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Article Title: High Gain Zeta Converter with ANFIS Based MPPT for Standalone Application with Galvanic Isolation

High Gain Zeta Converter with ANFIS Based MPPT for Standalone Application with Galvanic Isolation

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ABSTRACT

The installation of Photovoltaic (PV) systems is steadily increasing globally, as they stand as the primary means of accessing the electrical grid. A considerable amount of effort is dedicated to ensuring the optimal functioning of these PV systems. As a result, the goal of this proposed work is to achieve stable DC-link voltage of the ZETA Converter using the ANFIS MPPT strategy. In this proposed approach, a ZETA converter is used, which results in improved voltage gain and reduced ripple content of the output voltage and current. An isolation transformer is integrated into the system to provide galvanic isolation. This transformer enhances safety by isolating the output from the high-frequency converter from the PV system and other components. Galvanic isolation prevents the transmission of electrical faults and protects connected loads. The output from the isolation transformer is supplied to a DC load through a rectifier. The diode bridge rectifier converts the alternating current (AC) output from the transformer into direct current (DC), making it suitable for powering DC loads. To stabilise the converter's output voltage and mitigate the intermittent nature of PV, an intelligent MPPT is used, which also aids in maintaining DC-link voltage without distortions and ripples from the converter. The entire paper is validated through a MATLAB simulation 2021a.

Keywords: Photovoltaic (PV), ZETA converter, ANFIS MPPT, isolation transformer, high-frequency converter, diode bridge rectifier.

1 Introduction

Energy consumption is rising in our quickly industrialising world, making it urgently necessary to find affordable, effective, and environmentally friendly technical solutions. Anticipating future obstacles such as renewable energy sources (RES) and climate change is becoming more and more crucial. One of the most important energy sources in the world, photovoltaic (PV) sources are expected to be the best option for energy generation by 2040 due to its clean, dependable, and emission-free nature. Comparing the PV panel's output voltage to those currently present in the conventional power grid, it is very low [1]. An inherent limitation of non-isolated single-switch cascaded converters is their difficult-to-expand circuit topologies, which restricts their capacity to provide voltage step-up [2]. By combining a DC-DC boost

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converter or isolated DC-DC converters, such as flyback, Cuk, and SEPIC converters, with a regular VSI, the low DC input voltage was increased and a buck-boost inverter was produced. Two-stage inverters, which process power twice in this topology and have been researched in great detail, have several limits in terms of both component count and control complexity [3]. More sophisticated dc-dc converters are being used to achieve significant voltage gains. Through simple adjustments to the transformers' turn ratio, isolated dc-dc converters may readily achieve significant voltage step-up [4]. Multiple switching frequencies are used in switching frequency modulation (SFM), a kind of pulse width modulation (PWM), to operate DC-DC converters. By widening the power spectrum, it has helped to reduce the production of electromagnetic interference (EMI) [5]. Fuzzy logic and artificial neural network (ANN) techniques are used since the maximum power point changes with increasing insulation and temperature due to the non-linearity of the power-voltage and current-voltage characteristics. The complicated algorithm that requires a digital signal processor and the corresponding high expenses are the disadvantages of this approach [6]. Low energy conversion efficiency resulting from non-linear PV arrays' I-V behaviour, which is reliant on changing weather conditions, is one of the main challenges facing PV panels. A Maximum Power Point Tracking (MPPT) system is needed to maximise the monitored PV efficiency [7]. Highly non-linear correlations between the system's inputs and outputs are mapped using AI-based techniques, and fuzzy logic is employed to convert linguistic and heuristic words into numerical values [8]. Using these traditional methods, single switch buck-boost converters are employed. These converters lack a high voltage conversion ratio and isolation between the input and output sides [9]. To accomplish this isolation, for example, a transformer is used by both a forward converter and a flyback converter, as was previously mentioned. One inherent drawback of hard-switching converters is their propensity for substantial switching losses. Their efficiency is negatively impacted by this issue, particularly at higher operating frequencies [10]. The following list illustrates the structure of the paper: The introduction is described in Section I. Section II provides a description of the latest works. Part III provides an explanation of the proposed model and description. Section IV presents the findings. The conclusion is given in Section V.

