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HYBRID ENERGY SYSTEM FOR EV CHARGING STATION USING PV FED Z-SOURCE MODIFIED LUO CONVERTER AND FUEL CELL INTEGRATION

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Abstract

Electric vehicle (EV) adoption is rising rapidly, necessitating the development of efficient and sustainable EV charging stations. Conventional EV charging stations depend heavily on grid power, leading to energy security concerns, high costs, and limited renewable energy utilization. This paper proposes a hybrid energy system integrating photovoltaic (PV) technology and fuel cells through a centralized DC bus. A Z-source modified Luo converter is used in the PV system, regulated by a Walrus-optimized PI controller to ensure stable voltage output. A boost converter with a PI controller enhances the fuel cell's output voltage. The energy sources are connected to a three-phase voltage source inverter (VSI) to deliver consistent power to the EV charging stations. The proposed system optimizes energy utilization, improves efficiency, and reduces dependency on fossil fuels, making it a viable solution for future EV infrastructure.

1. Introduction

The growing demand for electric vehicles (EVs) necessitates a reliable and sustainable charging infrastructure. Conventional EV charging stations rely significantly on the power grid, leading to increased operational costs and energy security concerns. To address these issues, hybrid energy systems integrating renewable sources such as solar energy and fuel cells have been explored. However, existing solutions often face challenges related to power stability, energy management, and efficiency. This paper introduces an optimized hybrid energy system leveraging a Z-source modified Luo converter and an intelligent PI controller to improve the reliability and sustainability of EV charging stations.

2. Literature Review

Isla Ziyat *et al* [2023] have proposed new concept charge curve and waveform (EV-CPW) data for AC electric vehicle charging. The file contains charging curves and high-resolution current/voltage AC waveforms for 12 different electric vehicles, including popular EVs and plug-in hybrids. Benchmarking is performed to compare EV charging behavior with new recommendations for standard models

Yating Ding *et al* [2024] have proposed the new electric vehicle system (EV) has emerged as an important strategy to reduce carbon emissions. However, the inadequacy and inconsistency of charging stations have reduced consumers' willingness to purchase electric cars, leading to stagnation in the electric car market.

Shahid Jaman *et al* [2023] have proposed a new framework using grid-tied modular Inverter with Integrated bidirectional charging points for residential applications are designed to increase grid reliability by providing uninterrupted services and ensuring grid security

G. Dhasharatha *et a*l [2024] have proposed a The new frame uses a nine-stage quadrupole boost (NLQB) inverter that can measure the capacitor's own voltage, simplifying the working efficiency. More importantly, due to this

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self-measurement, there is no need for a power meter or a connected power meter to measure the power. A capacitor is connected to a voltage generator output stage with a suitable charge/discharge scheme

Dong Sik Kim ***et al*** **[2024]** have proposed a The use of new methods for EV charging time based on a combination of AC slow and DC fast chargers has been compared with the reduction of costs compared to various charging vehicles. AC payments have dynamic time of use (TOU) plans in addition to fixed-rate plans.

Leloko J. Lepolesa ***et al*** **[2024]** have proposed a The new system uses a network-level dynamic pricing strategy to efficiently charge EVs using distributed and balanced lines between residential and commercial/commercial suppliers. . Based on evidence that most EVs

Kaleb Phipps ***et al*** **[2023]** have proposed a new framework uses EV user-centric SC applications. A high degree of security is provided to minimize the probability of a serious error that poses a dangerous risk to the user. of the distribution line to control where and when EVs charge.

Yunhe Yu ***et al*** **[2024]** have proposed the new framework adopts the MIP EV smart charging algorithm and is designed for low-energy applications. The SC-Alg implementation includes the parameters used and is equipped with a flexible switching strategy to control the parameters. SC-Alg showed good and stable results with or without external pressure

V. C. Mahaadevan ***et al*** **[2024]** have proposed the new system uses AViTRoN (Advanced Visual Tracking Guidance and Navigation), designed for charging robots in electric vehicle (EV) charging applications. AVIRoN integrates advanced technologies for charging port detection, navigation, and enhanced user experience.

