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AN INNOVATIVE FALCON OPTIMIZED PI CONTROLLER WITH ANN CONTROLLER FOR DUAL PV POWERED EV CHARGING SYSTEM

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Abstract: The deployment of two photovoltaic (PV) generators for electric vehicles (EVs) is a good way to promote sustainable energy use. However, traditional control methods like Proportional-Integral (PI) controllers face significant drawbacks, such as limited adaptability to fluctuating solar irradiance dynamic load conditions. This project proposes an innovative Falcon Optimized Proportional-Integral controller integrated with an artificial neural network controller for a dual photovoltaic powered electric vehicle charging system. The proposed system utilizes two PV arrays to harness solar energy, which is then fed into a high-gain Luo converter to efficiently boost the voltage. A Pulse Width Modulation (PWM) generator is employed to regulate the switching pulses, enhancing the stability and efficiency of the conversion process. The charging system integrates a single-phase Voltage Source Inverter (VSI) along with an LC filter to produce a smooth AC output suitable for grid connection. The bidirectional DC-DC converter enables effective power flow management between the EV battery and the grid, supporting both charging and discharging operations. The Falcon optimization algorithm is used to fine-tune the parameters of the PI controller, achieving optimal performance in response to dynamic changes in load and input conditions. Simultaneously, the ANN controller enhances the system's adaptability by predicting and adjusting to real-time operating conditions, thereby ensuring consistent and efficient charging. Finally, this project is implemented by Matlab Simulation 2021a**.**

***Index Terms* - Renewable Energy Sources; Photovoltaic System; PI controller (PI); Voltage Source Inverter (VSI); Electric Vehicles (EV)**

I. INTRODUCTION

The shift to efficient transportation has been sped up by the sustainable development of electric vehicles (EVs). As a more environmentally friendly option to hybrid vehicles, electric vehicles contribute significantly to the reduction of greenhouse gas emissions and the effects of climate change. But the quick rise in EV use brings with it new difficulties, especially with regard to infrastructure for charging EVs. The need for quick and easy charging stations is growing, yet integrating fast and ultrafast charging stations puts a lot of strain on the current power system. This cause power outages, voltage drops, and peak hour overloads, requiring effective strategies to address these issues. The creation of a reliable and adaptable charging system that makes use of cutting-edge energy management techniques and renewable energy sources, such photovoltaic (PV) systems, is one viable solution to these problems.

The primary topics of this project are the integration of DC power generation systems into power plants and the design and implementation of battery energy storage systems based on multi-port converters. Apart from facilitating efficient EV charging, the proposed system provides Vehicle-to-Home (V2H) scenarios, wherein Plug-in Electric Vehicles (PEVs) function as backup generators and home battery storage systems in the case of power outages or distribution system failures. This work attempts to improve system performance and optimize charging by utilizing a space vector modulation technique in conjunction with a Multi-Mode Converter (PCMM). In addition, the integration of artificial neural network (ANN) control was studied to enhance the monitoring of electric vehicle charging. This approach provides better control performance and greater flexibility than traditional proportional input (PI) controllers. This process uses experimental and computational data to confirm the payment system's viability and efficacy. The findings show that, in typical home contexts, the PCMM accomplish the design goals and work well with an independent Energy Management System (EMS). The aim is to use this research to support the development of a more robust and sustainable electric vehicle charging system, helping to achieve greater energy efficiency and moving towards stronger energy availability in the future.

II. LITERATURE SURVEY

In the upcoming decade, electric and hybrid vehicles will be the most prevalent automobiles that need to adhere to urban traffic regulations. This paper presents model predictive current control (MPCC) as a method to control single-phase full-bridge inverters during combined operation in battery mode. The MPCC method has a faster response time compared to feedback-based control. Compared with the ordinary MPCC method, the current output has similar characteristics.

