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

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***Abstract*— In this study, we will plan and examine the operation of a Multilevel inverter. A comparison is made between the suggested inverter and the most recent iteration of multilevel inverters, and the results are verified by means of ONLT-PWM. A controller-based system can improve output and control. In the proposed topology, we have trained and implemented both a PI controller, a traditional control approach, and an artificial intelligence-based Artificial neural network - feed forward architecture controller. While multilevel inverters have various uses, they are not suitable for all kinds of projects because of limitations like harmonic injection, low output voltage, and so on. Thus, the proposed inverter is built with fewer switches and a sophisticated controller to eliminate the aforementioned shortcomings. Renewable energy applications, such as Solar Photovoltaic Applications, are a good fit for the suggested multilevel inverter. Using the aforementioned methods, the performance of a new multilayer inverter will be demonstrated for a range of input values, and the output will be verified either using hardware or MATLAB/SIMULINK.**

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

I. INTRODUCTION

The depletion of natural resources, the effects on the environment, the increasing need for new energy sources, and the difficulties in meeting this need are the primary topics of the majority of the literature produced this century. Connected non-linear electronic equipment degrades power quality and system efficiency by the generation of unwanted harmonic components. Many various approaches have been offered in the existing literature in an effort to overcome these obstacles. With the electric grid serving as the "load side" of the converter, multi-level converters are gaining popularity as power interfaces. Multilevel inverters provide superior efficiency and output waveforms than other traditional two level pulse width modulated (PWM) converters, and can be easily interfaced with renewable energy sources like PV arrays, wind, and fuel cells even in high power applications.

Compared to simpler single-level inverters, multi-level inverters have higher switching losses and lower reliability because of the greater number of power semiconductor devices required for switching. Yet, inverter systems and induction motors are more central to process control in industrial applications like manufacturing. For such uses, it is possible to keep the converter circuit's output voltage THD within the IEEE 519 tolerance limits. It is crucial that enterprises address the problem of harmonics in multi-level inverter circuits. Researchers have developed a new theory of elimination in order to pinpoint the optimal switching patterns for filtering out individual harmonics like the fifth, seventh, eleventh, and thirteenth. Since there are 15 dc sources in a three-phase eleven-level multi-level inverter, solving the corresponding system of equations gets increasingly challenging as the number of dc sources increases. As an example, we explore the elimination theorem and how it can be used to solve polynomial problems.

When the inverters were originally introduced, they were primarily used to power the aid stack structure breaks down. But now, as a result of rapid development in inverter technology, that's all changed upgrades the range of their software skyline. In the past, a two-level inverter was used to provide output at two different voltages, however this method is fraught with problems due to inharmonic voltages and current flows inside the circuit. As a result, developments have been made in existing inverters to allow for more than two levels, resulting in a topology known as multilevel inverter topology, which allows for the delivery of a pure sinusoidal waveform at the output voltage while also dampening noise within the output and reducing the frequency with which accidents occur.

Because of the inverter's several stages, harmonics are abundant. The traditional methods for eliminating harmonics have limitations that are overcome by using a switching scheme based on artificial intelligence. As an example, in the case of an 11-level cascade multilevel inverter, understanding the switching pattern for harmonic reduction is crucial. With today's modern energy grid, renewable sources of energy play a crucial part in generating electricity. To provide the stable energy that modern businesses and households rely on, the conversion of DC to AC must be handled by a power electronic equipment. The origins of the multi-level inverter can be traced back to the development of inverters used to change AC to DC power supplies (DC). In 1975, it made its debut.As opposed to traditional inverters, which only have two settings, In order to improve power quality, multilevel inverters draw from many DC sources, resulting in a stepped voltage waveform that closely resembles a sinusoidal waveform. Moreover, it alleviates dv/dt strain and electromagnetic interference.It operates at both fundamental and high switching frequency PWM, making it suitable for both high- and medium-power applications, and its output voltage is of good quality despite the low rating of the semiconductor devices it employs. Many applications, such as DC and AC high voltage power lines, electric drive, power factor compensation, natural resources communications, etc., find usage in multi-level inverter topology configurations. Improvements in DC performance, gate control circuitry, power quality, fault tolerance, and overall dependability have been the primary areas of focus for multi-level inverters.

The Neutral Point Clamped (NPC), Flying Capacitor (FC), and Cascaded H-Bridge (CHB) are the three primary topologies into which academics have sorted Multilevel Inverters. With its flexible design, ease of usage, and lack of ancillary components like diodes and capacitors, the cascaded H-bridge has found widespread use. By employing the CHB topology, the voltage output waveform is improved while the total harmonic distortion is minimised.There are two primary types of cascaded H-Bridge inverters, known as symmetrical and asymmetrical topologies. The dc voltage sources in a symmetrical topology are all the same value. As the dc voltage sources in an asymmetric architecture are not all the same, we can select the appropriate unit based on our needs. Asymmetrical inverters, in contrast to the 2 symmetrical inverters, offer a wider variety of voltage waveforms at the output with a smaller footprint (fewer switches).