Fenil Ramoliya ***et al*** **[2024]** have implemented a After analyzing the negative factors such as location, workday, holiday and user, a new strategy for high-performance EV charging was used to utilize the EV energy consumption and distribution model in the smart environment.

Nivedita Naik ***et al*** **[2023]** have the design is based on the mathematical model of e-DAB converter using Generalized Average Model (GAM) and Average Output Current Linearization Model (AOCLM). This paper conducts a safety analysis and proposes a new strategy to control current and power during EV charging to reduce fuel consumption

Luca Argiolas ***et al*** **[2022**] have the model uses mixed-use modelling as a flexible tool to assess the economics of BESS performance in supply lines. A case study of photovoltaic charging stations in the Netherlands, including the Dutch electricity market, confirms the costs, performance and economics of the solution and the feasibility of the project.

Heba M. Abdullah ***et al*** **[2022]** have proposed a Micro project for deployment of electric vehicle charging stations (EVCS) using new standard layers of Electric Vehicle Assessment and Evaluation (EVI-PAT) for solar energy. In order to assess the feasibility of the system, the study materials of Qatar University (QU) campus were selected to integrate electric vehicle charging and photovoltaic energy generation to evaluate the efficiency of the planning process.

Yu Yang ***et al*** **[2024]** have proposed new ideas for the best design of solar and battery-powered electric vehicle (EV) charging stations. Two different payment management systems have been developed: MPC and rule-based system. MPC uses solar energy and demand forecasting to solve two optimization problems to determine the single charging rate.

Ajay Kumar Gupta ***et al*** **[2024]** have developed this architecture uses multiple uncoordinated electric power stations (EVCS) and aims to maximize efficiency. In contrast, electric vehicles (EVs) aim to reduce costs. Here, we introduce a game development that reduces the limitations in implementing the Competitive Hospitality Game (CHG) to achieve cost balance among multiple non-cooperative players in a competitive market. In CHG, each player is expected to have a good job.

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Muddsair Sharif ***et al*** **[2023]** have A new concept of using deep learning (DRL) based context-aware smart charging for electric vehicles is proposed, which takes into account the needs and goals of each participant. DRL-based systems adapt to changing conditions such as time of day, location and weather, optimize flight decisions by balancing payment, and reduce stress, payment of electricity work for the driver's favorite and maintenance office at the same time.

Shahab Sabzi ***et al*** **[2024]** have implemented the architecture uses a machine learning-based framework to optimize EV charging by considering the driver's satisfaction measured by the public's behavior, state-of-the-art (SoC), charging-connected devices, and cost-effective behavior of new models. Driving satisfaction is defined as the degree to which the electric car pays well according to the driver's needs.

Andrei Blinov ***et al*** **[2022]** have proposed a new concept for electric vehicle (EV) charging based on variable windings, where a three-phase solution (VRU) based on a Vienna rectifier is tested while switching bank (CSC) in feedback from two different current connections. Since the VRU operates at low frequency, the changes are negative and the CSC is responsible for coupling the active line current with the output voltage control.

Sepehr Najafi Larijani ***et al*** **[2023]** have proposed the new system uses electric generators (ERS) and electric generators, battery energy storage (BESS) and FCS electronics (FCS-ESCH). The Intermodal Sustainable Electric Transportation System (SETS) is designed to reduce the peak electricity demand in FCS, especially in strategic areas close to electric train stations, parking lots and garages.

S. Harini ***et al*** **[2022]** have proposed a new concept it is recommended to use a multi-port ZQR DC/DC converter to charge the battery from EV. The advantage of this switch is to increase the ratio and reduce the difference, keeping the current constant even at 0.4 duty cycle,

Several studies have explored the integration of renewable energy sources into EV charging stations. Prior research has focused on using photovoltaic (PV) panels, wind energy, and energy storage systems to enhance charging station efficiency. However, these approaches often struggle with inconsistent power generation and grid dependency. Researchers have proposed advanced power electronics and controllers to mitigate these challenges, but further optimization is necessary to enhance performance. The proposed system builds on this research by employing a Z-source modified Luo converter and a fuel cell integration strategy, improving power stability and efficiency.

