF), proves to be efficient, flexible, and quicker due to the reduced voltage controller count through batch control techniques. This approach combines the use of CHB filters and AI-based control mechanisms to improve compensation performance and reduce switching stress in multilevel inverters. The CHB filter allows for increased voltage and switching frequency, leading to better compensation performance compared to traditional 2-level filters. It also reduces the number of required filter inductors and switching stress at higher frequencies. However, it is important to note that the increased number of inverter-switching states in multilevel inverters can make them more expensive and challenging to maintain. Despite this, the cost-effectiveness and performance of multilevel inverters justify their use in medium and high-voltage, high-power applications. To enhance reference extraction and compensation, this approach combines artificial neural networks (ANNs) with fuzzy logic controllers (FLCs). The FLCs regulate the DC voltage and generate gate pulses for the inverter's IGBTs, simplifying control by eliminating the need for clamping diodes. Harmonic cancellation is applied at the Point of Common Coupling (PCC) to improve current quality and power factor. The ANN is chosen for its adaptability and ability to manage harmonics. It continuously analyzes the load current and dynamically adjusts parameters. ANNs can quickly adapt to changing conditions and estimate Fourier coefficients without relying on a mathematical model. Fuzzy logic-based controllers are used to address uncertainties, with the FLCs receiving linguistic input from ANNs trained with data from PI controllers. The integrated approach, which includes ANN-based harmonic extraction and FLCs for voltage and current management in multilevel inverter-based active power filters, proves to be efficient, flexible, and quicker due to the reduced voltage controller count through batch control techniques.

B. Proposed System

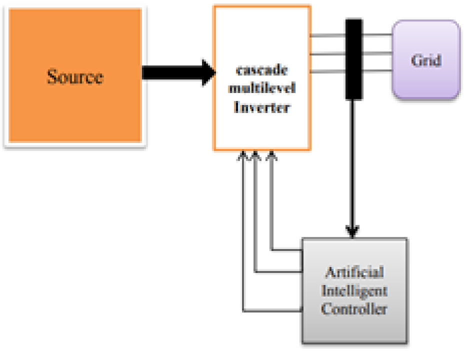

Fig.2 Block diagram of the proposed system

According to research, a 7-level cascade multilevel inverter provides the highest level of efficiency by balancing lower harmonic distortion at lower levels with lower switching losses at higher levels. In a solar-powered setup, an artificial intelligence-based controller controls the inverter bridge's firing using an ANN-based tactic. Although a higher-rated PV array with a forward converter may potentially be appropriate, separate PV arrays are used to provide dedicated DC supply for each H-bridge. The 7-level cascade multilevel inverter is triggered by the AI controller using the modulation index at the best firing angles (1, 2, 3, 4, and 5). As seen in the given block design, the entire system is capable of integrating with a nano grid.

C. Literature Survey

[1] Bushra Masri et al 2022 Modular

At first, inverters provided the aid stack structure with a lifeline during breakdowns. However, inverter technology has rapidly advanced, revolutionising their possibilities. Two-level inverters were common in the past, although they had drawbacks including unbalanced current and voltage fluxes inside the circuit. Innovations have enabled the development of multilevel inverter topology, which can deliver a pure sinusoidal output voltage while lowering noise and operating frequency, to address these problems.

[2] Abualkasim Bakeer et al 2021

This study addresses the problems with model predictive control (MPC) when system parameters are unclear. MPC is sensitive to parameter changes even though it provides quick answers and trustworthy tracking. An artificial neural network (ANN)-based model-free control strategy is suggested as a solution to this. The ANN is initially trained using data produced by MPC. The method is evaluated using MATLAB/Simulink on a three-cell flying capacitor inverter, revealing greater robustness against parameter fluctuations and decreased total harmonic distortion when compared to traditional MPC. Its usefulness when used with a DSP controller is confirmed by Hardware-in-the-Loop (HIL) simulation.

[3] Matthew Baker et al 2020

The extensively used cascaded multi-level inverter (CMI) in the field of power electronics has complicated semiconductor components, making it difficult to identify and repair internal flaws. The goal of this study is to quickly identify and categorise internal faults in CMIs using a recurrent neural network (RNN) with long short-term memory (LSTM). By differentiating between internal faults and potentially disruptive events in power electronic distribution grids (PEDGs), the RNN-LSTM system intends to improve the security of both the digital and physical layers of PEDGs and prevent infrastructure disruptions.

[4] Y.W. Sea et al 2019

In contrast to a standard cascaded H-bridge MLI, the 15-level asymmetrical multilevel inverter (MLI) shown in this paper uses fewer switches to produce an uneven sinusoidal output voltage. This 15-level MLI accomplishes its waveform with just 10 switches (16.67% fewer than CHBMLI). A particle swarm optimization-based selective harmonic minimization pulse-width modulation method is used to establish precise switching angles, which are essential for obtaining low total harmonic distortion (THD) (SHMPWM). The MLI can produce an output waveform that resembles a sinusoidal wave at a modulation index of 0.70, according to simulation findings performed with PSIM. Using the same circumstances, the performance of the MLI is further validated over a range of inductive loads.

C. Objectives

MLI topologies have advantages like better harmonic profiles, higher efficiency, and increased voltage capacity. Cascaded MLI (CMLI) is particularly promising because to its modular nature for modulation, control, and protection. High-power applications frequently use it because of its favourable input/output current and voltage characteristics. Space-vector modulation (SVM) is frequently utilised for harmonic performance, but other pulse-width modulation (PWM) techniques, such as multiple-carrier PWM, are also used. Lower switching frequencies in multilayer schemes are required in high-power scenarios such as HVDC transmission because the topology's resilience to high input voltage is crucial. MLI topologies that are often used include the diode-clamped, flying capacitor, multicellular, cascaded, and hybrid H-bridges. Traditional inverters include issues such high THD, increased switching stress, and restrictions for high-voltage applications.

