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# Development of Artificial Intelligence Based Multilevel Inverter Using MATLAB/Simulink

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***Abstract*— This study focuses on the development and evaluation of a multilevel inverter, comparing it with the latest iterations of multilevel inverters and verifying its performance using ONLT-PWM. Multilevel inverters offer several advantages but suffer from limitations such as harmonic injection and low output voltage, making them unsuitable for certain projects. To address these limitations, the proposed inverter topology incorporates a reduced number of switches and a sophisticated controller. Two control approaches, a traditional Proportional-Integral (PI) controller and an Artificial Intelligence-based Artificial Neural Network (ANN) with a feed-forward architecture, are trained and implemented. The proposed multilevel inverter, along with the controller-based system, aims to eliminate the shortcomings associated with traditional multilevel inverters. Renewable energy applications, particularly solar photovoltaic systems, are identified as suitable areas of application for the proposed multilevel inverter. The performance of the new inverter design is demonstrated and validated using either hardware or MATLAB/Simulink simulations, considering a range of input values.**

***Keywords*— Artificial Intelligent (AI), neural network - feed-forward architecture controller, MATLAB/SIMULINK**

## I. INTRODUCTION

The literature of this century has extensively discussed the depletion of natural resources, environmental consequences, the increasing demand for alternative energy sources, and the challenges associated with meeting this demand. One of the key issues in power systems is the degradation of power quality and system efficiency caused by unwanted harmonic components generated by non-linear electronic equipment. To address these challenges, researchers have proposed various approaches, and multi-level converters are gaining popularity as effective power interfaces. These converters offer higher efficiency, improved output waveforms, and seamless integration with renewable energy sources such as PV arrays, wind turbines, and fuel cells. However, the use of multi-level inverters comes with its own challenges, including higher switching losses and lower reliability due to the increased number of power semiconductor devices required. The problem of harmonics in multi-level inverter circuits needs to be addressed, and researchers have developed the elimination theorem to identify optimal switching patterns for filtering out specific harmonics. However, as the number of DC sources increases in multi-level inverters, solving the associated system of equations becomes more complex. Inverter technology has evolved from converting AC to DC power supplies. Traditional two-level inverters have limitations, including inharmonic voltages and current flows. To overcome these limitations, multilevel inverter topologies have been developed, allowing for the delivery of pure sinusoidal waveforms at the output voltage while reducing noise and minimizing accidents. Harmonics remain a challenge in multi-level inverters due to their multiple stages. Artificial intelligence-based switching schemes have emerged as effective solutions to eliminate harmonics. Among the various topologies, the cascaded H-Bridge topology is widely used due to its flexibility, ease of use, and elimination of additional components. There are two main types of cascaded H-Bridge inverters: symmetrical and asymmetrical topologies. Asymmetrical inverters offer a wider range of voltage waveforms with a smaller physical footprint compared to symmetrical inverters. This paper focuses on the construction of a nine-level cascaded H-Bridge inverter using the Optimal Nearest Level Pulse Width Modulation (ONLT-PWM) approach. This approach reduces the number of switches and DC sources while allowing for precise calculation of switching states and duty cycles. To address system issues, a new controller methodology based on a PI controller and an AI-based ANN approach is proposed. The proposed methodology results are verified through simulations using MATLAB. Artificial intelligence techniques, particularly artificial neural networks (ANNs), play a significant role in solving real-world problems associated with multi-level inverters.

## II.Literature Survey

a. Bushra Masri et al 2022 Modular

Multi-Level Inverters (MLI) has become of great importance for electrical energy supplement to grids due to their modularity, low Total Harmonic Distortion (THD), and require fewer filters, Multi-Level Inverters (MLI) have emerged as a critical component of electrical energy augmentation of networks. Nonetheless, For multilayer inverters to generate high voltage, a greater number of power switches must be used, which increases the likelihood of malfunctions and failures. Open-Circuit (OC) faults are a common kind of failure in active electronics and have been the subject of a lot of studies. Thus, this study provides an in-depth discussion of the methodologies including Artificial Intelligence (AI) algorithms for diagnosing and pinpointing OC failure in various multilevel inverter topologies. At first, we identify and briefly explain two basic categories of fault diagnostic approaches for OC switch failure. Thereafter, we have a lengthy discourse about AI algorithms. Also, specific criteria with several standards are developed to discriminate amongst tactics explored in publishing.

