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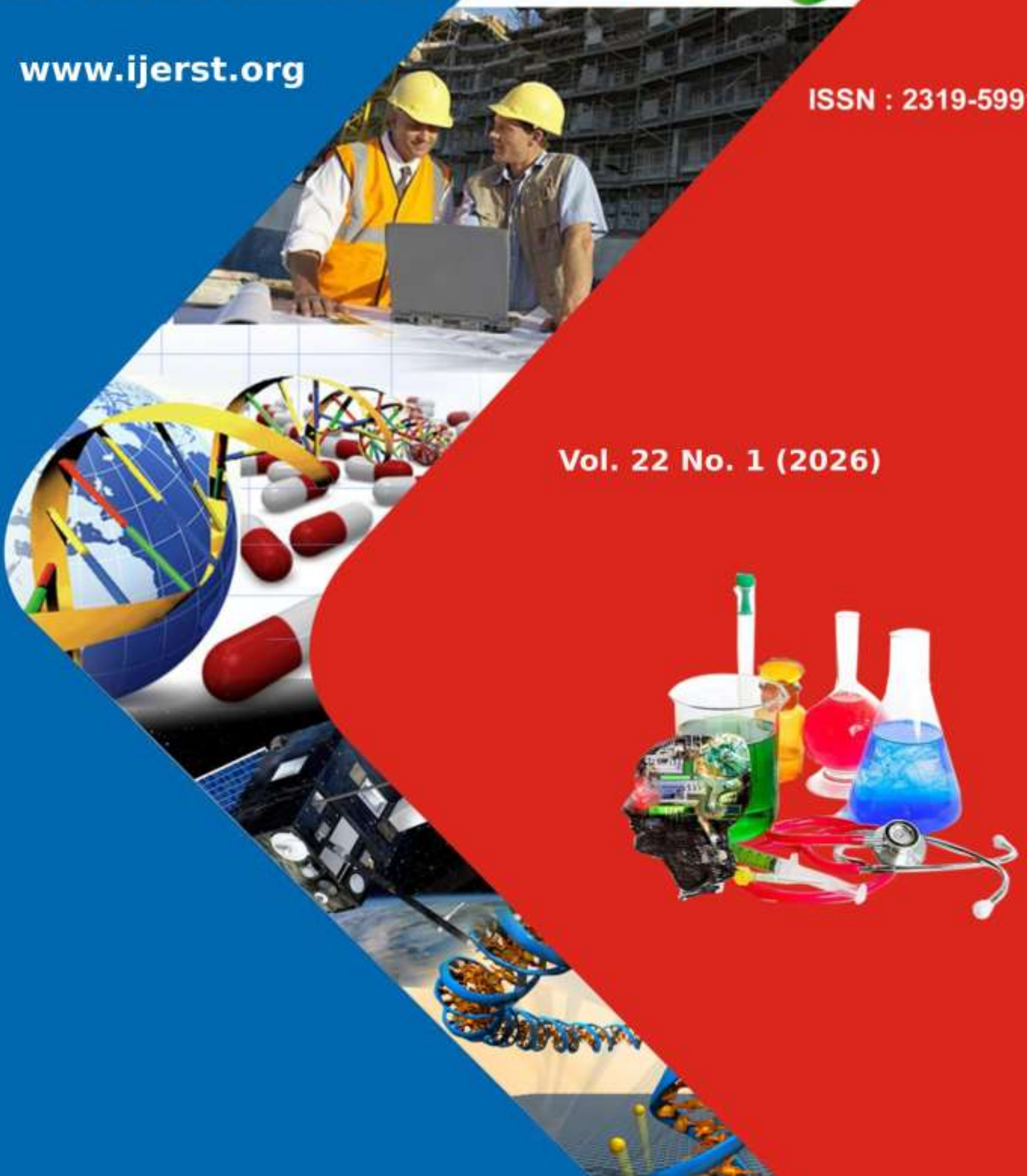

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Research Paper

DESIGN & SIMULATION OF SOLAR PANEL FED CASCADED H BRIDGE MULTILEVEL INVERTER USING ANN CONTROLLER

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ABSTRACT

The increasing dependence on solar energy demands advanced power electronic interfaces capable of delivering high-quality AC power to electrical loads and utility grids. Multilevel inverters are an effective solution due to their ability to synthesize near-sinusoidal waveforms with reduced switching stress. This work focuses on the simulation and design of a solar photovoltaic-fed cascaded H-bridge multilevel inverter employing an Artificial Neural Network (ANN)-based control technique. Independent DC sources derived from solar panels are utilized to generate multiple voltage levels, enhancing output voltage quality while minimizing harmonic distortion. The ANN controller is trained to determine appropriate switching states, allowing the inverter to adapt to nonlinear system behavior and variations in solar irradiance and load conditions. The proposed system is developed and analyzed using MATLAB/Simulink, and its performance is evaluated in terms of output voltage stability, harmonic profile, and dynamic response. Simulation results indicate that the ANN-controlled cascaded H-bridge inverter provides improved harmonic suppression and faster dynamic performance compared to conventional control methods, demonstrating its effectiveness for renewable energy conversion applications.