SIMULATION RESULT

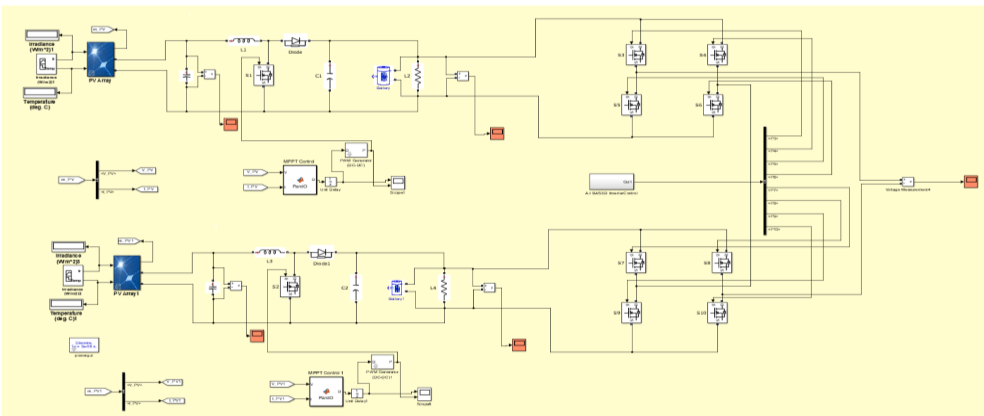

Fig. 3 Simulation model of AI Based Inverter Control Block

Fig. 3 displays the multilevel inverter simulation model. They may be easily connected to clean energy sources like wind turbines, solar panels, and fuel cell systems. Multilevel inverters outperform traditional two-level pulse width modulated (PWM) converters in terms of effectiveness and the waveforms they produce.

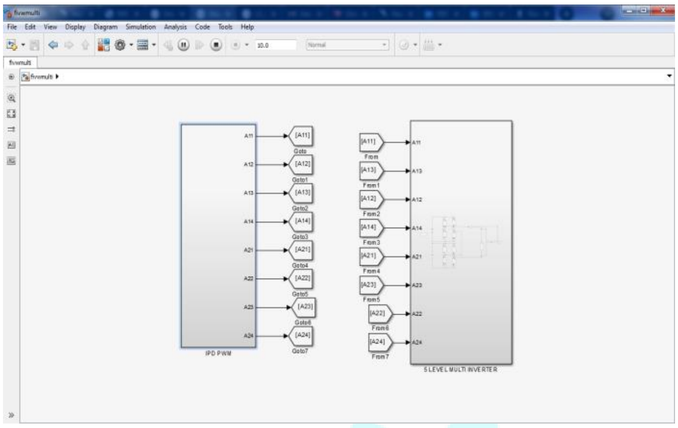

Fig. 4 Simulation model of the IPD PWM with Multi Level Inverter

The performance of the new inverter design is illustrated and tested across a wide range of input values using MATLAB/Simulink simulations.

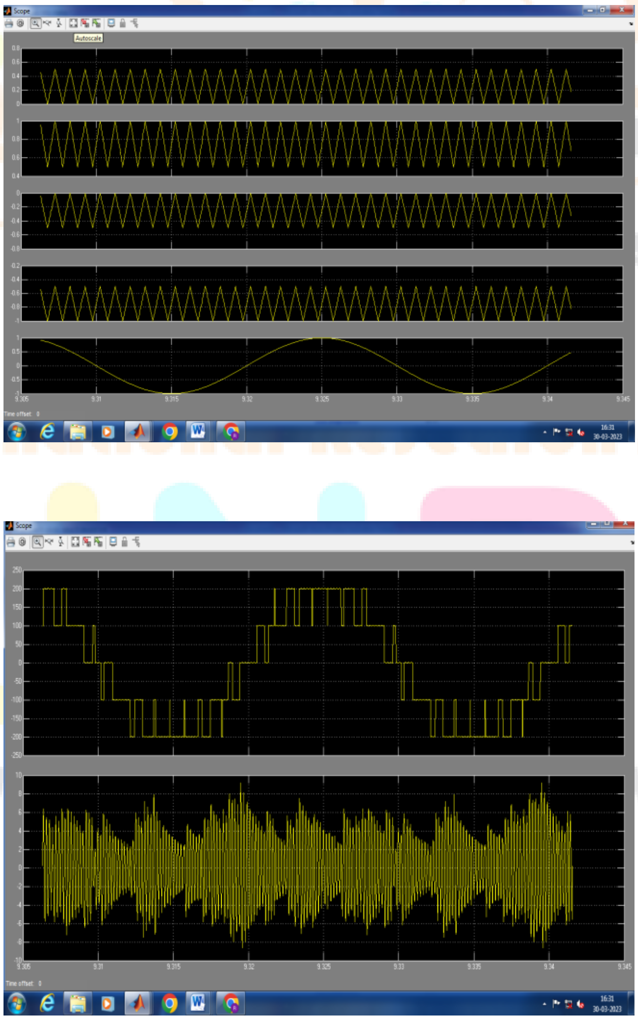

Fig. 5 Simulation Output

Figure 5 depicts the outcome. As a result, a multilevel inverter topology has recently been developed in current inverters to allow for a maximum of seven stages, allowing for the transmission of a pure sinusoidal waveform at the voltage that is output while also lowering resultant noise and the frequency in which it is functioning.

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