Md. Mizanur Rahman et al [2022] proposed a comprehensive nonlinear stability analysis and active compensation method for a utility-scale single-stage grid-connected photovoltaic (PV) system. Considering the weakness of the maximum power point finding (MPPT) algorithm based on increment (INC) and the impact of the operation of the conversion process of the photovoltaic system, the explanation demonstration function (DF) based on security analysis is carried out [1].

Ghulam Hafeez et al [2022] demonstrated load scheduling, battery energy storage control, and improving user comfort are critical energy optimization problems in smart grids. Energy products include renewable energy production methods, traditional energy production methods, battery charging and discharging methods, competitive prices, transportation methods of incoming goods, etc., including battery power storage, controller operation to improve the transportation time, energy production and usage or comfort [2].

Mohammed Jameel et al [2022] proposed the integration of electric vehicles and renewable energy, the negative carbon footprint of electric vehicles has been increasingly increased in recent years, but the reliability of the related products is a major concern today. Therefore, the incentive-based fuzzy fault tree analysis (NIBFFTA) method is proposed for the reconstruction of the power system by considering the impact of the new-based hybrid wind-solar power generation of electric vehicles and renewable energy [3].

Erdem Gumrukcuet al [2022] developed a strategy to manage an electric vehicle charging station (EVCSs) with a grid-side interface based on a Modular Multilevel Converter (MMC). The MMC topology has been investigated because it reduce the footprint by allowing switching that is not connected to the middle of the power distribution and the power supply to be used in the internal distribution. The current at the gate interface should be uniform and sinusoidal [4].

Wanke cao et al [2022] described a lateral motion control scheme for a distributed drive electric vehicle. It determines the uncertainty and random movements of the connected car in detail. Shared driving vehicles are based on well-known E/E models, including in-car connectivity, vehicle speed control and advanced driver assistance systems (ADAS), to ensure safety and comfort in traffic [5].

Aamir Mehmooda et al [2023] described integrating solar photovoltaic (PV) energy into the residential sector. Firstly, statistical methods are used to identify the synergistic and balancing effects of DPs, and data augmentation method is used to identify DPs with solar energy effect. Then, the impact of solar photovoltaic system on energy sustainability is evaluated by considering the optimized DP and energy-economic-environmental decision evaluation [6].

Shahid Jaman et al [2023] developed a novel grid-connected modular inverter for an integrated bidirectional charging station for residential applications. By boosting grid security and offering buffer services, the technology is intended to assist the grid. It has a bi-directional, modular inverter that doubles as an EV charger. In addition to charging and discharging the EV battery, the system may also store extra grid power during periods of low demand and deliver targeted power to the grid during periods of high demand [7].

Abdul Hafeez et al [2023] presents a comprehensive data-driven approach based demand-side management for a solar-powered electric vehicle charging station connected to a microgrid. This method uses solar-powered EV charging stations to pay for the energy needed when demand is highest, thus reducing the usual energy consumption and reducing the current EVCS problem [8].

Enrico Giglio et al [2023] suggested that the increasing penetration of variable renewable energy sources is progressively eroding the ability of conventional power plants to ensure grid stability. Other assets, including storage and management, need to be different and make the system stable, but all contributions need to be analyzed and worked out with the electrical model first. Modeling operating parameters such as special needs will increase the economic impact, especially when using long-term plans with room needs [9].

Amir Ahmadifar et al [2023] proposed the development of an Energy Management System (EMS) for a Renewable Energy Community (REC) with a load-generation balancing objective. In this context, a rule-based optimization mechanism for REC control is based on the scope of the experimental area and takes into account the lack of measurements and historical data. The lack of these data, together with the inconsistent behavior of renewable energy resources, indicates the uncertainty that is not captured in the EMS data and ultimately affects the appropriate REC management [10].

Frede Blaabjerg et al [2023] proposed an integrated grid of renewable energy sources (REN) requires efficient and reliable electricity transfer from the grid, especially in situations where the demand for high control and flexibility increases. Power converters, built with advanced management and information technology, play an important role in large-scale REN generation. The integration of the electric power grid is aimed at large-scale REN electricity generation [11].