2 Recent Works

Yugeswar Reddy O *et al* (2023) [11] have proposed combining small-signal stability and environmental economic goals for the best possible functioning of a droop-controlled standalone DC mG. The main eigenvalue that influences the stability of the system and two additional goals are optimised by the suggested method. A network configuration stability study based on Eigen values is presented, whereby the buses of the network may be linked to dispatchable DG or constant power load (CPL).

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Shatakshi Jha ***et al*** **(2023) [12]** have concentrated on the difficulties of running an independent microgrid consisting of solar PV, diesel generator (DG), and battery storage (BS). The multi-objective and coordinate control of converters is intended to accomplish power management, sustain distributed generation (DG) operation within the fuel economy zone (FEZ), and enhance DG load capacity under nonlinear load conditions. Furthermore, the DG current's total harmonic distortion is kept at 5% in accordance with IEEE 519 standards. In addition, the control stops negative sequence currents from flowing into the DG in the case of single- or double-phase unbalanced faults.

Srimannarayana Kovvali ***et al*** **(2023) [13]** possess the proposed topology's operational modes, as well as calculations for voltage stress, capacitors, losses, and other factors at different stages. When these are contrasted with modern research, it becomes clear that this topology is more beneficial in terms of lower total standing voltage, the number of switches, cost factor, improved efficiency, and gate driver circuit count. Through simulations based on MATLAB/Simulink, the theoretical performance may be verified, and prototype experiments can verify the results. Modulation index changes, frequency modulation, switching frequency variations, input voltage fluctuations, and load variations are all included in the experimental findings.

Anuradha Tomar ***et al*** **(2023) [14]** have shown how to conceptualise, design, develop, and test a single-phase micro inverter (SP µI) based on photovoltaic (PV) technology in order to address three main problems with PV-based electrical systems in rural areas: 1) to operate efficiently over a wide range of input voltage variations/irradiance; 2) to maintain system efficiency within a reasonable bound even under light load; and 3) to offer dependable and stable operation in difficult/outdoor operating environments.

Niraja Swaminathan ***et al*** **(2022) [15]** has proposed a fixed zone perturb and observe (FZPO) method for photovoltaic (PV) systems that aims to increase steady-state efficiency and provide quick, drift-free maximum power point tracking (MPPT) without the need for extra sensors. The power-voltage (P-V) curves of the PV array are separated into several zones using distinct zone border voltages for various irradiance circumstances using this approach. This method uses a combination of fixed and adaptive step sizes to increase performance. The computational load is decreased by computing the adaptive step size using straightforward mathematical formulas.

3 Proposed Work Explanation

The DC power produced by the solar panels in this proposed standalone solar power system is channelled into a Zeta converter. Next, the load is linked to the converter's output. The system's goal is to maximise the solar panels' power production, and it uses the ANFIS MPPT algorithm to do this. This algorithm continuously monitors the solar panels' highest power point and

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modifies the converter output accordingly. A high-frequency converter receives the Zeta converter's output.