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1.INTRODUCTION

The use of renewable energy sources has become important because conventional energy sources are limited and cause pollution. Solar energy is widely used since it produces clean electricity, works silently, and needs very little maintenance. It can be applied in homes, industries, and remote areas. Power electronic devices are important in solar systems because they help convert and control electrical power. Common two-level inverters create sudden voltage changes, which increase harmonics and losses and place stress on electronic parts. To overcome these problems, improved inverter designs are required. Multilevel inverters produce the output voltage in small steps instead of one large step. This results in smoother voltage and better power quality. The cascaded H-bridge inverter is suitable for solar applications because it has a simple structure, allows modular expansion, and can use separate DC sources from individual solar panels. However, the performance of this inverter depends on how it is controlled. Simple control methods may not respond well to changes in sunlight, temperature, or load. These changing conditions make the system harder to control and require more effective control techniques. Multilevel inverter (MLI) technology has gained attention in recent years due to its ability to produce near-sinusoidal output waveforms, improve voltage quality, and enhance overall system efficiency in medium- and high-power applications. Intelligent control techniques

such as fuzzy logic and Artificial neural networks have therefore emerged as solutions for optimizing voltage regulation and harmonic mitigation in inverter systems.
In this research, an 11-level inverter controlled using a Fuzzy Logic Controller (FLC) is first developed and evaluated as a reference model.
Building on this, a novel 15-level inverter topology is proposed and implemented, incorporating an Artificial Neural Network (ANN)– based controller for enhanced dynamic response and improved waveform synthesis. A notable feature of the proposed system is the use of a reduced count of MOSFET switches, diodes, and DC input sources without compromising the level-generation capability. MATLAB/Simulink simulations reveal that the ANN-controlled 15-level inverter delivers a much lower total harmonic distortion(THD). compared to the 11-level fuzzy-controlled system, confirming the advantages of integrating AI-based control strategies into advanced multilevel inverter architectures.

2.LITERATURE REVIEW

[1] Hybrid Intelligent Control for Solar PV Cascaded H-Bridge Inverters

Introduction:

Cascaded H-bridge multilevel inverters are used in solar systems because they are easy to expand and give better quality output voltage. How the inverter is controlled is very important, especially when sunlight changes or the load varies. Learning-based control methods help the inverter adjust quickly, reduce unwanted harmonics, and work more efficiently. This ensures smooth and stable operation of the solar inverter system.

Conclusion:

This study shows that smart control methods, especially neural network–based ones, can greatly improve the performance of solar PV cascaded H-bridge multilevel inverters. These controllers help keep the output voltage stable and improve power quality even when conditions change. Because of this, intelligent control methods provide a reliable and efficient solution and have strong potential for wider use in future solar energy systems.

[2] Neural Network Controller for Grid-Tied Multilevel Inverters Introduction

Grid-connected multilevel inverters play a major role in renewable energy systems by ensuring efficient power transfer and acceptable power quality at the point of coupling. The work presented by explores the use of a neural network-based control approach for single- phase grid-tied multilevel inverters. By replacing traditional control loops with an adaptive neural structure, the study aims to achieve improved harmonic suppression and more robust inverter operation.

Conclusion

The study confirms that neural network-based controllers can effectively improve the harmonic performance of grid-tied multilevel inverters. The adaptive nature of the neural controller enables better regulation of voltage and current are varying operating conditions when compared to conventional PI control methods. Reduced harmonic distortion and improved dynamic behavior demonstrate the suitability of intelligent control strategies for grid-connected inverter applications.

[3] ANN-Based Model Predictive Control for Cascaded H-Bridge Inverters Introduction

Cascaded H-bridge multilevel inverters are widely used in medium-power applications due to their ability to generate high-quality voltage with reduced harmonic distortion. Conventional model predictive control (MPC) offers precise dynamic performance but requires intensive computations, which grow significantly with more inverter levels.

Conclusion

The study shows that an ANN can effectively replicate the behavior of a multistep MPC in a cascaded H-bridge inverter while drastically reducing computation time. Simulation results demonstrate that the ANN-based controller maintains similar output voltage quality and dynamic performance compared to conventional MPC.