3. Proposed System

3.1 System Overview

The proposed hybrid energy system integrates a PV array and a fuel cell through a centralized DC bus. The PV system employs a Z-source modified Luo converter optimized by a Walrus-optimized PI controller to regulate voltage and generate PWM signals for power control. The fuel cell is paired with a boost converter, also controlled by a PI controller, to improve output voltage. The energy from both sources is directed to a three-phase VSI, ensuring efficient AC power delivery to the EV charging station.

4. System Design and Implementation

This paper proposes a hybrid energy system designed for EV charging stations, integrating photovoltaic (PV) technology with fuel cells through a centralized DC bus. The PV array employs a Z-source modified DC-DC converter, optimized by a Walrus-optimized PI controller to maintain stable voltage output and generate PWM signals for efficient power regulation. The fuel cell is paired with a boost converter, also controlled by a PI controller, to improve its output voltage. Both energy sources feed into a three-phase VSI, which transforms DC power into AC for grid integration, with an LC filter ensuring clean power delivery. Additionally, a bidirectional DC-DC converter facilitates effective energy management between the battery and the DC bus. The battery's operation is overseen by an Artificial Neural Network (ANN) controller, which dynamically adjusts charging and discharging in response to power demand and availability. This hybrid system aims to enhance energy efficiency,

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improve grid reliability, and offer a sustainable solution by leveraging the complementary strengths of PV and fuel cell technologies. The Block diagram representation of Proposed system is shown in Fig.1

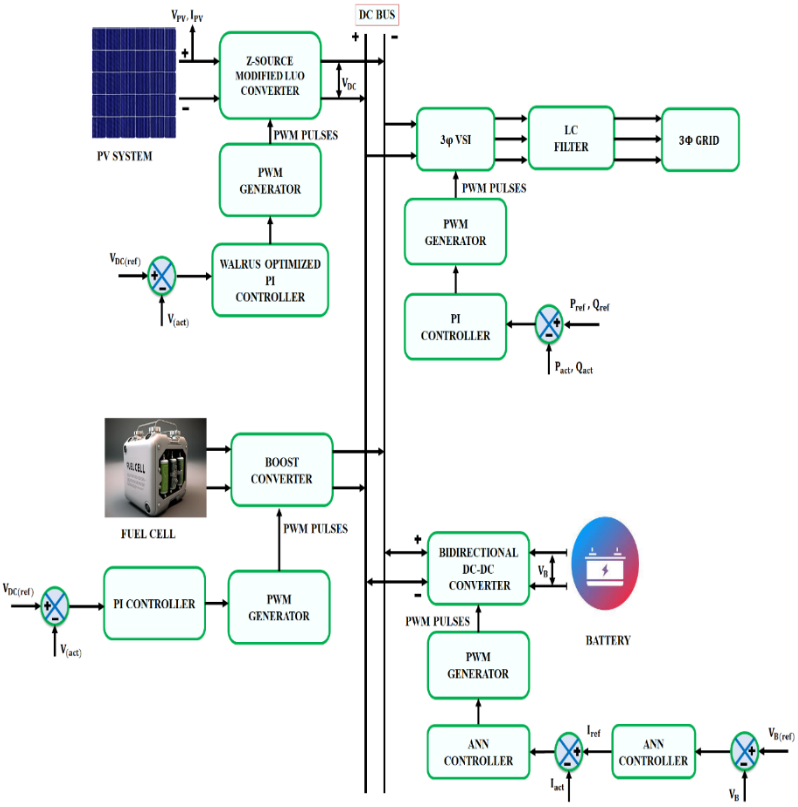

Fig.1 Block diagram representation of Proposed system

4.1 PV System with Z-Source Modified Luo Converter

The PV system operates with a Z-source modified Luo converter, optimizing voltage control using a Walrus-optimized PI controller. The controller dynamically adjusts the duty cycle to maintain stable output voltage, reducing power fluctuations and improving efficiency. The source modified Luo converter is shown in Fig.2. the Luo converter is operated in two modes as represented by Fig.3 (a) and (b)