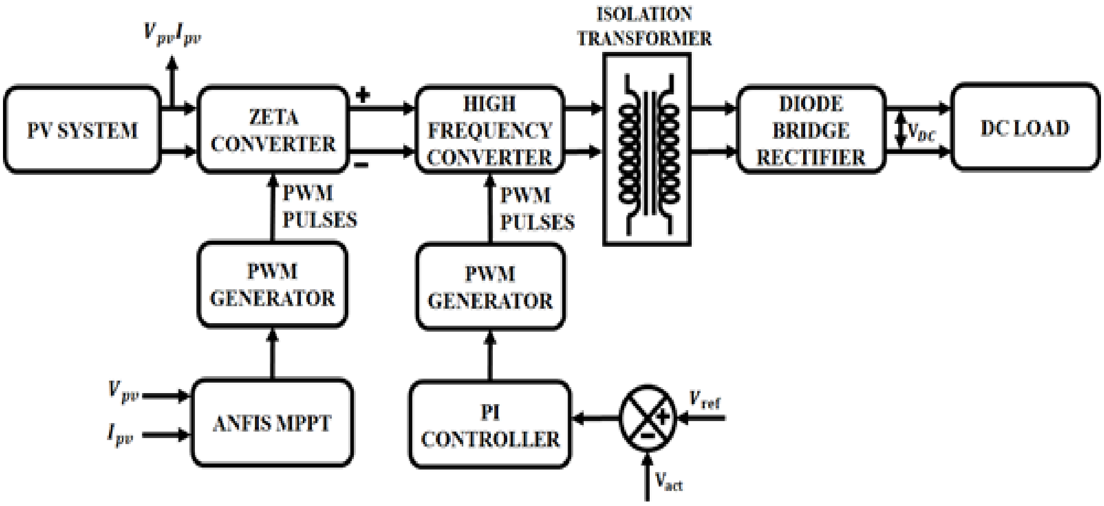

Figure 1: *Proposed block diagram*

A PI controller, which is in charge of this converter, guarantees the accuracy and stability of the voltage output. In order to convert electrical power, improve efficiency, and enable the next phases of power distribution, the high-frequency converter is essential. Galvanic isolation is provided by an isolation transformer that is built into the system. By separating the high-frequency converter's output from the PV system and other parts, this transformer improves safety. Galvanic isolation shields linked loads and stops electrical faults from spreading. Through the use of a rectifier, the isolation transformer's output is sent to a DC load. The transformer's AC output is changed into DC by rectifier, which enables DC loads to be powered.

3.1 Solar PV System

The solar photovoltaic system, which generates energy from sunlight, is the component of the solar PV system. In order for the solar panels to withstand wind, rain, hail, and corrosion, they must be mounted on a sturdy and robust structure.

Peak voltage and peak current, as well as the maximum output from the solar PV system, are all abstracted with the aid of MPPT. Based on the varying input solar intensity and temperature, the solar panels generate solar electricity from the sunshine.

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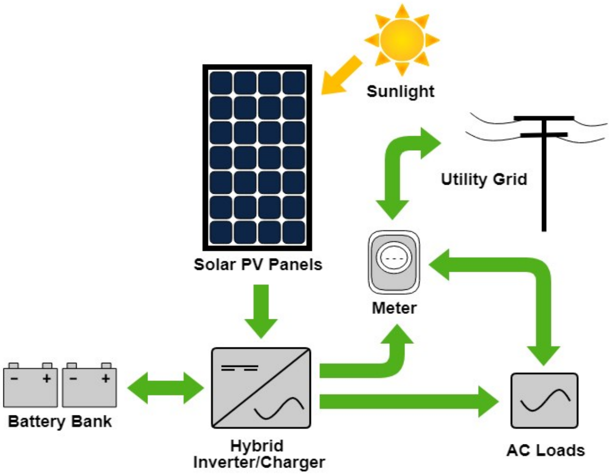

Figure 2: *Solar PV System connected to the grid*

3.2 PV Array

All that is needed to create a photovoltaic array is the serial or parallel connecting of many PV modules. Since the power produced by a single module might not be enough to fulfil the needs of trading applications, the modules are secured in an array or grid configuration to meet load demands. An array's modules are interconnected in the same way as cells inside modules.

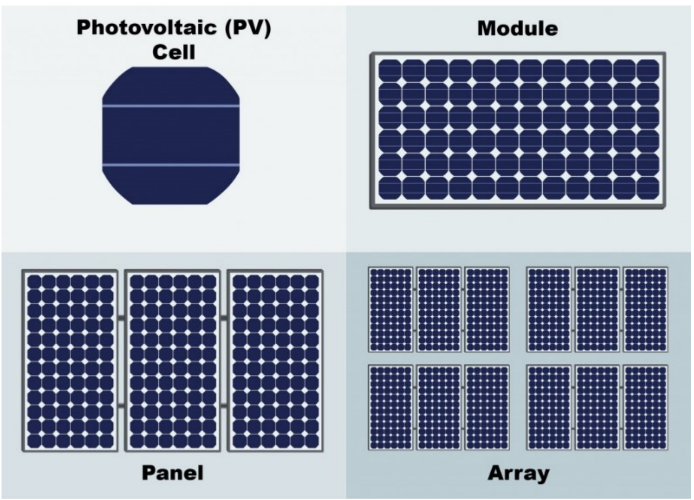

Figure 3: *Photovoltaic system*

3.3 Modeling of PV Cell

The tracking controller, power converters such as DC-DC converters and inverters, and many series and parallel combinations of PV modules make up the PV system utilised for power conversion. Therefore, the DC voltage may be increased using a DC-DC converter, and the

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DC voltage can be converted to AC using an inverter. Based on the load rating, the PV panel should be selected.

