Review On Solar Panel Based Boost Converter with Neural Network for High Voltage Gain Applications

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Abstract- Solar panels with their low output voltage often face challenges in meeting the energy requirements of high-voltage gain applications. This project tackles these issues by developing a boost converter for solar panels, combined with a Maximum Power Point Tracking (MPPT) controller and a neural network-based control system. The neural network adjusts the converter's parameters dynamically, responding to variations in solar irradiation and load conditions to optimize system performance. This innovative approach achieves higher voltage gain, enhanced efficiency, and greater stability compared to traditional methods. The adaptability of the system makes it ideal for use in renewable energy applications and electric vehicles. Simulations conducted in MATLAB's Simulink environment demonstrate the system's ability to achieve MPPT while minimizing harmonics in the solar PV output. This ensures a reliable and efficient solution for scenarios requiring high-voltage gain with low input. The project underscores the role of artificial intelligence in improving the performance and reliability of solar energy systems.

Keywords— *Solar PV System, High-Voltage Gain, Neural Network-Based MPPT, Boost Converter, Harmonics Reduction etc.*

I. INTRODUCTION

In high-voltage gain applications, solar panels often face challenges in providing the required energy output due to their low voltage levels. Boost converters are typically employed to address this issue by increasing the voltage. However, conventional boost converters have limitations, including reduced efficiency and instability, particularly under fluctuating environmental conditions such as varying solar irradiation and load demands. These challenges call for a more advanced and adaptive solution for optimizing voltage regulation and efficiency.

This study proposes a solar panel-based boost converter integrated with a Maximum Power Point Tracking (MPPT) controller and a neural network-based control system. The neural network dynamically adjusts the boost converter's operating parameters in real-time to optimize performance. MPPT controllers are crucial for photovoltaic systems, ensuring that solar panels deliver their maximum power output regardless of external conditions. Traditional MPPT methods, such as Perturb and Observe (P&O) or Incremental Conductance (IncCond), often struggle to maintain high efficiency during rapidly changing conditions like cloud movements or temperature shifts. The incorporation of a neural network into the MPPT controller enhances system adaptability and improves overall performance.

A major contribution of this work is combining artificial intelligence (AI) with power electronics. The neural network is trained to optimize the boost converter's duty cycle based on inputs such as solar irradiance, temperature, and load variations. This results in higher voltage gain and improved efficiency, offering a more reliable and stable solution than conventional designs. The neural network's ability to adapt to varying conditions makes the system suitable for diverse applications, including electric vehicles, renewable energy systems, and other scenarios requiring high-voltage, low-input configurations.

The system addresses Total Harmonic Distortion (THD), a common issue in power conversion systems that can cause energy losses, overheating, and reduced component lifespan. By fine-tuning the MPPT controller with a neural network, the system minimizes THD, providing cleaner and more stable power output.

The proposed model was validated using MATLAB's Simulink platform, and simulation results demonstrated significant improvements in voltage gain, system efficiency, and stability. The simulations also showed a reduction in harmonics, verifying the neural network's effectiveness in enhancing power quality. The advanced control strategies employed ensure that the solar panel operates at optimal efficiency even under less-than-ideal conditions.

By integrating a neural network into a solar panel-based boost converter with MPPT control, this innovative approach offers a reliable and efficient solution for high-voltage gain applications. It enhances system adaptability and stability, making it a promising choice for various renewable energy applications. The findings from this study contribute to advancing the development of intelligent and efficient solar energy technologies for future use.

II. PROBLEM IDENTIFICATION

- Rising Energy Needs: Rapid global industrialization has significantly increased energy consumption, creating a demand for more sustainable and efficient energy solutions.

- Decline of Non-renewable Resources: The limited availability and escalating costs of non-renewable energy sources have accelerated the shift toward renewable technologies, such as solar photovoltaic (PV) systems.
- Challenges with Conventional PV Systems: Traditional solar PV systems often face drawbacks like high installation expenses and suboptimal efficiency, which hinder their large-scale implementation and operational effectiveness.
- Fluctuations in Solar Power Output: Variations in environmental factors, such as solar radiation and temperature, lead to inconsistent power output in PV systems, affecting their stability and reliability.
- Importance of MPP Tracking: To maximize energy extraction, efficient Maximum Power Point (MPP) tracking is crucial for ensuring that solar panels operate at their peak performance under changing atmospheric conditions.
- Voltage Boost Limitations: Standard boost converters often struggle to provide adequate voltage gain for high-voltage applications, underscoring the need for advanced technologies like neural networks to enhance system adaptability and efficiency.