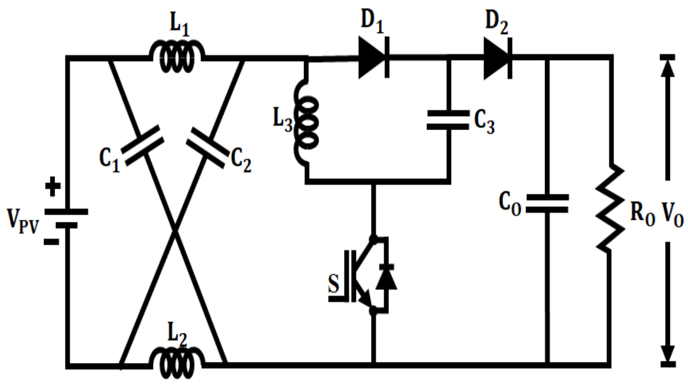

Fig. 2 Z Source Modified Luo Converter

Mode-1:

In this mode, the switch S is active so the inductor L_3 is charged causes the capacitor C_3 discharge, as shown in Figure 4. The diode D_1 is forward biased, D_2 is reverse biased and the capacitor C_O is discharged. Here, the input

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part is isolated from the load side. The inductors L_1 and L_2 are charged and capacitors C_1 and C_2 are discharged. The Mode-1 operation is

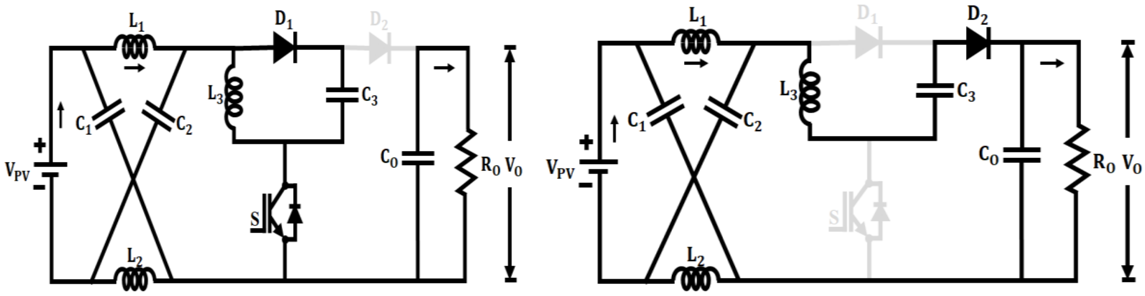

Figure 3 (a) Mode-1 Operation (b) Mode-2 Operation

Mode-2:

In this mode, the switch S is OFF thereby the inductor L_3 is discharged making the capacitor C_3 charge. Here, diode D_1 is reverse biased, D_2 is forward biased and capacitor C_O is charged. The waveforms as in Fig 4 can be observed at the converter

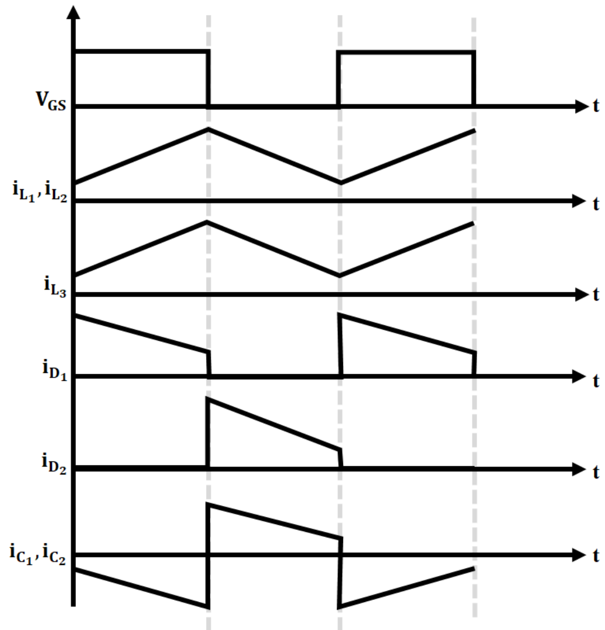

Fig.4 Waveform of developed converter

4.2 Fuel Cell with Boost Converter

The fuel cell system includes a boost converter managed by a PI controller. This setup enhances voltage output and ensures consistent power delivery. The boost converter steps up the fuel cell voltage to match the system requirements.

