A Novel Transformer Less Grid Connected PV System with Optimal Control Strategy

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ABSTRACT

This research proposes an innovative grid-connected photovoltaic (PV) system that incorporates both neural network and fuzzy logic techniques in a combined optimal control strategy. The system aims to optimize the performance and efficiency of PV installations while eliminating the need for a transformer. By utilizing neural networks, the system can learn and adapt to real-time data, enabling accurate predictions and efficient control of the PV system. The fuzzy logic component adds a human-like decision-making capability, allowing the system to handle uncertainties and variations in environmental conditions. The combined approach offers improved power generation and grid synchronization, along with enhanced power quality and stability. This novel PV system provides a cost-effective and intelligent solution for grid-connected PV installations, enabling efficient utilization of solar energy.

INTRODUCTION

In recent years, the integration of photovoltaic (PV) systems with the electrical grid has gained significant attention due to the increasing demand for renewable energy sources. Grid-connected PV systems allow for the efficient utilization of solar energy while contributing to the reduction of greenhouse gas emissions. Traditional grid-connected PV systems typically rely on a step-up transformer to match the PV array voltage with the grid voltage. However, these transformers introduce additional cost, weight, and efficiency losses [1]. To address these challenges, this study introduces a novel transformer-less grid-connected PV system that incorporates a combined optimal control strategy using neural network and fuzzy logic techniques [2]. This innovative approach aims to optimize the performance, efficiency, and cost-effectiveness of grid-connected PV systems while eliminating the need for a transformer.

The neural network component of the control strategy enables the PV system to learn and adapt to real-time data. By analyzing inputs such as solar irradiance, temperature, and load demand, the neural network can make accurate predictions and optimize the operation of the PV system [3]. This adaptive capability allows the system to operate at its highest efficiency point, maximizing power generation under varying environmental conditions. In addition to the neural network, the control strategy incorporates fuzzy logic techniques [4]. Fuzzy logic provides a mechanism to handle uncertainties and variations in the PV system's operating conditions. By using linguistic variables and rules, the system can make intelligent decisions, mimicking human-like reasoning and decision-making processes [5]. This fuzzy logic component enhances the system's ability to respond to dynamic changes in solar irradiance, temperature fluctuations, and load variations, ensuring optimal operation and power generation [6].

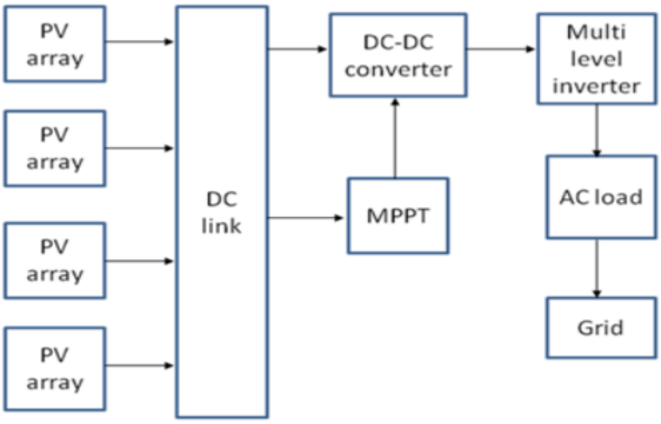

Fig 1 Block Diagram

The combined optimal control strategy, integrating neural network and fuzzy logic techniques, offers several advantages. Firstly, the elimination of the transformer reduces system complexity, cost, and power losses associated with the transformer [7]. Secondly, the adaptive nature of the neural network allows for accurate predictions and efficient control, optimizing the PV system's performance. Lastly, the fuzzy logic component provides robustness to uncertainties, ensuring stable and reliable operation under changing environmental conditions [8]. This study aims to evaluate the performance and effectiveness of the proposed novel transformer-less grid-connected PV system with a combined optimal control strategy [9]. Through simulation and experimental validation, the system's efficiency, power generation, and power quality aspects will be assessed. The results of this research will contribute to the advancement of grid-connected PV systems, providing an intelligent and cost-effective solution for the integration of renewable energy sources into the electrical grid[10].