b. Abualkasim Bakeer et al 2021

Power electronics have made extensive use of model predictive control (MPC) because of its intuitive nature, rapid dynamic response, and reliable reference tracking. Yet it has parametric uncertainties since it depends on the Modeling of the system mathematically allows us to anticipate the best possible switching states at the next sampling period. That's why it's so important to have well-defined parameters; otherwise, you end up with a poorly-designed MPC. This research thus proposes an ANN-based model-free control technique for reducing the inverter's sensitivity to parameter mismatching while maintaining a high level of performance. There are two interconnected steps to this procedure. As a first step, we employ MPC as an expert controller of the investigated converter to generate data for later use in training the suggested ANN. In this example, a four-level, three-cell flying capacitor inverter is used. In this research, the suggested technique is simulated using MATLAB/Simulink under a range of realistic operating circumstances. The simulation results are then reported and compared to those of the conventional MPC scheme, showing that the proposed control strategy outperforms the conventional MPC in terms of robustness against parameters mismatch and low total harmonic distortion (THD), particularly when changes are made to the system's parameters. Moreover, Hardware-in-the-Loop (HIL) simulation utilising the C2000TM-microcontroller-LaunchPadXL TMS320F28379D kit is used to offer experimental validation of the proposed technique, showing that the ANN-based control strategy can be applied to a DSP controller.

c. Matthew Baker et al 2020

In a grid where power electronics are preponderant, the cascaded multi-level inverter (CMI) is finding widespread use (PEDG). These classes of power converters have more semiconductor components, which increases the need for fault identification, isolation, and self-healing. However, both the digital and physical layers of the PEDG are vulnerable to assault. If these hostile behaviours aren't identified and categorised quickly, they may have disastrous consequences for the electricity infrastructure. Due to inherent flaws in the inverters, anomaly identification and categorization in PEDG is notoriously difficult. The primary goal of this research is to develop a recurrent neural network (RNN) using long short-term memory (LSTM) to identify and classify internal errors in CMI and differentiate them from harmful activity in PEDG. The proposed anomalous classification framework is an inverter module that communicates with systems for intrusion detection in the PEDG secondary control layer.

d. Y.W. Sea et al 2019

To create an output voltage waveform with asymmetrical sinusoidal components, a typical asymmetrical cascaded H-bridge multilevel inverter (CHBMLI) uses a cascade of twelve power switches. There are fifteen-volt levels. This study details the workings of and the results obtained from an asymmetrical 15-level multilevel inverter (MLI) that uses fewer power switches. As compared to the CHBMLI, the 15-level asymmetrical MLI requires just 10 power switches, a reduction of 16.67%. To get an output voltage waveform with minimal total harmonic distortion, the switching angles used in the MLI must be correctly calculated, making the computation of switching angles another crucial part of MLI design (THD). In this study, the best switching angles for the 15-level asymmetrical MLI are determined using a selective harmonic minimization pulse-width modulation (SHMPWM) approach based on particle swarm optimization (PSO). To verify the efficacy of the ideal switching angles used in the 15-level asymmetrical MLI, a PSIM simulation model is built. Simulation findings reveal that at modulation index 0.70, the 15-level asymmetrical MLI may generate a staircase output voltage waveform resembling a sinus wave utilising PSO-based SHMPWM optimised switching angles. This is in addition to the 15-level asymmetrical MLI's performance validation using a variety of inductive loads at the same modulation index.

## III.Proposed artificial intelligence controller-based multilevel harmonic filter

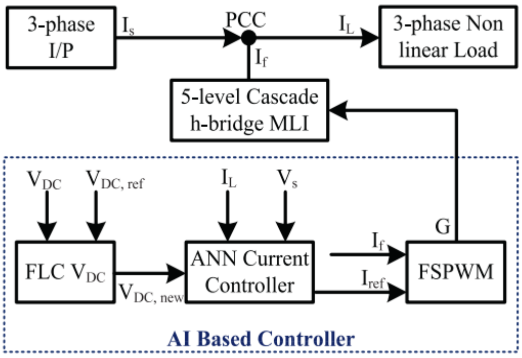


Fig 1 . Block diagram of Artificial Intelligence (AI) based controller for the multilevel harmonic filter.