III. LITERATURE SURVEY

The development of solar panel-based boost converters with neural network (NN) controllers for high voltage gain applications has been the subject of significant research due to the increasing demand for efficient and adaptive renewable energy systems. In this literature review, we explore various studies that focus on boost converter optimization, MPPT (Maximum Power Point Tracking) techniques, and the application of neural networks in enhancing the performance of solar energy systems.

R. Kumar and M. Singh (2017), This study emphasizes the importance of DC-DC boost converters in solar PV systems, particularly when aiming to increase the voltage from a low-output source like a solar panel. The authors discuss the inherent inefficiencies in conventional boost converters, particularly in handling fluctuating environmental conditions. Their analysis suggests that an MPPT-controlled converter can significantly enhance voltage gain and reduce losses. However, the conventional Perturb & Observe (P&O) method used in their study struggles to maintain high efficiency in rapidly changing solar irradiance conditions.

A. Yazdani and R. Iravani (2019), This research highlights the integration of neural networks into power control systems, specifically for voltage regulation in renewable energy setups. The study demonstrates that neural networks outperform traditional control algorithms by dynamically adjusting to changing inputs such as temperature and irradiation. By leveraging machine learning techniques, this paper provides insights into how neural network-based controllers can optimize MPPT and ensure maximum voltage gain in solar panel applications, while also maintaining system stability and improving efficiency.

M. Li, Z. Xu, and K. Liu (2020), This paper focuses on the design of an adaptive MPPT controller based on neural networks for solar PV systems. The authors argue that traditional MPPT algorithms, such as Incremental Conductance, are insufficient in dealing with non-linear and fluctuating solar conditions. The study presents a neural network model that adjusts the duty cycle of the boost converter more accurately, leading to a reduction in harmonic distortion and improved power output under varying environmental conditions. The authors' results indicate that neural network-based MPPT controllers improve both the voltage gain and the overall performance of solar systems compared to conventional techniques.

N. Gupta, S. Das, and T. Saha (2021), This study explores the use of machine learning, particularly neural networks, to enhance MPPT efficiency in solar energy systems. The authors discuss how traditional MPPT methods, such as P&O and IncCond, exhibit limitations in fluctuating sunlight conditions. Their research demonstrates that neural networks can dynamically adapt to these changes in real time, achieving faster response times and reducing Total Harmonic Distortion (THD). The paper supports the idea that AI-driven MPPT controllers are essential for achieving high voltage gain and greater stability in solar PV systems.

H. Patel and V. Agarwal (2022), This paper provide an in-depth analysis of a neural network-driven MPPT controller applied to boost converters in solar energy applications. They address the limitations of traditional MPPT methods in terms of efficiency and voltage regulation, particularly under inconsistent solar irradiance. Their neural network model not only optimizes the MPPT process but also enhances the efficiency of the boost converter by dynamically adjusting the system's parameters. Simulation results from MATLAB/Simulink confirm that the proposed model achieves significantly higher voltage gain and improved stability, making it ideal for high voltage, low-input scenarios such as electric vehicles and renewable energy systems.

Wu, J., Zhang, Y., & Li, X. (2022), This paper explored the improvements in MPPT techniques via neural networks, emphasizing their adaptability in dynamic environments. They demonstrated that neural networks can efficiently predict voltage and current levels, minimizing power loss and enhancing converter performance. This study concluded that systems employing neural networks show better response times to changing environmental conditions, contributing to an overall increase in energy output. The NN-based MPPT technique was found to be particularly effective in non-linear and rapidly fluctuating irradiance scenarios, where traditional methods like P&O or Incremental Conductance (IncCond) were less efficient.