3.PHOTOVOLTAIC TECHNOLOGY

3.1 Introduction

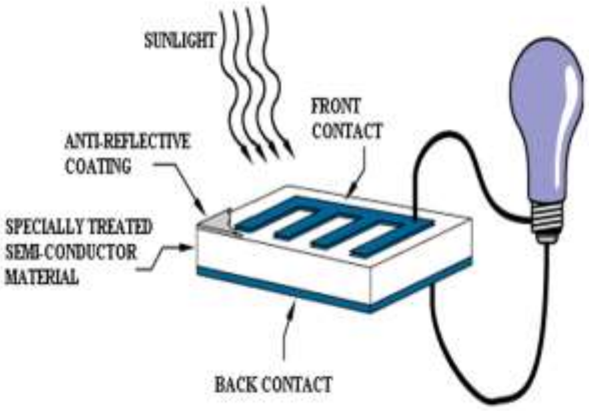

Fig 3.1: Photovolatic Topology

3.2 Solar cell

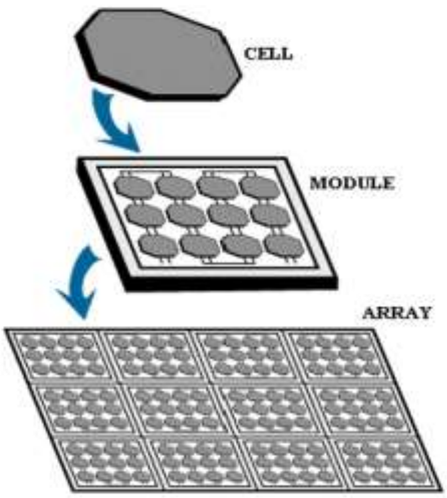

Fig 3.2: Solar Cell

4.MULTILEVEL INVERTER

4.1 Types of Multilevel Inverter:

Multilevel inverters are three types

- Diode clamped multilevel inverter
- Flying capacitors multilevel inverter
- Cascaded H- bridge multilevel inverter

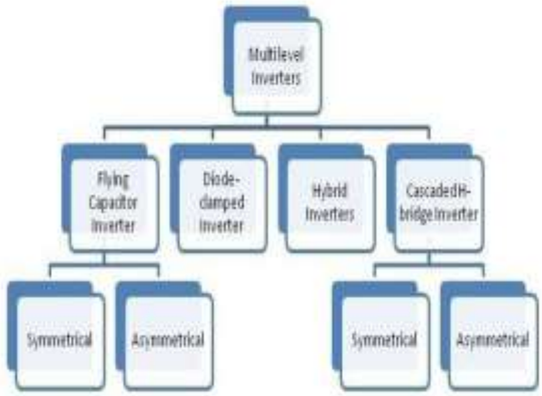

Fig 4.1: Types of multilevel Inverters

4.2 CASCADED H-BRIDGES INVERTER

A single-phase structure of an m-level cascaded inverter is illustrated in Figure 3.1. Each separate dc source (SDCS) is connected to a single-phase full-bridge, or H-bridge, inverter. Each inverter level can generate three different voltage outputs, $+V_{dc}$, 0, and $–V_{dc}$ by connecting the dc source to the ac output by different combinations of the four switches, S_1, S_2, S_3, and S_4. To obtain $+V_{dc}$, switches S_1 and S_4 are turned on, whereas $–V_{dc}$ can be obtained by turning on switches S_2 and S_3. By turning on S_1 and S_2 or S_3 and S_4, the output voltage is 0. The ac outputs of each of the different full-bridge inverter levels are connected in series such that the synthesized voltage waveform is the sum of the inverter outputs. The number of output phase voltage levels m in a cascade inverter is defined by m = 2s+1, where s is the number of separate dc sources. An example phase voltage waveform for an 11-level cascaded H-bridge inverter with 5 SDCSs and 5 full bridges is shown in Figure 4.2.

The total output voltage $v_{an} = v_{a1} + v_{a2} + v_{a3} + v_{a4} + v_{a5}$.