Objectives:

To implement falcon optimized PI controller with ANN controller for a dual PV-powered EV system.
To maximize solar energy utilization with the high-gain Luo converter.
To leverage the ANN controller for real-time prediction and adjustment of operating conditions.
To optimize performance and minimize power losses using the Falcon optimized PI controller.

III. MODELING AND CONFIGURATION OF DUAL PV POWERED EV CHARGING SYSTEM

Nowadays, the demand for energy in our daily life is increasing. It leads to the idea that electric vehicles (EVs) are pollution-free. The world population continues to grow and more and more electric vehicles are needed. Electric vehicles play the most important role in electric transportation. Therefore, electric automobiles will become a clean and green vehicle for the current transportation systems when the electricity required to charge them comes from renewable energy sources like solar and wind. The energy management method is effective for photovoltaic systems with electric vehicle battery charging capability while using the electric vehicle battery as energy storage, reducing the photovoltaic effect and enabling photovoltaic systems to be installed on the grid. In the power management of electric vehicle battery-photovoltaic systems, the impact of the high penetration of electric vehicles and photovoltaics on the distribution network has been reduced, and the self-use of the photovoltaic system is a good development.

In this project, a dual PV charging system for EVs integrating a Falcon Optimized PI controller with an ANN controller is proposed. The system harnesses energy from two PV arrays, which is then boosted to a higher voltage through a high-gain Luo converter shown in figure 1. To regulate this process efficiently, a pulse width modulation (PWM) generator controls the switching pulses. The system employs a single-phase voltage source inverter (VSI) coupled with an LC filter to produce a stable AC output suitable for grid integration. A bidirectional DC-DC converter is integrated to manage power flow between the EV battery and the grid, enabling both charging and discharging functionalities.

The Falcon optimization algorithm refines the PI controller parameters for optimal performance amidst varying load and input conditions. In parallel, the ANN controller improves system adaptability by forecasting and adjusting to real-time conditions, ensuring efficient and reliable charging. This innovative approach reduces power losses and enhances battery longevity. The project is developed using MATLAB Simulation 2021.