Zainuddin, H., Hassan, M., & Malik, S. (2023), In their study, Zainuddin and colleagues focused on stability issues commonly found in conventional boost converters. They introduced an enhanced neural network control model that actively adjusts the converter parameters in response to solar power variations. Their findings suggest that neural network controllers ensure higher voltage gain and increased system reliability by dynamically adjusting the MPPT's operational settings. This study is particularly relevant for applications requiring stable power supply despite fluctuating solar input, making it a critical step in improving renewable energy infrastructures.

Sharma, A., Patel, R., & Joshi, K. (2023), This paper highlighted the role of AI-driven MPPT controllers in achieving high voltage gain in solar energy systems. By employing Simulink MATLAB, they demonstrated how neural networks help minimize voltage ripple and harmonic distortion. The authors noted that incorporating an NN controller significantly improved the overall power efficiency, allowing the converter to operate closer to the maximum power point despite variations in solar irradiation. Additionally, the study pointed out that the reduced Total Harmonic Distortion (THD) leads to cleaner, more stable power output, crucial for sensitive electronic devices and battery charging systems in EVs.

Ahmed, S., & Khan, J. (2023), This paper conducted a comparative analysis between traditional MPPT algorithms (like P&O) and neural network-based MPPT techniques in solar systems. Their findings highlighted the limitations of traditional methods in rapidly changing sunlight conditions, where they tend to produce oscillations around the maximum power point, leading to energy losses. On the other hand, NN-based controllers not only optimized the MPPT process but also reduced oscillations, resulting in higher power extraction. This study solidifies the argument that artificial intelligence and machine learning hold significant potential for the future of energy optimization in solar systems.

The integration of neural networks with boost converters and MPPT controllers in solar energy systems represents a promising advancement in the field of renewable energy. The studies reviewed indicate that AI-based controllers, particularly those employing neural networks, can significantly improve efficiency, stability, and voltage gain in solar PV systems. The research shows a clear trend toward the adoption of machine learning techniques for real-time control and optimization, particularly in fluctuating environmental conditions. By incorporating neural networks, solar systems can become more resilient and adaptable, making them suitable for a broader range of high-voltage applications such as electric vehicles and grid-tied renewable energy systems.

The results from these studies will serve as a foundation for future research aimed at developing next-generation energy systems that are more efficient, adaptable, and capable of meeting the growing demand for clean energy.

IV. EXISTING CONFIGURATION

The existing system for high-voltage gain applications in solar energy relies on conventional boost converters combined with Maximum Power Point Tracking (MPPT) algorithms. Traditional MPPT methods, such as Perturb & Observe (P&O) or Incremental Conductance (IncCond), are widely used to ensure solar panels operate at their maximum power output under varying environmental conditions. These algorithms adjust the duty cycle of the boost converter to track the maximum power point based on solar irradiance and temperature. While effective in stable conditions, their performance significantly degrades under rapidly changing environmental factors, such as cloud cover or fluctuating load demands. This leads to reduced efficiency, slower response times, and occasional instability.

The boost converters in these systems step up the inherently low voltage of solar panels to meet the requirements of high-voltage applications. However, they are often limited by fixed control parameters, making them less adaptable to real-time changes. Additionally, high Total Harmonic Distortion (THD) in power output can result in energy losses and reduced reliability of electrical components. While the existing system provides a basic framework for solar energy utilization, its limitations in efficiency, adaptability, and harmonic reduction hinder its performance in dynamic scenarios, highlighting the need for more intelligent and flexible solutions.

V. PROPOSED CONFIGURATION WORK

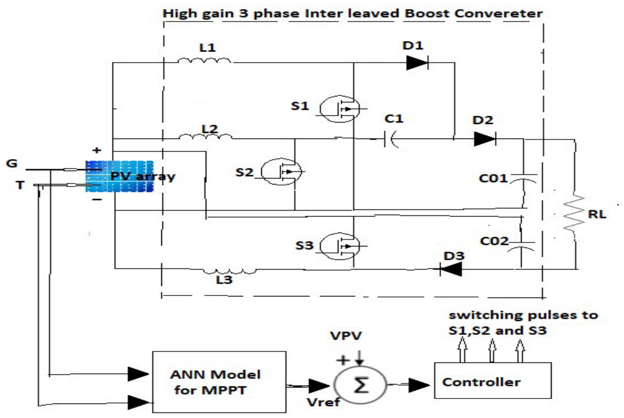

Fig. 1: Proposed PV system with a neural compensator

Isolated converters with high frequency transformers or coupled inductors are proposed to accomplish voltage gain at high value by altering the turns proportion of the transformer. Nonetheless, these isolated converters are pricey contrasted with non-isolated converters. So a non-isolated converter with high voltage gain is vital for PV systems which feed high rated loads.