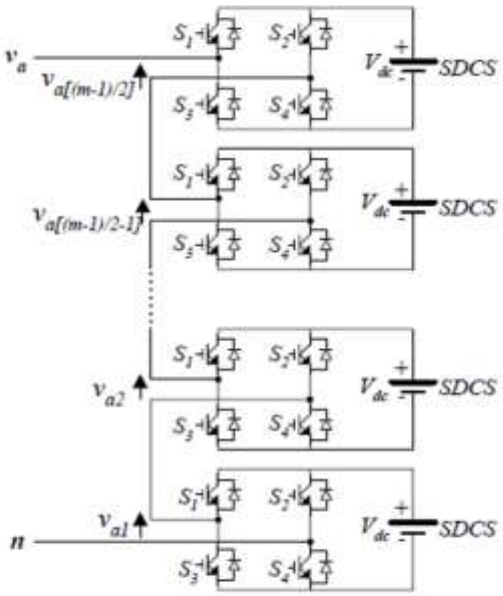

Fig 4.2: Single-phase multilevel cascaded H-bridges inverter

S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S10	S12	Output Voltage
1	1	0	0	0	1	0	1	1	1	0	0	5Vdc
0	1	0	1	0	1	0	1	1	1	0	0	4Vdc
1	1	0	0	1	1	0	0	0	1	0	1	3Vdc
0	1	0	1	1	1	0	0	0	1	0	1	2Vdc
0	0	1	1	1	1	0	0	0	1	0	1	1Vdc
0	1	0	1	0	1	0	1	0	1	0	1	0Vdc
1	1	0	0	0	0	0	1	0	1	0	1	-1Vdc
0	1	0	1	1	1	1	0	0	1	0	1	-2Vdc
0	0	1	1	0	0	0	1	0	1	0	1	-3Vdc
0	1	0	1	0	1	1	1	0	0	1	1	-4Vdc
0	0	1	1	0	1	1	1	0	0	1	1	-5Vdc

Table 4.1: Switch states of Cascaded H-Bridge Multilevel Inverter

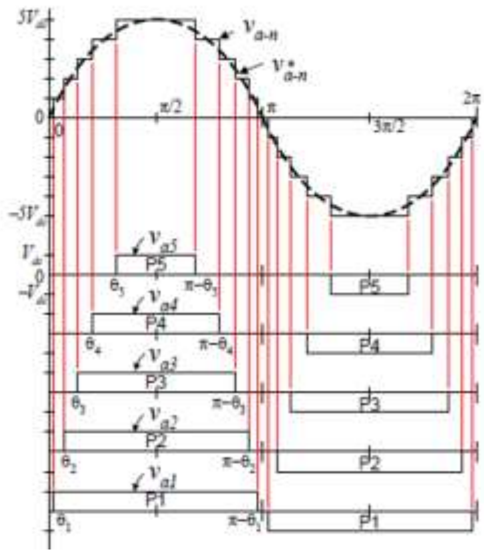

Fig 4.3: Output phase voltage waveform of an 11-level cascade inverter.

The conducting angles, θ_1, θ_2, ..., θ_S, can be chosen such that the voltage total harmonic distortion is a minimum. Generally, these angles are chosen so that predominant lower frequency harmonics, 5th, 7th, 11th, and 13 , harmonics are eliminated. More detail on harmonic elimination techniques will be presented in the next section. Multilevel cascaded inverters have been proposed for such applications as static var generation, an interface with renewable energy sources, and for battery-based applications. Three-phase cascaded inverters can be connected in wye, as shown in Figure, or in delta. The inverter could be controlled to either regulate the power factor of the current drawn from the source or the bus voltage of the electrical system where the inverter was connected. Peng [20] and Joos [24] have also shown that a cascade inverter can be directly connected in series with the electrical system for static var compensation. Cascaded inverters have also been proposed for use as the main traction drive in electric vehicles, where several batteries or ultra capacitors are well suited to serve as SDCSs.

4.11 Applications of Cascaded H-Bridge Multilevel Inverter

- Motor drives
- Active filters
- Electric vehicle drives
- DC power source utilization
- Power factor compensators
- Back to back frequency link systems
- Interfacing with renewable energy resources.

5.ARTIFICIAL NEURAL NETWORK

Conventional control techniques, such as sinusoidal pulse-width modulation (SPWM) and hysteresis control, often struggle to maintain high-quality output in photovoltaic (PV)-fed multilevel inverter systems. An Artificial Neural Network (ANN) is a computational model inspired by the structure and functioning of the human brain. It consists of interconnected processing units called neurons, which work together to process information, learn from data, and make decisions or predictions.

ANNs are widely used in pattern recognition, classification, control systems, signal processing, and optimization. They are useful for solving complex, non-linear problems where traditional mathematical models are difficult to apply.

An ANN typically has three main layers

- Input Layer – receives the input data
- Hidden Layer(s) – performs computation and feature extraction
- Output Layer – produces the final result Through a learning process called training, ANNs adjust their internal connection weights using algorithms such as backpropagation to minimize errors.

5.2 Fundamentals of ANN

An Artificial Neural Network (ANN) is a smart method that works in a way similar to the human brain. It learns from data and improves its performance over time. An ANN has three main parts: an input layer, hidden layers, and an output layer. Each neuron receives information, gives it importance using weights, and processes it to produce an output. By adjusting these weights again and again, the network reduces errors and learns to give better results.