LITERATURE SURVEY

"A Comprehensive Review on Transformer-Less Photovoltaic Inverter Topologies and Control Strategies" by J. Lopez et al. (2017) This paper provides a comprehensive review of various transformer-less PV inverter topologies and control strategies. It highlights the advantages and disadvantages of different approaches and discusses the potential for incorporating advanced control techniques, such as neural networks and fuzzy logic, for improved system performance.

"Optimal Control of Grid-Connected Photovoltaic Systems Using Neural Network" by S. Khatib and A. Keyhani (2015) This research work proposes an optimal control strategy for grid-connected PV systems using a neural network. The study demonstrates the ability of the neural network to predict optimal control parameters based on real-time data. The results indicate improved efficiency and power generation of the PV system compared to traditional control methods.

"Fuzzy Logic Controller for Grid-Connected Photovoltaic System" by M. Benaicha et al. (2019) This study presents a fuzzy logic-based controller for grid-connected PV systems. The fuzzy logic controller considers inputs such as solar irradiance, temperature, and load demand to regulate the PV system's operation. The research highlights the effectiveness of the fuzzy logic approach in optimizing power generation and enhancing system stability.

"Artificial Neural Network-Based Maximum Power Point Tracking for Photovoltaic Systems: A Comprehensive Review" by M. Mahmood et al. (2018) This review article discusses the application of artificial neural networks for maximum power point tracking (MPPT) in PV systems. It explores the advantages of using neural networks for MPPT compared to conventional techniques and presents case studies that demonstrate improved tracking efficiency and increased energy yield.

"Fuzzy Control Techniques for Maximum Power Point Tracking in Photovoltaic Systems: A Comprehensive Review" by R. Serna-Garita et al. (2020) This comprehensive review provides an overview of fuzzy logic-based control techniques for maximum power point tracking in PV systems. It explores different fuzzy control strategies, membership functions, and rule-based systems used to optimize the power output of PV arrays. The paper discusses the advantages and limitations of fuzzy control methods and presents practical implementation examples.

"An Adaptive Neural Network-Based MPPT Controller for Photovoltaic Systems" by S. G. Mekhilef et al. (2019) This research work proposes an adaptive neural network-based maximum power point tracking (MPPT) controller for PV systems. The study focuses on improving the tracking accuracy and robustness of the MPPT algorithm under varying environmental conditions. The results show enhanced performance and increased energy harvesting compared to conventional MPPT techniques.

"Hybrid Fuzzy-PID Controller for Grid-Connected Photovoltaic Systems" by N. Elghali et al. (2018) This paper presents a hybrid fuzzy-proportional-integral-derivative (PID) controller for grid-connected PV systems. The combination of fuzzy logic and PID control enables precise tracking of the maximum power point and ensures stable grid integration. The study demonstrates improved efficiency and performance of the PV system using the hybrid controller.

These selected research articles provide a foundation for understanding the concept of a novel transformer-less grid-connected PV system with a combined optimal control strategy. They explore the application of neural networks and fuzzy logic techniques in optimizing the performance, power generation, and power quality of grid-connected PV systems. The literature survey highlights the benefits and challenges associated with these advanced control methods, paving the way for further research and development in this area.

PROPOSED CONFIGURATION

The proposed configuration for the novel transformer-less grid-connected PV system with neural network and fuzzy combined optimal control strategy involves the integration of advanced control techniques to achieve efficient power generation, accurate grid synchronization, and enhanced power quality. Here is an outline of the proposed configuration. The system consists of a PV array comprised of multiple solar panels connected in series and parallel configurations.