See Figure 1 for an explanation of the proposed harmonic filter's Cascade H-bridge inverter (CHB) filter and AI-based control system. The suggested approach improves compensation performance over a 2-level filter with less switching stress at higher frequencies and fewer filter inductors. with increased voltage and switching frequency. Nevertheless, due to the increased number of inverter-switching states, MLI-based filters are often more costly and more to regulate. Also, the cost and performance of using these filters at medium and high voltage at high power levels is justifiable.

The suggested method employs an artificial neural network to modify the instantaneous power theory and extract the reference/compensating component (ANN). Moreover, the approach employs not one but two distinct Fuzzy Logic Controllers (FLC): one to regulate dc voltage (Vdc), and another to generate gate pulses for the IGBTs in the inverter circuit (Fig. 1). CHBMLI has a simple modular design because it eliminates the need for clamping diodes, which simplifies the control system. By injecting the harmonic cancellation component into the power circuit at the point of common coupling (PCC), the suggested harmonic filter may lessen harmonic distortion in the current and boost the power factor. The artificial intelligence controllers suggested here are reliable, can work without a mathematical model, and are flexible enough to deal with uncertainty. It is the ANN's flexibility and ability to separate harmonics that lead to its selection.

The ANN keeps a constant eye on the harmonic content of the load current. ANN learns from this stream of data in real-time and makes corrections to the controller's settings as needed. In contrast to more conventional controllers like PI or low/high pass filters, ANNs may be quickly adjusted to new conditions. By using an ANN, estimating the Fourier coefficients that correspond to harmonics is a simple and fast process. As a bonus, the mathematical model is not necessary to build the ANN. Thus, we are deciding upon and developing the ANN. A basic control structure that takes into account uncertainties may be designed with the help of a fuzzy logic-based controller. Thus, the dc side capacitor voltage equilibrium and current error correction for modulation are handled by a controller based on fuzzy logic. These controllers feature a verbal rather than a mathematical mapping between input and output, requiring far less tuning work. Data from the PI controller's performance is utilised to train an ANN, which in turn provides FLC with linguistic data. Including ANN-based harmonic extraction through IPT, FLC for voltage and current management for MLI-based APF, and their respective synergies, the proposed approach is both more efficient and flexible. Also, the system is quicker because of a reduction in the number of voltage controllers according to the batch control technique of voltage regulation.

## IV.Proposed System

While overall harmonic distortion is greater at lower levels and switching losses are larger at higher levels, research indicates that an 11-level cascade multi-level inverter is the most efficient design. The inverter bridge in this suggested approach of a solar-powered 11-level cascade multi-level inverter is fired using an ANN-based control strategy. Each H-bridge in a multilevel inverter needs its own dedicated DC supply, which comes from the PV array. As a result, individual PV arrays have been deployed for each Hbridge.

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One higher-rated PV array with a forward converter may do this. Below is a block schematic of the suggested plan for your perusal. An artificial intelligence-based controller has been fed the modulation index at the output bus of 11 levels cascades multi-level inverter. The 11-level cascade multi-level inverter is activated by the AI controller at the optimal firing angles of 1, 2, 3, 4, and 5. A nano grid may serve as an interface for the whole system.

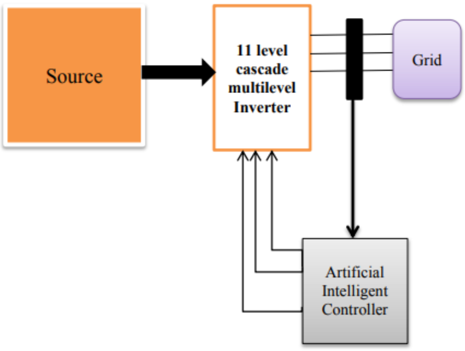


**Fig. 1 Block diagram of the proposed system**

V.Objectives

1. The main purpose of a multilevel inverter is to provide sinusoidal waveforms with low-level harmonic content to reduce distortion in a grid and maximize power efficiency
2. To reduce the number of power switches used with the help of new multilevel inverter topology 3. To study the performance of an 11-level inverter with the help of MATLAB/SIMULINK.
4. To get better the output by synthesizing a staircase waveform imitate a sinusoidal waveform. That waveform has low distortion and also reduces the dv/dt stress