In solar-based multilevel inverter systems, ANN is used as an intelligent controller. It takes inputs such as reference signals, solar panel voltage, load current, and changes in weather conditions. Based on this information, the ANN decides how the inverter should switch and operate. This helps the system work smoothly, maintain stable voltage, reduce distortion, and improve overall efficiency.

5.2 ANN Architecture for Multilevel Inverter Control

For cascaded H-bridge inverter systems, the Artificial Neural Network is generally structured as follows:

1. **Input Layer:** This layer collects key system variables such as DC-link voltages, the desired reference AC voltage, and operating load conditions.
2. **Hidden Layers:** One or more intermediate layers are used to process the input data. These layers employ nonlinear activation functions to effectively represent the dynamic and nonlinear behavior of the inverter system.
3. **Output Layer:** The final layer produces control outputs in the form of switching pulses or PWM modulation signals for each H-bridge module.

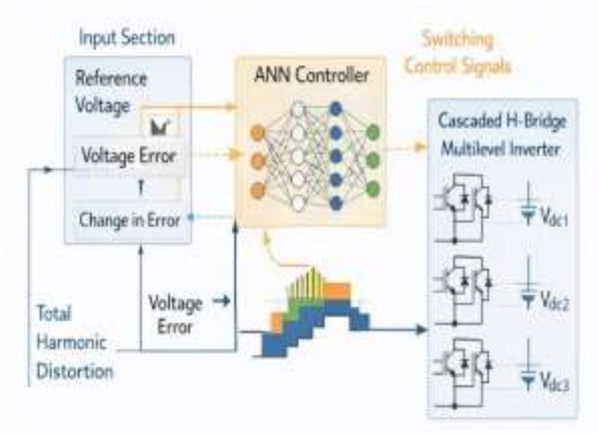

Fig 5.1: ANN Controller

5.4 Implementation Considerations

The performance of an ANN-based control strategy strongly relies on careful selection of input variables, an appropriate network structure, and well-prepared training data. A network that is too large can demand unnecessary computational effort and slow down system response, while a network that is small it may not effectively represent the nonlinear characteristics of the inverter system. Once the training process is completed, the ANN must be correctly incorporated into the inverter control system or simulation model so that it can generate reliable and accurate switching signals for each cascaded H-bridge module during operation.

- ➢ Generates optimal switching pulses for power semiconductor devices
- ➢ Improves dynamic response and voltage regulation
- ➢ Handles nonlinearities and parameter variations effectively
- ➢ Enhances system stability under varying load and

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source conditions ANN-Based Control Structure Input Layer Reference voltage, error signal, change in error, DC voltage Hidden Layer(s) Processes data using trained weights Output Layer Produces switching pattern or modulation index.

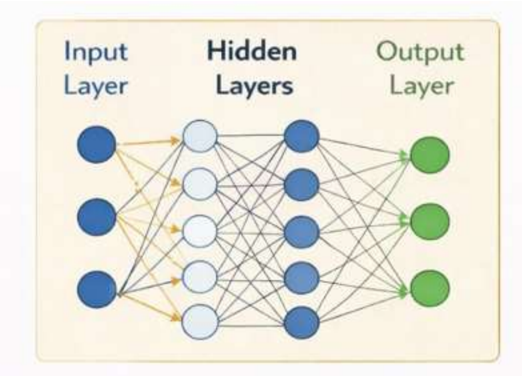

Fig 5.2: Simple ANN Controller

5.3 Advantages of ANN Based Control

- Lower output voltage distortion
- Faster control compared to traditional methods
- Robust performance under load variations
- Reduced switching losses

6.SIMULATION RESULTS AND ANALYSIS

This chapter presents the design, simulation, and performance evaluation of a photovoltaic (PV)-fed cascaded H-bridge (CHB) multilevel inverter system using an artificial neural network (ANN) controller. The simulation is developed in MATLAB/Simulink to assess the system's ability to maintain high-quality AC output under varying environmental conditions and load disturbances. The objective is to demonstrate that the ANN controller can adaptively manage the nonlinear behavior of PV sources and ensure efficient renewable energy conversion.

The obtained results confirm that the inverter operating under ANN control produces higher- quality output voltage, improved operational robustness, and a substantial decrease in harmonic distortion. These improvements demonstrate the suitability of the proposed control methodology for advanced, energy-efficient power conversion systems. Overall, the study verifies the practical applicability and reliable performance of the proposed multilevel inverter architecture supported by an intelligent ANN-based control approach.