4.3 Energy Management Strategy

An intelligent energy management system monitors power generation, load demand, and battery storage. The bidirectional DC-DC converter facilitates efficient energy transfer between the battery and the DC bus, ensuring optimal power distribution.

4.4 Walrus optimized PI controller

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The Walrus optimized PI controller is a sophisticated control strategy designed to improve the performance of traditional proportional-integral (PI) controllers by optimizing their parameters for specific application requirements, The flow chart illustrates the sequence of steps in the PI controller.

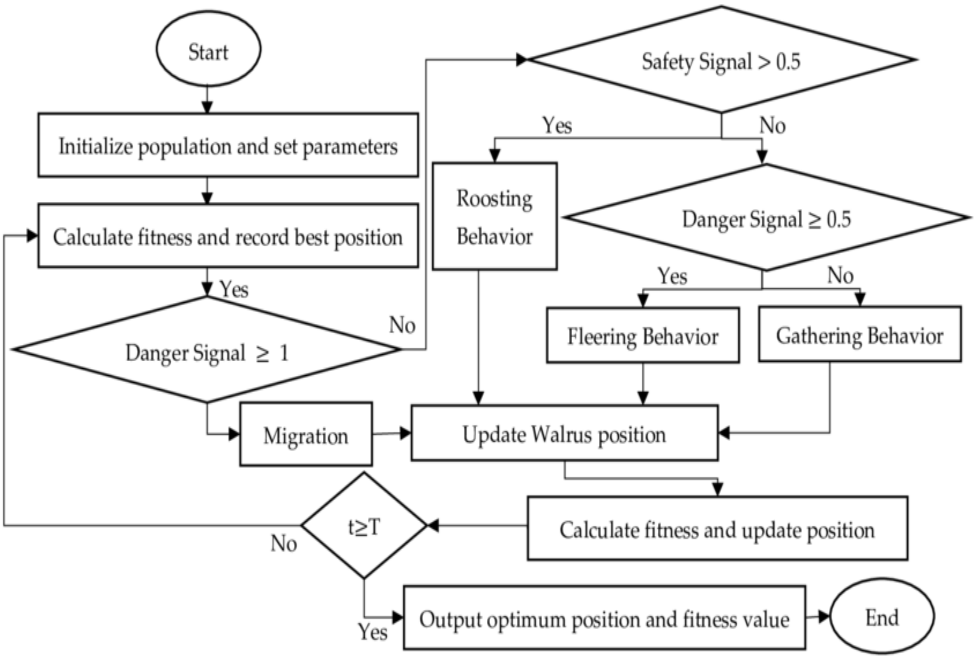

Fig.5 Flow Chart for Walrus Optimized PI Controller

4.5 Integration with Three-Phase VSI

The three-phase VSI converts DC power to AC for grid compatibility. An LC filter is used to smooth the output, ensuring minimal harmonic distortion and improved power quality.

5. Results and Discussion

The proposed hybrid energy system was simulated using MATLAB/Simulink to evaluate its performance. The results indicate significant improvements in voltage stability, efficiency, and energy utilization compared to conventional systems.