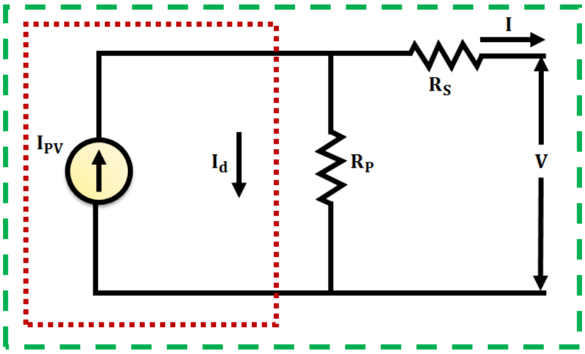

Figure 4: *Equivalent circuit of PV cell*

All of the current I is the difference between current flowing through the diode (I_d), current created by light (I_{ph}), and the rest.

$$I = I_{ph} - I_d - I_{sh} \tag{1}$$

$$I_0 = I_{sc}\, exp\left(\frac{-V_{OC}}{A}\right) \tag{2}$$

The IV and PV curves of a single solar panel for various irradiances are displayed in Figure 5 below.

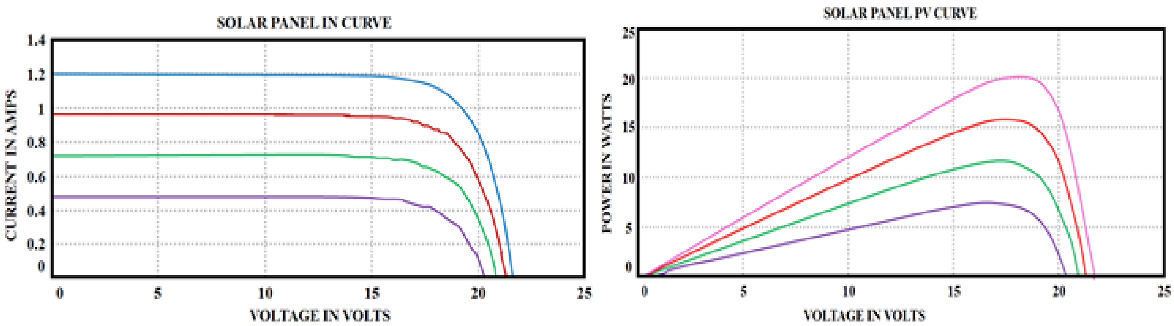

Figure 5: *Single solar module (a) IV curve (b) PV curve*

3.4 High Frequency Isolation Transformer

An isolation transformer is a transformer used to transfer electrical power from an AC power source to a piece of equipment or a device, usually out of consideration for safety, while maintaining the powered item's isolation from the power source. Galvanic isolation, or the absence of an electrical connection between the input and output sides, is what isolation

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transformers perform instead of altering the voltage level of the power they transport. Ground loops, noise, and electric shock can all be prevented by the isolation these transformers offer.

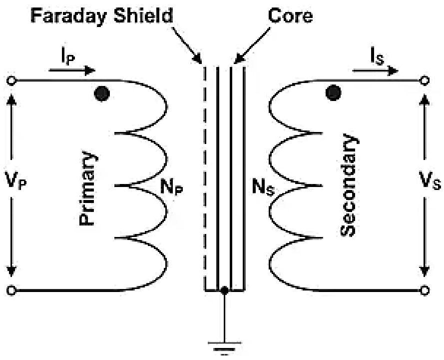

Figure 6: *High Frequency Isolation Transformer*

4 Results and Discussion

The following outcomes are attained when the proposed task is simulated using MATLAB.