6.1 Existing System

The existing system considered in this study is an 11-level multilevel inverter controlled using a Fuzzy Logic Controller (FLC). The system utilizes a conventional multilevel topology with a moderate number of MOSFET switches, diodes, and isolated DC sources to generate stepped voltage levels. The FLC is responsible for shaping the output waveform by adjusting the switching states based on a rule-based control mechanism. The FLC controller does not require an accurate mathematical model and can handle non-linearities reasonably well, making it suitable for low-to-medium complexity power conversion systems.

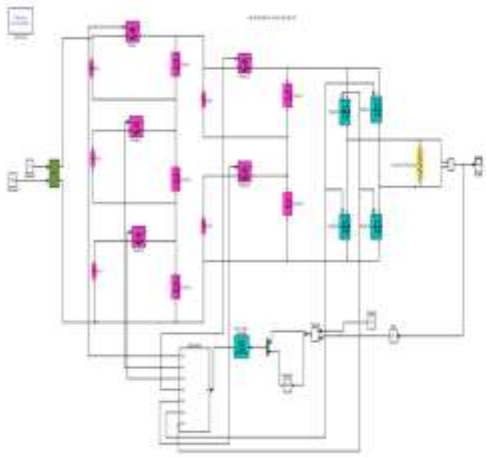

Fig 6.1: FLC connected 11 level inverter circuit

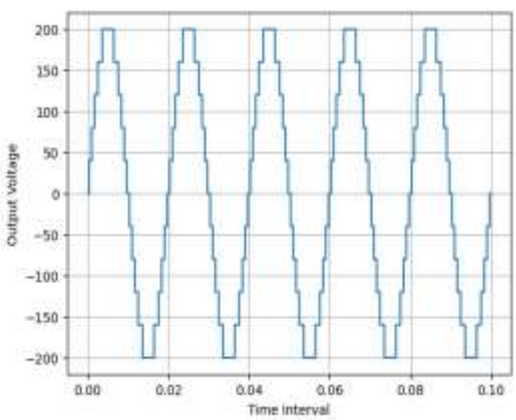

Fig 6.2:11 level output waveform

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While the existing 11-level inverter provides acceptable output quality and stability, its harmonic performance is limited by the number of voltage levels and the capability of the FLC to adapt to dynamic changes. Additionally, the hardware count is still relatively high, leading to increased cost and complexity. As load and input conditions vary, the fuzzy controller may not optimally minimize distortion, resulting in a waveform that, although usable, is not ideal for sensitive or high-performance applications. These limitations highlight the need for a more advanced topology and an intelligent control strategy capable of optimizing switching behavior, reducing harmonic content, and enhancing power quality with fewer components.

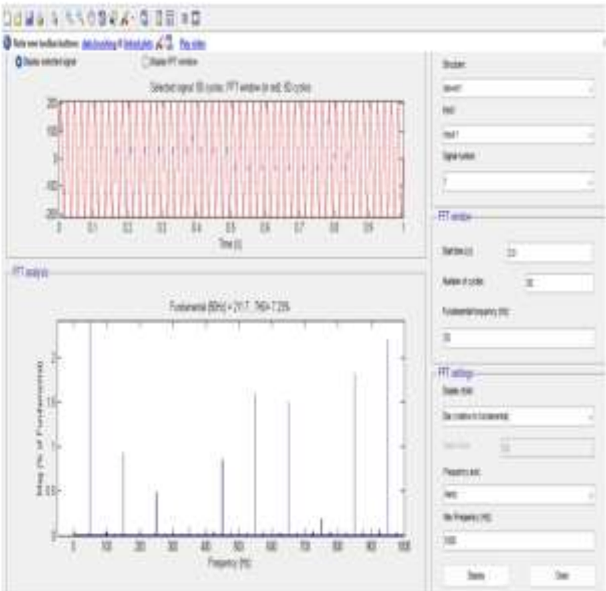

Fig 6.3:11 level THD

6.1Disadvantages of the Existing System

- Requires a comparatively high number of switches, diodes, and DC sources.
- Fuzzy Logic Controller performance decreases under rapidly changing load conditions.
- Output waveform still contains noticeable harmonic components.
- System hardware becomes bulky and more expensive to implement.
- Less efficient for high-performance or sensitive load applications.

6.1 Proposed System

The proposed system introduces a 15-level inverter topology controlled by an Artifical Neural Network (ANN)–based intelligent controller. Unlike conventional designs, this configuration is engineered to significantly reduce the number of MOSFET switches, diodes, and DC input sources while still achieving the required voltage step levels. The reduction in hardware components leads to a more compact, cost-effective, and reliable inverter structure. The ANN controller is trained to generate optimal switching signals based on input conditions such as reference voltage and load variations. Its learning capability enables the controller to adapt to non-linear behavior effectively than traditional methods.