CASE 1 : Constant temperature & constant intensity

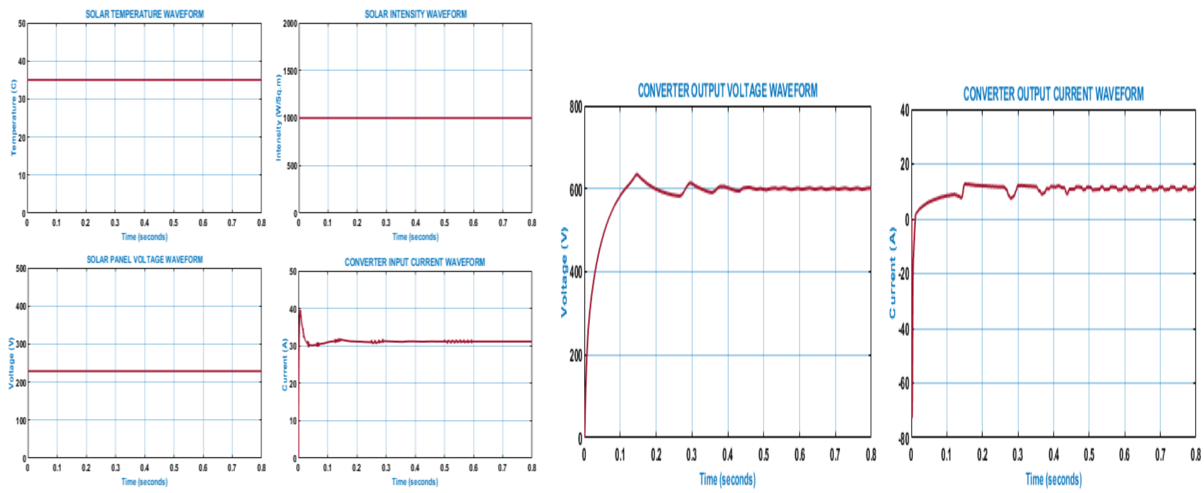

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Fig. 6 (a) Solar Panel and Converter Input Waveform
(b) Converter Output Waveform

Fig 6 illustrates two waveforms associated with the converter components of a solar system. The first image shows the converter output voltage waveform, which varies from about 600 volts to 800 volts over the period shown. The second diagram shows the converter output current waveform, which varies between positive and negative, indicating the bidirectional nature of the current. These waveforms provide information about the operation and behaviour of the converter, which is a key component in converting solar energy produced by the panels into usable electricity.

CASE 2 : Varying temperature & varying intensity

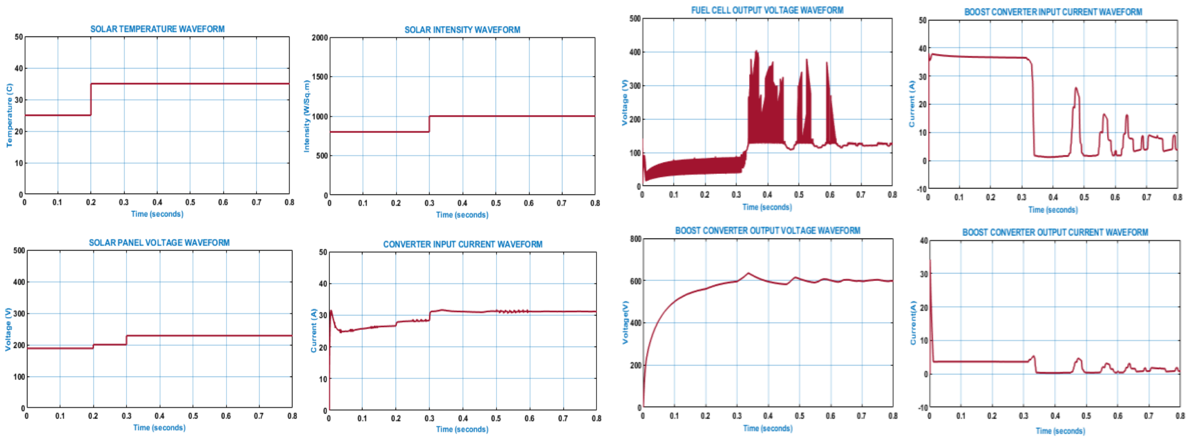
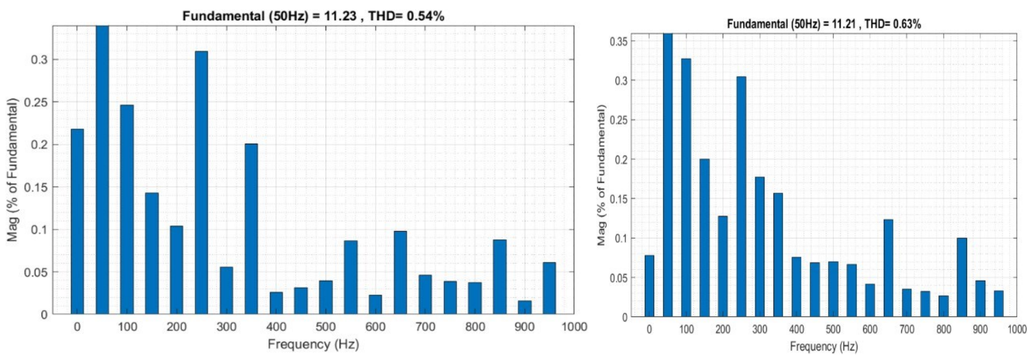