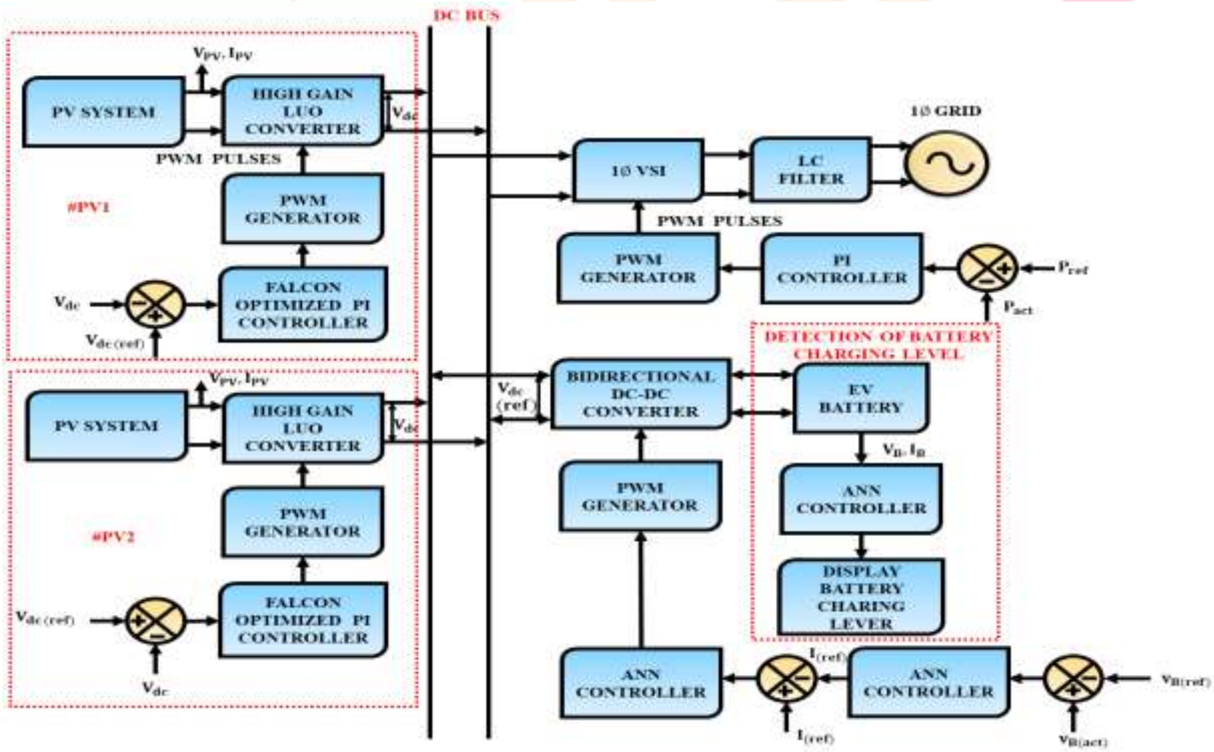

Figure 1. Block Diagram of Dual PV Powered EV charging System

Modeling of the Dual PV Powered EV Charging System:

A. PV Panel

The PV system consists of two photovoltaic (PV) arrays, each functioning independently to harness solar energy shown in figure 2.

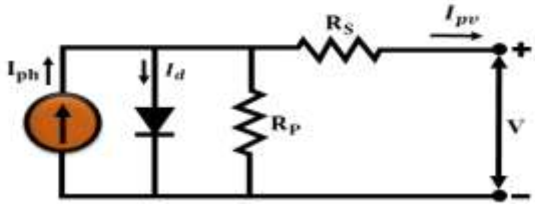

Figure 2. PV Cell

By utilizing two separate PV systems, the overall reliability and energy output of the system are enhanced, contributing to a sustainable energy solution that minimizes reliance on fossil fuels and reduces carbon emissions [12,13].

B. High-gain Luo Converter

The high-gain Luo converter typically incorporates capacitors and inductors in both the input and output stages, which not only boost the voltage but also improve efficiency by reducing switching losses and ripple.

C. Falcon Optimized PI Controller

The FALCON optimized PI controller is an advanced control strategy specifically designed to enhance the performance of proportional-integral (PI) controllers in various applications, particularly in power electronics and renewable energy systems.

This optimization technique focuses on fine-tuning the parameters of the traditional PI controller to achieve improved stability, responsiveness, and accuracy in controlling dynamic systems. The FALCON approach employs algorithms that adaptively adjust the controller gains based on system performance metrics, enabling the controller to better handle variations in system behavior and external disturbances. By optimizing the tuning process, the FALCON optimized PI controller minimizes overshoot and settling time, ensuring that the system reaches its desired set point quickly and efficiently.

D. Single Phase VSI

A single-phase voltage source inverter (VSI) is a device that converts direct current (DC) to alternating current (AC) in a single-phase configuration shown in figure 3. It uses semiconductor switches to switch the DC voltage on and off, resulting in a modulated AC output. This inverter is particularly important in applications such as renewable energy systems, where it converts the DC output from solar panels into usable AC power for residential or commercial use.

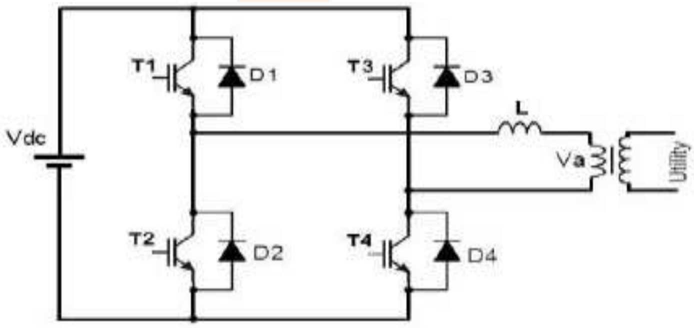

Figure 3 Single Phase VSI

E. LC Filter

An LC filter is a circuit consisting of an inductor (L) and a capacitor (C) designed to select frequency components in a signal. Its main function is to allow certain frequencies to pass while attenuating others, which makes it important in many applications such as electrical power and signal processing.