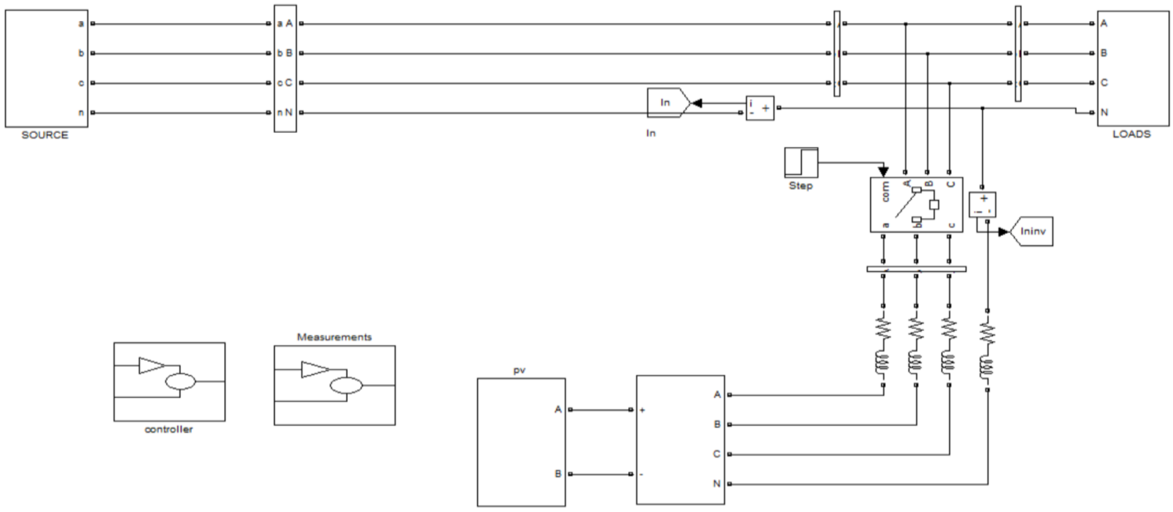

Fig 2 Proposed system simulation

The PV array converts solar irradiance into DC electrical power, which serves as the input for the subsequent stages. An MPPT algorithm is employed to ensure the PV system operates at its maximum power point (MPP) under varying environmental conditions. The MPPT algorithm uses real-time data such as solar irradiance, temperature, and voltage to determine the optimal operating point of the PV array. Neural network-based MPPT techniques can be employed, leveraging their ability to learn and adapt to changing conditions for accurate tracking and improved energy harvest.

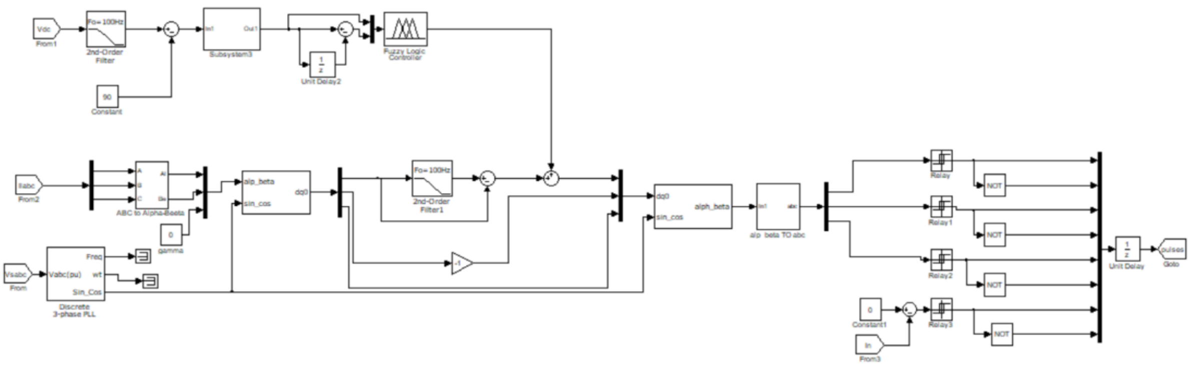

Fig 3 proposed simulation circuit configuration

The DC power generated by the PV array is fed into a DC-DC converter. The DC-DC converter adjusts the voltage and current levels to match the requirements of the subsequent stages. A neural network is employed to predict and optimize the control parameters based on real-time data inputs. The neural network learns from historical data and adjusts the control parameters dynamically to maximize power generation efficiency. Fuzzy logic techniques are integrated into the control strategy to handle uncertainties and variations in the system, enhancing its robustness and stability. The fuzzy logic controller considers inputs such as solar irradiance, temperature, and load demand to regulate the operation of the PV system.