Fig. 7 (a) Solar Temperature and Converter Input Current Waveform
Fig (b) Fuel Cell and Boost Converter Output Waveform

The Fig 7 illustrates a comprehensive overview of the waveforms associated with a solar energy system. It includes the solar temperature waveform, solar intensity waveform, solar panel voltage waveform, and converter input current waveform.

Figure 7 shows the various waveforms associated with a fuel cell and boost converter system. The first graph shows the fuel cell output voltage waveform and shows the large variation over the indicated period. The second diagram shows the boost converter input current waveform varying between positive and negative, indicating the bidirectional nature of the current. The third figure shows the boost converter output voltage waveform remaining constant around 600 volts. The fourth diagram shows the boost converter output current waveform varying between positive and negative. These waveforms provide information about the fuel cell's operation and behaviour and support switching of equipment throughout the body. The THD evaluation in phase R.Y, B is shown in Fig 8



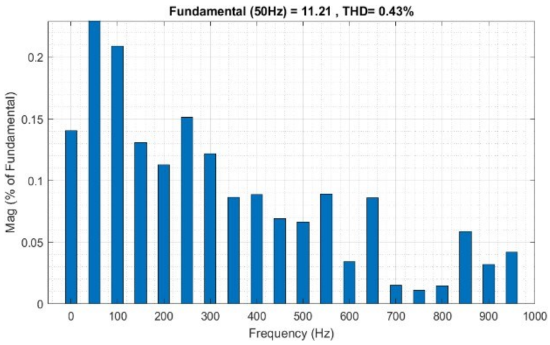


Fig. 8 THD in Phase R,Y,B

The key findings include:

- **Voltage Stability**: The Walrus-optimized PI controller successfully maintains stable output voltage under varying load conditions.
- **Efficiency**: The integration of PV and fuel cell sources improves overall energy efficiency, reducing dependency on grid power.
- **Power Quality**: The three-phase VSI ensures smooth AC power delivery with minimal harmonics.
- **Cost-Effectiveness**: Reduced reliance on grid power lowers operational costs and enhances economic feasibility.

6. Conclusion

The proposed hybrid energy system provides a sustainable and efficient solution for EV charging stations. By integrating PV technology, fuel cells, and advanced power electronics, the system enhances energy utilization, reduces grid dependency, and improves reliability. Future work will focus on real-time implementation and testing in practical scenarios, as well as exploring AI-based optimization techniques for further efficiency improvements.

References

1. Ziyat, A. Gola, P. R. Palmer, S. Makonin and F. Popowich, "EV Charging Profiles and Waveforms Dataset (EV-CPW) and Associated Power Quality Analysis," in IEEE Access, vol. 11, pp. 138445-138456, 2023.
2. Y. Ding, F. Chen, J. Feng and H. Cheng, "Competition and Pricing Strategy of Electric Vehicle Charging Services Considering Mobile Charging," in IEEE Access, vol. 12, pp. 88739-88755, 2024.
3. S. Jaman, M. Abdel-Monem, T. Geury and O. Hegazy, "Development and Validation of an Integrated EV Charging Station With Grid Interfacing Inverter for Residential Application," in IEEE Access, vol. 11, pp. 115751-115774, 2023.
4. G. Dhasharatha, M. H. Khan and B. Mangu, "A Novel Nine-Level Quadruple Boost Inverter for Electric Vehicle Applications," in IEEE Access, vol. 12, pp. 60694-60704, 2024.
5. D. S. Kim, Y. Mo Chung and B. Jin Chung, "On the Electric Energy Rate Plans in Charging Electric Vehicles," in IEEE Access, vol. 12, pp. 97196-97206, 2024.
6. L. J. Lepolesa, K. E. Adetunji, K. Ouahada, Z. Liu and L. Cheng, "Optimal EV Charging Strategy for Distribution Networks Load Balancing in a Smart Grid Using Dynamic Charging Price," in IEEE Access, vol. 12, pp. 47421-47432, 2024.
7. Y. Yu, L. De Herdt, A. Shekhar, G. R. C. Mouli and P. Bauer, "EV Smart Charging in Distribution Grids–Experimental Evaluation Using Hardware in the Loop Setup," in IEEE Open Journal of the Industrial Electronics Society, vol. 5, pp. 13-27, 2024.