E. Bidirectional DC-DC Converter

A bidirectional DC-DC converter is an electrical power supply that to convert direct current (DC) between different voltages in two directions shown in figure 4. This type of conversion is important for applications where energy must flow in both directions, such as energy storage, electric vehicles, and renewable energy networks. The primary feature of a bidirectional DC-DC converter is its ability to facilitate two-way power flow, allowing for voltage step-up and step-down as required. These converters employ advanced control strategies to efficiently manage energy transfer, ensuring voltage levels are maintained and optimizing performance. They are particularly valuable for battery charging and discharging, enabling effective energy management in electric vehicles and renewable energy systems. Additionally, bidirectional converters contribute to grid stability by managing energy flow between storage systems and the grid, making them essential components in modern energy management solutions [14].

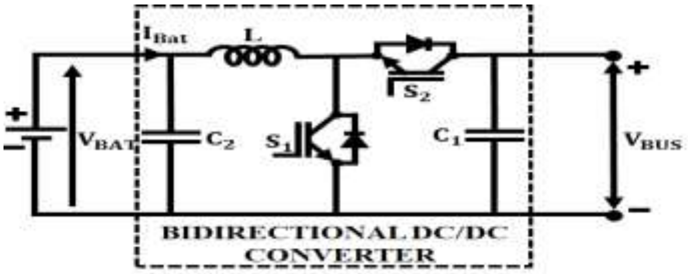

Figure 4 Bidirectional Dc-Dc Converter

IV. RESULTS AND DISCUSSIONS

MATLAB simulation is a powerful tool for engineers, researchers, and students, providing a reliable environment for modeling, testing, and optimizing systems. The overall matlab circuit diagram is shown in figure 5.