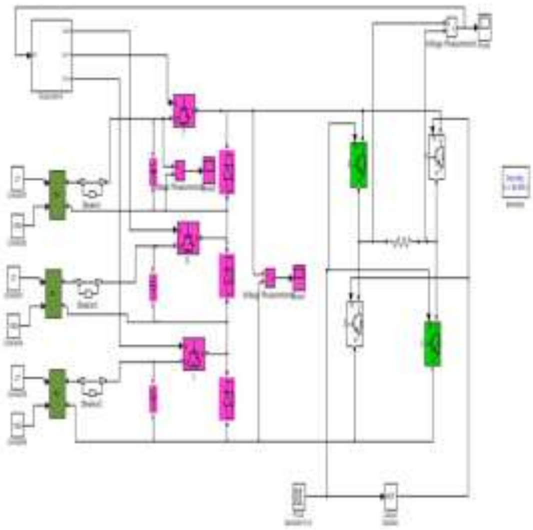

Fig 6.4: Proposed 15 level inverter

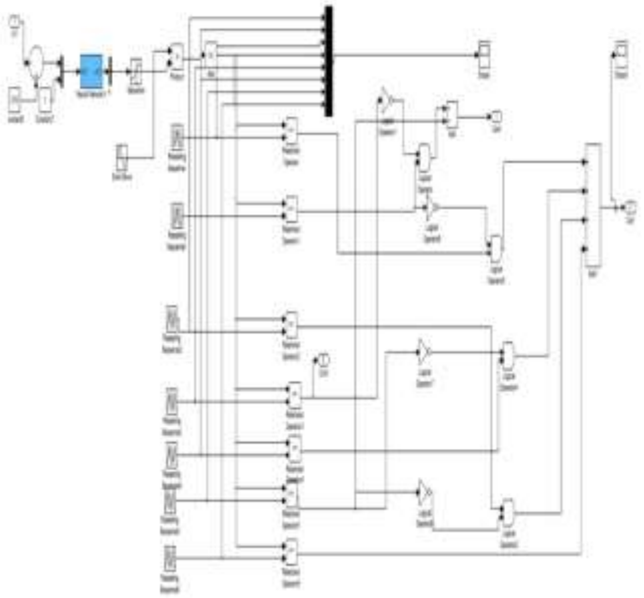

Fig 6.5: Level Shifting & ANN Control

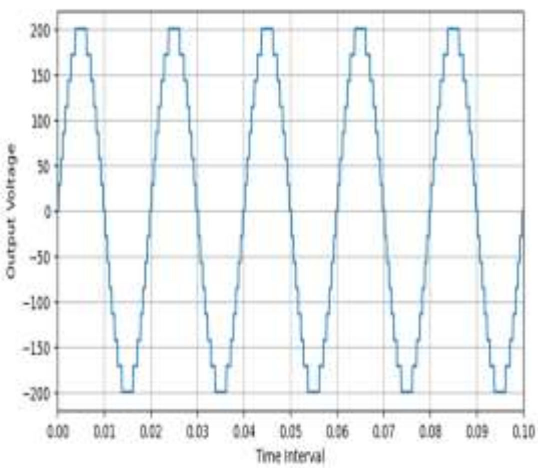

Fig 6.6:15 level inverter voltage

The ANN-based modulation generates smoother voltage transitions and precise switching patterns, which helps minimize stress on power devices and enhances the overall power quality of the output waveform. The proposed inverter's topology ensures balanced voltage levels while maintaining simplicity in design and ease of implementation. The intelligent control strategy allows the system to respond dynamically to variations in input or load conditions, thereby maintaining waveform quality without requiring complex tuning or rule sets.