ISSN 2454-9940

www.ijasem.org

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8. V. C. Mahaadevan, R. Narayanamoorthi, S. Panda, S. Dutta and G. Dooly, "AViTRoN: Advanced Vision Track Routing and Navigation for Autonomous Charging of Electric Vehicles," in IEEE Access, vol. 12, pp. 12402-12423, 2024.
9. K. Phipps, K. Schwenk, B. Briegel, R. Mikut and V. Hagenmeyer, "Customized Uncertainty Quantification of Parking Duration Predictions for EV Smart Charging," in IEEE Internet of Things Journal, vol. 10, no. 23, pp. 20649-20661, 1 Dec.1, 2023.
10. F. Ramoliya et al., "ML-Based Energy Consumption and Distribution Framework Analysis for EVs and Charging Stations in Smart Grid Environment," in IEEE Access, vol. 12, pp. 23319-23337, 2024.
11. N. Naik, C. Vyjayanthi and C. Modi, "Filter-Based Active Damping of DAB Converter to Lower Battery Degradation in EV Fast Charging Application," in IEEE Access, vol. 11, pp. 74277-74289, 2023.
12. L. Argiolas, M. Stecca, L. M. Ramirez-Elizondo, T. B. Soeiro and P. Bauer, "Optimal Battery Energy Storage Dispatch in Energy and Frequency Regulation Markets While Peak Shaving an EV Fast Charging Station," in IEEE Open Access Journal of Power and Energy, vol. 9, pp. 374-385, 2022.
13. H. M. Abdullah, A. Gastli, L. Ben-Brahim and S. O. Mohammed, "Planning and Optimizing Electric-Vehicle Charging Infrastructure Through System Dynamics," in IEEE Access, vol. 10, pp. 17495-17514, 2022.
14. Y. Yang, H. -G. Yeh and N. C. T. Dam, "Optimal Infrastructure Design and Power Management for a Photovoltaic and Battery Assisted Electric Vehicle Charging Station in Southern California," in IEEE Access, vol. 12, pp. 54101-54114, 2024.
15. A. K. Gupta and M. R. Bhatnagar, "St-Hot: A Prospect of Price Equilibrium in a Multi-Player Game for Electric Vehicle Charging Application," in IEEE Access, vol. 12, pp. 104391-104405, 2024.
16. M. Sharif, G. Lückemeyer and H. Seker, "Context Aware-Resource Optimality in Electric Vehicle Smart2Charge Application: A Deep Reinforcement Learning-Based Approach," in IEEE Access, vol. 11, pp. 88583-88596, 2023.
17. S. Sabzi and L. Vajta, "Optimizing Electric Vehicle Charging Considering Driver Satisfaction Through Machine Learning," in IEEE Access, vol. 12, pp. 102167-102177, 2024.
18. A. Blinov, D. Zinchenko, J. Rąbkowski, G. Wrona and D. Vinnikov, "Quasi Single-Stage Three-Phase Filterless Converter for EV Charging Applications," in IEEE Open Journal of Power Electronics, vol. 3, pp. 51-60, 2022.
19. S. N. Larijani, S. S. Fazel, M. Bozorg and H. J. Kaleybar, "Operation-Aware System Design for Synergistic Integration of Regenerative Braking Energy of Railway Systems into EV Fast Charging Stations," in IEEE Access, vol. 11, pp. 121811-121827, 2023.
20. S. Harini, N. Chellammal, B. Chokkalingam and L. Mihet-Popa, "A Novel High Gain Dual Input Single Output Z-Quasi Resonant (ZQR) DC/DC Converter for Off-Board EV Charging," in IEEE Access, vol. 10, pp. 83350-83367, 2022.