This paper uses the ONLT-PWM approach to construct an inverter with nine levels utilising a cascaded H-bridge topology with fewer switches and DC sources. Using the ONLT approach, the switching state and duty cycle of each phase of the converter may be calculated immediately. Optimal nearest level pulse width modulation describes this technique, which compares the carrier signal (DC) to a reference signal (SINEWAVE). Technology based on optical frequency-shifting (ONLT) is used to reduce the THD and boost the Vrms. When the desired result is obtained through the use of ONLT methods, this paper proposes a new controller methodology to alleviate a problem with the system. The controller, based on the PI controller method, is utilised as MPPT to track maximum power on the solar PV array, while the AI-based ANN approach is employed to reduce the reactive power and enhance the real power on the grid side. Waveforms of current and voltage are used to verify the results.We simulate the multilayer inverter topologies in MATLAB for nine levels, and we plan to extend the simulation to support up to 31 levels in the future. NLT is used to produce the output, and AI and PI Controller are utilised by the controller.

II. ARTIFICIAL CONTROL TECHNIQUES

The field of artificial intelligence (AI) encompasses a wide range of technologies aimed at creating intelligent machines that can carry out tasks with the same or greater efficiency than a human being, while also requiring significantly less human-like cognitive effort.

Artificial neural networks (ANNs), expert systems (ESs), fuzzy logic systems, and genetic algorithms (GAs) are the four basic ways in which AI generalities are related (GA). In this context, numerous procedures are applied, such as Siri, self-driving buses, Email spam screening, etc.

III.ARTIFICIAL NEURAL NETWORK (ANN)

Inspired by the biological neural networks that underpin the human brain's architecture, ANNs feature interconnected neurons that create layered networks and are conceptualised as nodes. ANN uses a neural network to transform a set of inputs into a corresponding set of outputs With an appreciation of pattern recognition and categorization, real-world issues are addressed by employing the neuron's underlying working principle and connectivity diagrams. This is done by breaking them down into subcategories based on the architecture, number of layers, topology, and network connections.

III. LITERATURE SURVEY

Bushra Masri et al 2022 Modular

low in Total Harmonic Distortion (THD), and requiring fewer filters, Multi-Level Inverters (MLI) have emerged as a critical component of electrical energy augmentation of networks. Nonetheless, despite In order 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 study. 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.

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 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.

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 of 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.

Y.W. Sea et al 2019

In order 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.

IV. Proposed artificial intelligence controller based multilevel harmonic filter

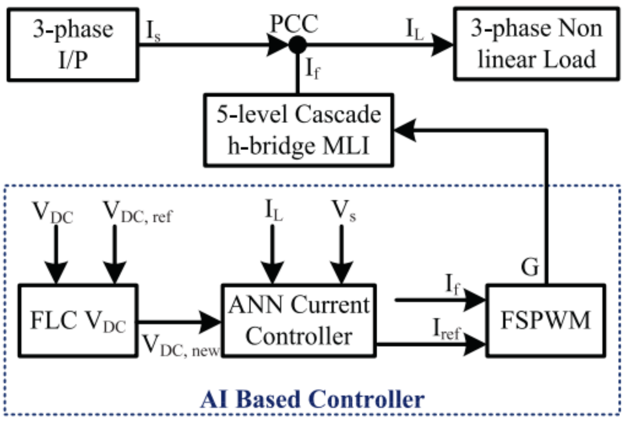

Fig 1 .Block diagram of Artificial Intelligence (AI) based controller for multilevel harmonic filter.

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.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 an added 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 developed with the help of a fuzzy logic based controller. Thus, the dc side capacitor voltage equilibrium and current error correction for modulation is 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 to a reduction in the number of voltage controllers according to the batch control technique of voltage regulation.

V.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. One higher-rated PV array with a forward converter may do this. Below is a block schematic of the suggested plan for your perusal. Artificial intelligence based controller has been fed the modulation index at the output bus of 11 level cascade 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.

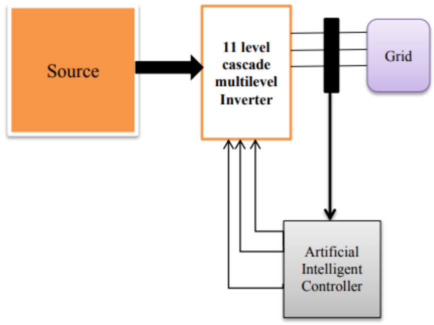

Fig. 1 Block diagram of the proposed system

VI. 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 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 a 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 the output voltage is larger, switching pressures on switching devices are increased, and the output voltage cannot be increased for high voltage applications.

VII 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 in order 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 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 the 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 a "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 that are currently on the market lack the capability to 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 an added 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.

VIII 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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