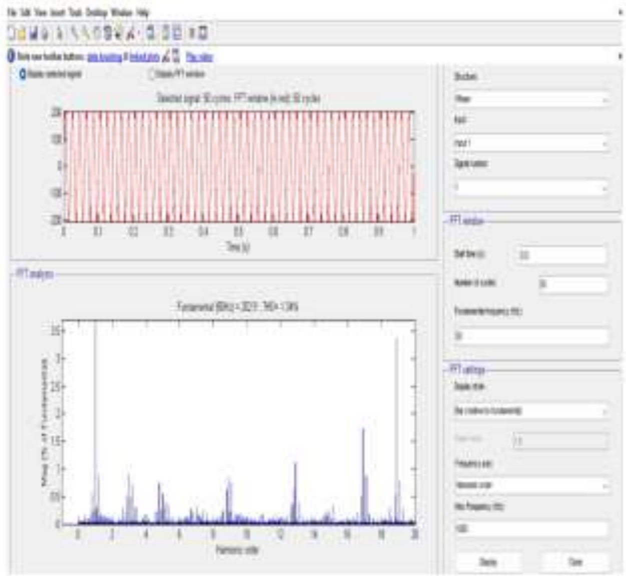

Fig 6.7:15 level inverter voltage THD

Compared to the existing 11-level inverter with FLC, the proposed 15-level ANN-controlled design demonstrates much lower harmonic content and superior waveform shaping. The combination of reduced hardware requirement and improved harmonic performance makes the proposed system ideal for modern applications that demand efficiency, compactness, and high output quality. This system bridges the gap between hardware optimization and intelligent control, offering a holistic solution to the challenges of multilevel inverter design.

6.6Applications

1. Renewable energy systems such as solar and wind power conversion.
2. Uninterruptible Power Supplies (UPS).
3. Smart grid and distributed energy resources.
4. HVAC and induction heating applications.

CONCLUSION

This work presents a comprehensive comparison between a conventional 11-level inverter using a Fuzzy Logic Controller and a proposed 15-level inverter controlled through an Artificial Neural Network. The analysis demonstrates that the proposed system effectively reduces the number of semiconductor components while achieving better output waveform with significantly lower harmonic distortion. The ANN controller plays a role in optimizing the switching sequence, adapting to dynamic load conditions, and ensuring accurate modulation without requiring extensive rule sets or manual tuning. The reduction in hardware complexity improves system reliability, cost efficiency, and thermal performance, making the proposed inverter a strong candidate for modern power conversion applications. The simulation results confirm that integrating intelligent control with optimized multilevel inverter topologies can greatly enhance power quality. Overall, the proposed design offers a compact, efficient, and high-performance inverter solution suitable for industrial and renewable energy applications.

REFERENCES

5. Agrawal, P., & Chandra, R. (2022). Performance evaluation of MIMO-OFDM in frequency- selective fading channels. *IEEE Access, 10*, 55621–55632.
6. Alkhateeb, A., & Heath, R. W. (2019). Hierarchical codebook design for millimeter-wave channel estimation. *IEEE Transactions on Wireless Communications, 17*(5), 1328–1341.
7. Akagi, H., & Fujita, H. (2007). A new power line conditioner for harmonic compensation in power systems. *IEEE Transactions on Power Delivery, 12*(1), 157–163.
8. Babaei, E. (2008). A cascade multilevel converter topology with reduced number of switches. *IEEE Transactions on Power Electronics, 23*(6), 2657–2664.
9. Nandigama, N. C. (2024). Data Science–Enabled Anomaly Detection in Financial Transactions Using Autoencoders and Risk Evaluation Mechanisms. Journal of Information Systems Engineering and Management. https://doi.org/10.52783/jisem.v9i2.44.
10. Dargahi, A., Gandomkar, M., & Taghizadeh, H. (2018). A modified PWM strategy for harmonic reduction in multilevel inverters. *IET Power Electronics, 11*(14), 2291–
11. Deepak, M., & Singh, B. (2020). ANN-based control for improved harmonics in multilevel inverters. *IEEE Transactions on Industrial Informatics, 16*(9), 5874–5882.
12. Nandigama, N. C. (2025). Leveraging Chatgpt for Multi-Language Data Engineering Code Generation in Distributed Analytics Systems. Journal of Informatics Education and Research.
13. Hassaine, L., Maussion, P., Pichon, L., & Fadel, M. (2007). Harmonic control of multilevel inverters. *Renewable Energy, 32*(10), 1671–1687.
14. Kalyan, P. V., & Rao, K. S. (2021). Neural network-based selective harmonic elimination in cascaded H-bridge inverters. *Electric Power Systems Research, 196*, 107265.
15. Kang, B., Kim, D., & Park, J. (2018). Improved multicarrier PWM method for high-level inverters. *IEEE Transactions on Power Electronics, 33*(3), 2349–2359.
16. Lai, Y. S., & Shyu, F. S. (2002). Topology for hybrid multilevel inverters. *IEEE Transactions on Industrial Electronics, 49*(5), 997–1007.
17. Lezana, P., Rodríguez, J., & Oyarzún, D. (2007). Harmonic elimination with AI techniques. *IEEE Transactions on Industrial Applications, 43*(2), 452–458.
18. Li, Z., Wang, Y., & Yang, J. (2019). Reduced switch-count multilevel inverter for renewable applications. *Energy Conversion and Management, 196*, 263–273.