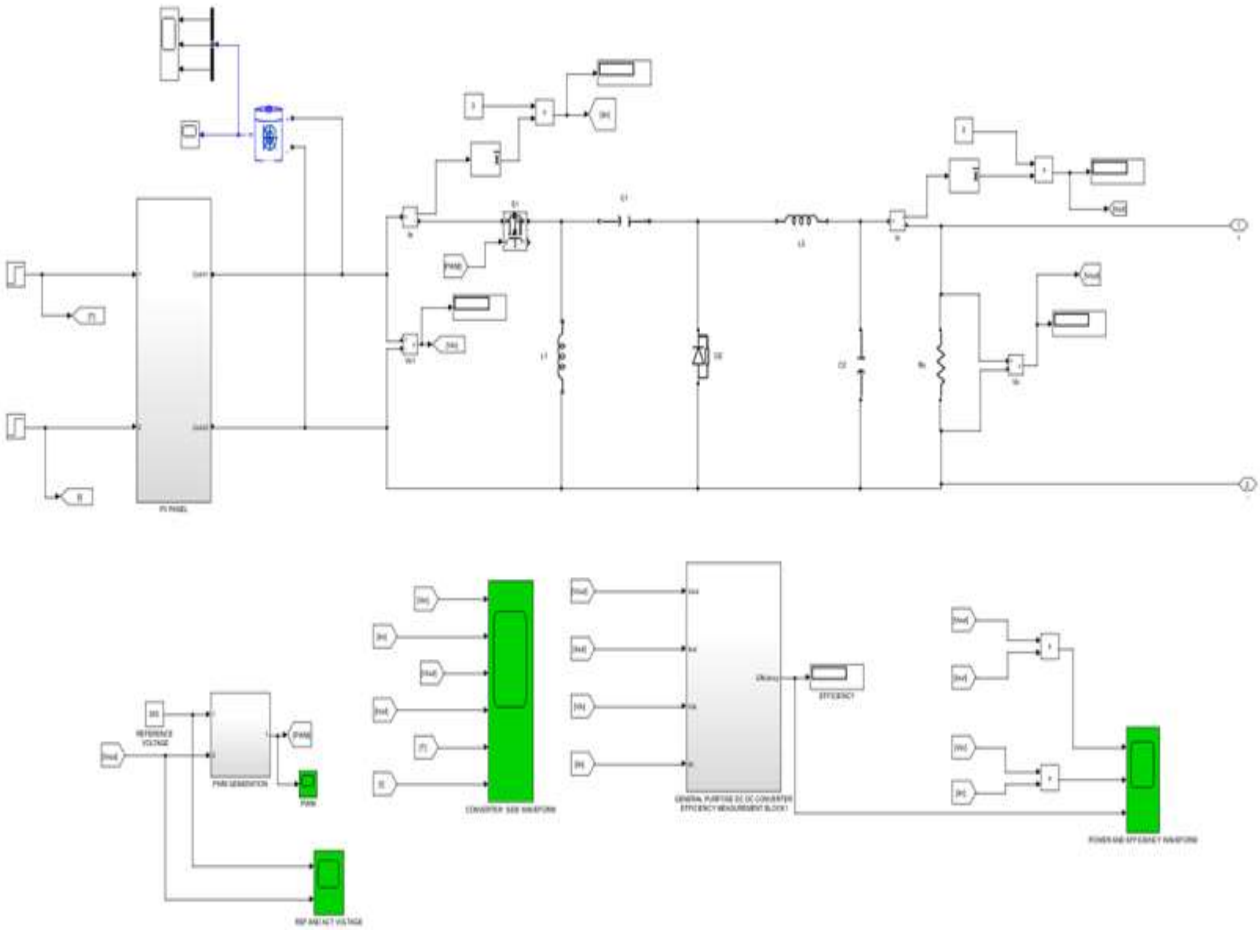

Figure 5.Over All Simulation Diagram

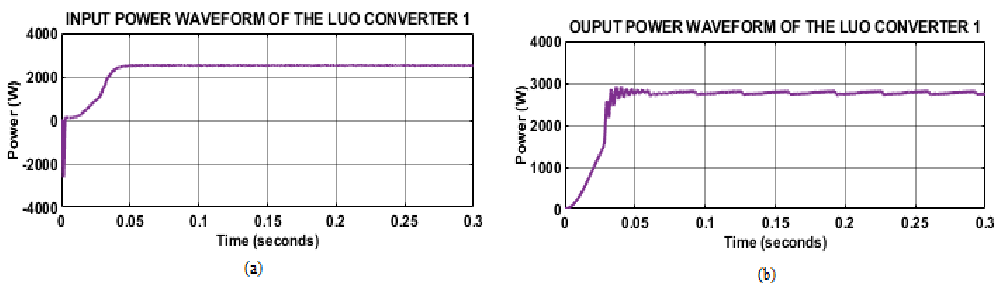

Figure 6 Input Power Waveform of LUO Converter 1

The input power waveform of the LUO converter 1 is shown in figure 6. These input powers fluctuated between around -4000 W and 4000 W over the 0.3 second time period. The output power waveform of the LUO converter 1 indicates the output power varying between approximately 0 W and 3500 W during the same time interval.