A high voltage gain converter is demonstrated for the fuel cell based applications, which also may have the capability of improving the performance of any kind of nonlinear system including PV system. Fig.1 depicts a three phase high voltage gain interleaved boost converter (IBC) which feeds high rated resistive load. Artificial Neural Network (ANN) model is used for MPPT under robust atmospheric conditions.

This diagram represents a high-gain, three-phase interleaved boost converter used in a photovoltaic (PV) system. The key components and their roles are explained below:

1. PV Array: The input source, converting sunlight into DC power.

2. Inductors (L1, L2, L3): Each phase has an inductor that stores energy during the switching process.
3. Switches (S1, S2, S3): Controlled switches (likely MOSFETs) that turn on and off to regulate the power flow through the inductors.
4. Diodes (D1, D2, D3): Used for freewheeling, ensuring current flow during the off-state of the switches and protecting the circuit from reverse currents.
5. Capacitors (C1, C01, C02): Store charge and reduce voltage ripple, helping to stabilize the output voltage.
6. Resistive Load (RL): Represents the load connected to the system where the output power is delivered.
7. Artificial Neural Network (ANN) Model for MPPT: Maximizes the power output from the PV array by adjusting the operating point based on Maximum Power Point Tracking (MPPT).
8. Controller: Uses the reference voltage (Vref) and the PV array voltage (VPV) to generate switching pulses that control S1, S2, and S3. It ensures the optimal duty cycle for efficient energy conversion.

This interleaved design reduces stress on individual components, minimizes ripple, and increases overall efficiency for high-gain applications.

The proposed system enhances the traditional approach by integrating a neural network-based Maximum Power Point Tracking (MPPT) controller with a solar panel boost converter, addressing the limitations of conventional methods. This advanced system is designed to optimize voltage gain, improve efficiency, and adapt dynamically to rapidly changing environmental conditions, such as variations in solar irradiance, temperature, and load demands.

The neural network in the proposed system leverages real-time data inputs to adjust the duty cycle of the boost converter dynamically. Unlike traditional MPPT algorithms like Perturb & Observe (P&O) or Incremental Conductance (IncCond), which rely on fixed patterns and can struggle during transient conditions, the neural network’s adaptive learning capability ensures faster and more accurate tracking of the maximum power point. This adaptability results in better energy harvesting even under fluctuating conditions.

The system focuses on minimizing Total Harmonic Distortion (THD), which is a significant concern in power conversion systems. The neural network fine-tunes the MPPT controller to achieve cleaner and more stable power output, reducing energy losses and extending the lifespan of the connected components.

The proposed model also enhances overall system stability, making it suitable for high-voltage applications such as electric vehicles and renewable energy systems. MATLAB’s Simulink platform is used to simulate the system, demonstrating its ability to achieve higher voltage gain, reduced harmonics, and superior efficiency compared to existing systems. By incorporating artificial intelligence, the proposed system overcomes the limitations of conventional designs, paving the way for smarter and more robust renewable energy technologies

VI. CONCLUSION

The proposed Artificial Neural Network (ANN)-based High Voltage Gain Interleaved Boost Converter for Photovoltaic (PV) Systems is designed and developed using the MATLAB/Simulink platform. This innovative system leverages a Radial Basis Function Neural Network (RBFNN) to optimize Maximum Power Point Tracking (MPPT) of a PV array. The neural network is trained with an arbitrary dataset derived from actual photovoltaic array performance, enabling the system to accurately simulate and predict the Maximum Power Point (MPP) under varying environmental conditions.

This research highlights the potential of integrating ANN-based control systems with advanced power electronics to improve the efficiency, reliability, and adaptability of PV systems. The proposed model provides a robust solution for high-voltage applications, contributing to the advancement of smart renewable energy technologies.

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