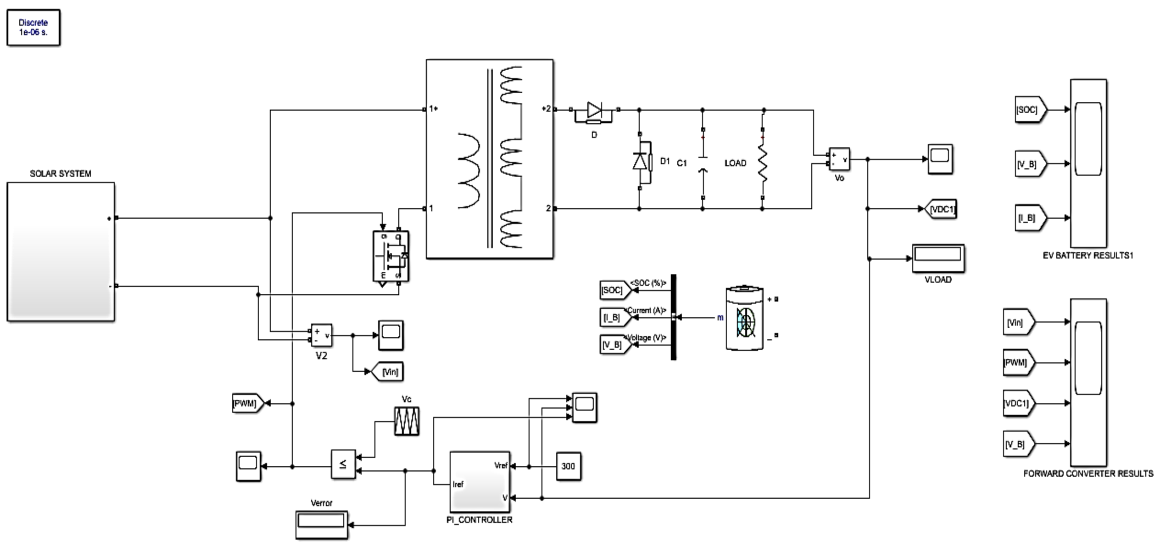

Figure 7: *Simulation Diagram*

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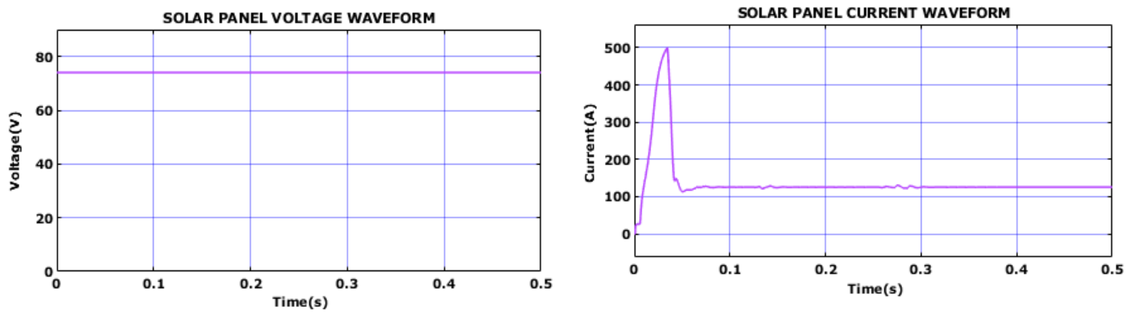

Figure 8: *Input voltage to the converter, Input current to the converter*

The solar panel voltage waveform shown in figure 8 was able to reach an input voltage of 75V at a constant temperature of 35$^{\hat{o}}$ $^{\text{temperature}}$ and 1000 w2/sq. irradiance.