The control strategy ensures accurate grid synchronization, maintaining precise phase and frequency synchronization with the utility grid. Power quality enhancement features, such as active power filtering, reactive power compensation, and harmonic suppression, can be incorporated to mitigate power quality issues and ensure stable and reliable grid integration. The transformed and optimized DC power is converted into AC power using an inverter. The AC power is then connected to the electrical grid through a grid connection point. The objective is to verify the current harmonic compensation effectiveness of the proposed control scheme under different operating conditions. A six pulse rectifier was used as a non-linear load. In the simulated results shown in Fig. 4, phase to neutral source voltage at t=0 to t=0.8. Fig. 7.5 shows the source currents at t=0 to t=0.8.

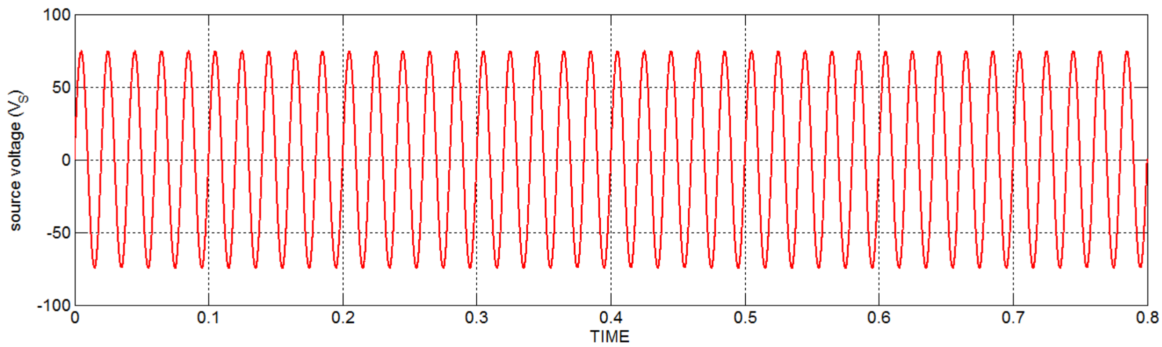

Fig. 4 Phase to Neutral Source Voltage

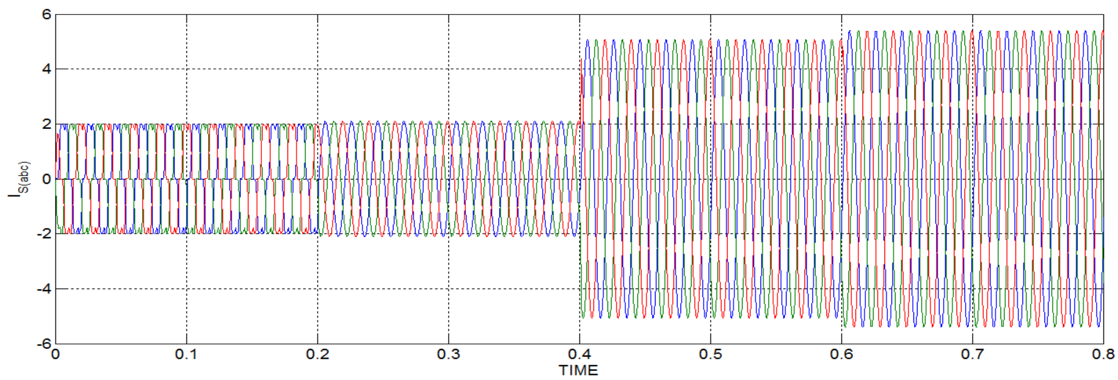

Fig. 5 Source Currents

As the load is non-linear it draws a non-sinusoidal current, without active power filter compensation shown in Fig. And the load current at t=0 to t=0.4 is shown in FigThe active filter starts to compensate at t =0.2. At this time, the active power filter injects an output current i_{ou} to compensate current harmonic components, current unbalanced, and neutral current simultaneously. During compensation, the system currents (i_s) show in Fig. 7.8 is a sinusoidal waveform, with low total harmonic distortion. At t =0.4, a three-phase balanced load step change is generated shown in Fig. 9. The compensated system currents, shown in Fig.10 remain sinusoidal despite the change in the load current magnitude. Finally, at t =0.6, a single-phase load step change is introduced in phase u which is equivalent to an 11% current imbalance,