The benefits of multilevel inverter topologies include greater voltage capabilities, higher efficiency, and a better harmonic profile. Although many designs for multilevel inverters (MLIs) have been proposed, the cascaded MLI (CMLI) looks to be the most promising owing to the modular nature of modulation, control, and protection needs of each full bridge inverter, it is widely employed in comparison to other inverter topologies in applications with large power ratings (FBI). It has excellent input and output current and voltage. Multiple-carrier pulse-width-modulation (PWM) systems provide the basis of several MLI-specific modulation techniques (PWM). The carriers may be positioned in two different ways: vertically and horizontally. In addition, the MLI operation makes considerable use of space-vector modulation (SVM), which provides excellent harmonic performance. When it comes to high-power applications like HVDC transmission, the topological structure of a multilayer inverter must be able to withstand very high input voltage. As a result of the multilayer strategy, the switching frequency of each switching device should be decreased. Diode-clamped, flying capacitor, multicell, cascaded H-bridge, and hybrid H-bridge multilevel topologies are only some of the more prevalent ones. Common issues with traditional inverters include Things like THD in which the output voltage is larger, switching pressures on switching devices are increased, and the output voltage cannot be increased for high voltage applications.

VI.Methodology

Novel topologies, such as those implemented using transformers or the pseudo-Zsource approach, have been suggested as a means of overcoming the constraints of currently existing multilevel inverters. It is important to note that switched-capacitor multilevel inverters, more especially the series-parallel form utilised in MLIs, have recently risen in favour. The H-bridge found at the end of a multilevel inverter must tolerate significant voltage surges while the system is collecting power. Studies are conducted on various topologies focused on minimising the number of separate dc sources, power switches, diodes, and capacitors to achieve a low-cost, space-saving design with low total standing voltage and low total power losses. The suggested structures are often modular and adaptable, allowing for cascading or arrangement to offer a wide variety of voltage levels to increase and approach the sinusoidal output voltage for medium- and high-power applications such as electric motors, solar PV integrated systems, and the like. Expert systems (ES), fuzzy logic (FL), artificial neural networks (ANN or NNW), and genetic algorithms (GA) are just a few examples of artificial intelligence approaches that have found widespread use in power electronics and motor drives in recent years. The purpose of artificial intelligence is to impart some kind of human or natural intellect into a computer so that it can reason like a person. The capacity to learn, self-organize, and adapt to its environment are common descriptors of an "intelligent system," which is generally synonymous with a system that has embedded computational intelligence. The merits of computational intelligence have been argued at length, and this may continue indefinitely. No one disputes, however, that computers may possess sufficient intelligence to aid us in resolving issues that are challenging to resolve through more conventional means. Multilevel inverters currently on the market cannot increase voltage. Since the voltage produced by PV panels and fuel cells is not high enough, converters developed for these systems will need to be able to enhance the voltage before they can be integrated with the grid. To provide just one example, various topologies may increase voltage. Seven-level MLIs are also capable of delivering a voltage gain of between 1.5 and 3. As a bonus, SCMLIs with nine output voltage levels may give a voltage gain of between 2 and 4. The next sections focus on SCMLIs, which are described because of their built-in voltage-boost capabilities. Because of the drawback of limited voltage gain in some MLI topologies, even when using a large number of power switches and isolated dc sources, significant attention has recently been directed towards the switched-capacitor multilevel inverter, a promising compact module with voltage boosting capability that requires the fewest number of dc sources.

## VII.Conclusion

As compared to more traditional inverter topologies, the asymmetric cascaded multilevel inverter that uses the VFPSPWM approach has several benefits. There is a significant drop in the number of necessary parts. Also, the performance of the is improved with the VFPSPWM technique's incorporation. Increases of up to a factor of three are possible with induction motors. Having fewer toque ripples allows machinery to run more smoothly. Since the inverter's THD and switching losses are kept to a minimum, the inverter's efficiency is increased. Thus, the suggested topology is a viable option for power-intensive tasks.

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