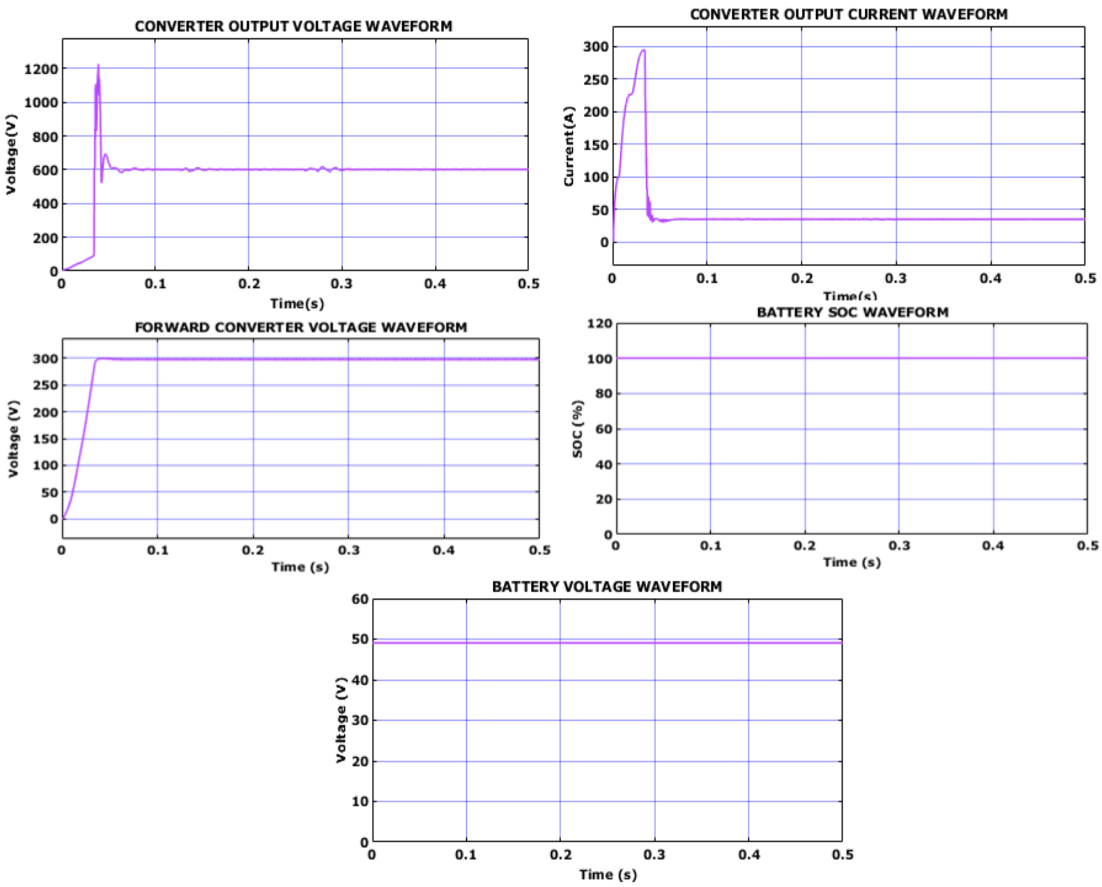

Figure 9: (a) *Converter output voltage, (b) converter output current, (c) Forward Converter, Waveforms of battery (d) SOC and (e) Voltage*

The converter current waveform, shown in figure 9(a), reached a current of 47A at a constant temperature of 35$^{\hat{o}}$ $^{\text{temperature}}$ and 1000 w2/sq. irradiance. The converter output voltage

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waveform, shown in figure 9(b), reached a voltage of 600V at a constant temperature of 35^{ô} ^{temperature} and 1000 w2/sq. irradiance. The waveform for a DC load with galvanic isolation for protection is shown in Figure 9(c) Forward Converter. The DC load receives the 300V generated by the converter as battery power.

Figure 9(d) displays the waveforms that indicate the battery's voltage and state of charge. The voltage of the battery is 12V. The waveforms for the battery's state of charge (SOC), which is 60% as shown in Figure 9(e), demonstrate how well the battery's SOC is monitored. Batteries are used to store the excess electricity produced by photovoltaic cells.

5 Conclusion

This research proposes a possible way to increase power production and boost system efficiency for off-grid solar PV systems: using ZET A converters with ANFIS MPPT. It is possible to track the maximum power point more accurately and respond to changing weather conditions more quickly when the ANFIS MPPT algorithm is used. The purpose of the proposed study is to apply sophisticated control strategies and power electronics components to maximise the energy conversion process' efficiency. The isolation transformer's galvanic isolation improves the system's safety and dependability, particularly in stand-alone applications. Because this system may function independently as a stand-alone device, it can be installed in locations without connection to the main power grid. Ultimately, Matlab simulation 2021a was used to implement this study, and the outcomes were effectively confirmed.

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