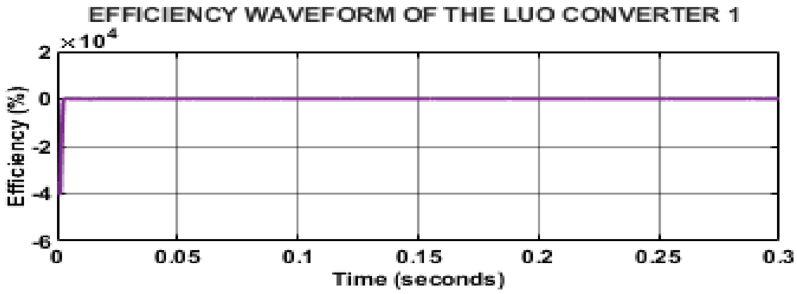

Figure 7 Efficiency Waveform of LUO Converter 1

Figure 7 shows the efficiency waveform of the LUO converter 1. The efficiency remained relatively constant, around 80% over the 0.3-second time period.

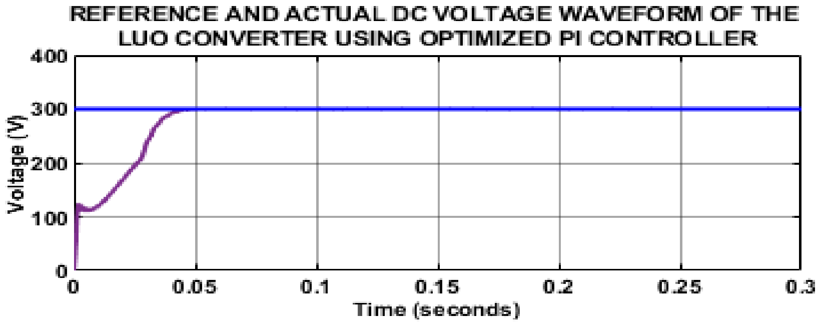

Figure 8 Reference and Actual Voltage Waveform of LUO Converter

The reference DC voltage waveform for the LUO converter shows in figure 8. Output voltage varying between approximately 100 V and 350 V over the 0.3 second time period. The actual DC voltage waveform closely tracks the reference voltage, indicating the optimized PI controller is effectively regulating the output voltage to the desired levels.

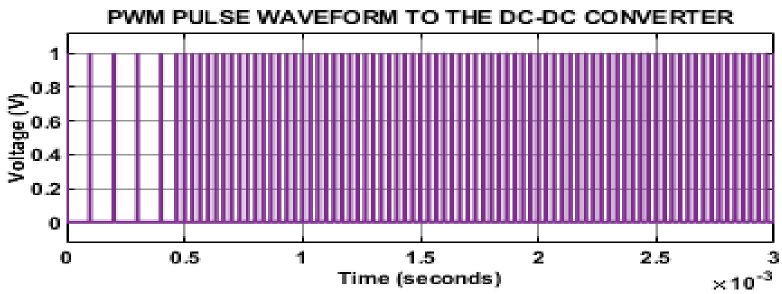

Figure 9 PWM Pulse Waveform

Figure 9 shows the PWM pulse waveform to the DC-DC converter. A series of square wave pulses with a voltage level of approximately 1 V over the 3 millisecond time period. The consistent pulse width modulation pattern is an important working process value, as it indicates the converter is receiving the necessary control signals to regulate the power conversion and output.

V. CONCLUSION

An innovative falcon-optimized pi controller with ANN controller for a dual PV-powered EV charging system was proposed in this project. The innovative dual photovoltaic-powered electric vehicle charging system presented in this project demonstrates a significant advancement in harnessing solar energy for efficient EV charging. By integrating a Falcon Optimized PI controller with an Artificial Neural Network (ANN), the system effectively manages dynamic conditions and optimizes the charging process. The utilization of two PV arrays and a high-gain Luo converter ensures efficient voltage boosting, while the single-phase voltage source inverter (VSI) and LC filter provide a clean AC output for grid connectivity. The bidirectional DC-DC converter further enhances power flow management, allowing seamless charging and discharging of the EV battery. Overall, the dual control strategy not only minimizes power losses but also extends battery life, showcasing a robust and adaptable solution for sustainable electric vehicle charging. The implementation through MATLAB Simulation 2021 further validates the system's efficacy, offering a practical approach to improving renewable energy utilization in electric vehicle infrastructure.

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