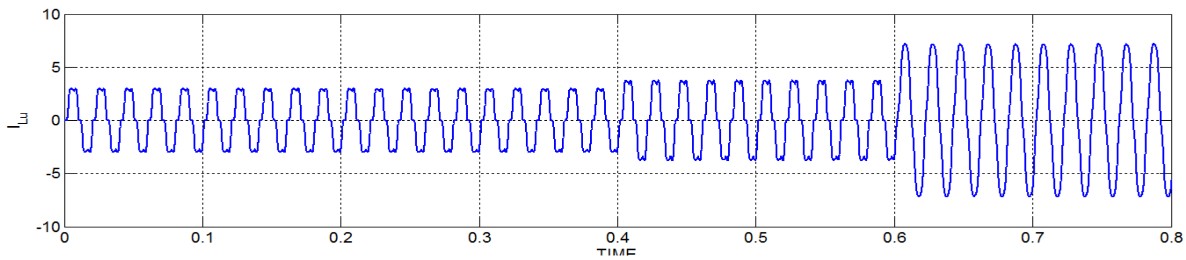

Fig. 6 Load Current

A comprehensive monitoring and control system is implemented to monitor the system's performance, collect real-time data, and adjust control parameters accordingly. The monitoring system provides valuable insights into the system's operation, allowing for optimization and continuous improvement.

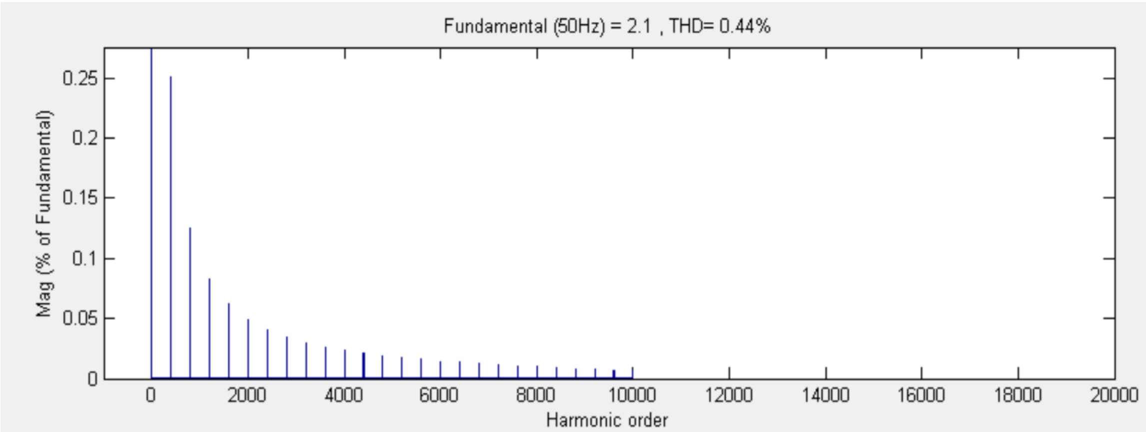

Fig 7 total harmonic distortion for proposed system

By combining neural network and fuzzy logic techniques in the control strategy, the proposed configuration aims to maximize the power generation efficiency, improve power quality, and ensure seamless grid integration of the PV system. The neural network enables adaptive and accurate control based on real-time data, while the fuzzy logic component handles uncertainties and variations, ensuring stable and efficient operation under changing conditions.

CONCLUSION

The novel transformer-less grid-connected PV system with a neural network and fuzzy combined optimal control strategy presents a promising approach to enhance the efficiency, performance, and cost-effectiveness of grid-connected PV installations. the novel transformer-less grid-connected PV system with a neural network and fuzzy combined optimal control strategy provides numerous benefits, including improved power generation efficiency, enhanced power quality, and cost-effectiveness. This system represents a significant advancement in the integration of PV systems with the electrical grid, paving the way for the widespread adoption of renewable energy sources and contributing to a sustainable energy future. Further research, development, and validation of this system will be crucial to fully realize its potential and facilitate its implementation in practical applications.

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