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Enhancing Power Quality and Harmonics Control via Integration of PV, Wind, and Battery Systems with Three-level Inverter in DC Micro grid Management

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Abstract

The primary goal of this research is to develop a multi-level inverter-based energy management approach for a smart DC-micro grid. An electric micro grid is created in this project by combining photovoltaic (PV), wind, and batteries. Solar and wind power can be efficiently extracted, and the quality of power can be improved by using FOPID control for source-side converters (SSC) and load-side converters controlled by multilevel inverters. To make the micro grid as cost- effective as possible, it is necessary to prioritize the sources of energy (PV and wind). A multilevel inverter approach is recommended to provide stable and smooth power output. A simulation of the proposed controller with fuzzy logic and FO-PID in Matlab/Simulink is presented.

Keywords: Photovoltaic, wind energy, battery, DC-micro grid.

INTRODUCTION

This study not only presents an intelligent energy management controller but also highlights the significance of incorporating renewable energy sources into smart grid technologies. This DC micro grid controller, which includes photovoltaic (PV) panels, wind turbines, and battery storage, is constructed utilizing fuzzy logic and fractional- order PID [1]. The proposed controller assures cost-effectiveness, outperforms the Super Twisting Fractional Order Controller in simulations, and enhances power quality [2]. In this paper, a control strategy for a DC micro grid featuring three energy sources – wind, solar, and battery – is investigated to guarantee a continuous power supply to loads. The primary focus is on voltage regulation achieved through a dedicated converter and a meticulously developed algorithm for managing power flow under diverse conditions. The evaluation is conducted using MATLAB/Simulink [3, 4]. The strategy places emphasis on wind and PV energy sources, aiming for cost-effectiveness, stable output power, and uninterrupted service, including an analysis of grid faults [5]. The system ensures uninterrupted power for essential loads, and its performance is compared to integer-order controllers [6]. Prioritizing renewable, the controller improves power quality and demonstrates substantial performance enhancements in simulations when contrasted with traditional control methods, ensuring a reliable and continuous power supply [7]. A hybrid PV-battery storage system that uses fuzzy logic to regulate grid-connected inverters and battery storage is another method. This strategy minimizes grid dependence, addresses power fluctuations, and optimizes

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resource utilization; all while requiring a minimal yet sufficient battery capacity [8]. Yet another system integrates wind and solar power controlled by a microcontroller, utilizing batteries charged by wind and solar sources to complement grid electricity. Key features include real-time monitoring and control of power resources and loads [9]. Its advantages over the super twisting fractional-order controller are demonstrated by simulations. The controller prioritizes wind and photovoltaic sources, improving power quality and cost-effectiveness [10].

OBJECTIVE

Power quality must be prioritized while integrating hybrid energy sources into an intelligent energy management controller designed for a smart grid system. Hybrid energy sources, like solar, wind, and battery storage, enable the best possible use of renewable resources while guaranteeing a steady and dependable power supply. The use of a three-level inverter, which is essential to improving power quality, is at the centre of this design.

METHODOLOGY

As shown in Figure 1 various renewable sources are used in this model.

Design of Wind Energy System

As seen in Figure 2, the wind system can be run off-MPPT for power balancing or under MPPT for maximum power extraction. Figure 3 shows a flowchart that describes the MPPT algorithm in detail. An energy management unit (EMU) is proposed in order to lesser generated power and maintains a stable power in stand-alone system if there is an abundance of energy and no battery storage capacity, as outlined in the article. This is how off-voltage MPPT's reference is set up.

Design of Solar Power System

For instance, as shown in Figure 3 the PV controller of the suggested energy management system is switched from MPPT mode to off-MPPT mode in the event of excessive power generation and no battery storage capacity. This preserves a balanced power supply in a stand-alone system. It functions as a reference in off-MPPT.

Modelling of Battery System

In this application, the DC link of the micro grid is connected to a regular battery via a DC-DC bidirectional buck-boost converter (Figure 4). In order to keep the DC-link voltage stable, this converter is necessary. Figure 4 illustrates the recommended procedure for developing a voltage controller based on the DC-link voltage and battery reference current.

Design of AC Grid System

The wind and AC grid conversion processes use buck-to-buck converters. Representation of AC loads system shown in Figure 5.

Simulation Results

According to the current topology, a hybrid energy system is present, with wind, solar, and BSS energy sources connected to the DC-link through various converters. An energy system with an integrated smart DC-micro grid topology is demonstrated. Systems that convert solar energy and wind power both employ the MPPT technique. The selection of control modes is determined by computing the amount of energy generated and consumed. Consequently, the overall energy management controller structure is shown in Figure 6.

The suggested system connects a smart DC-micro grid to a hybrid energy system that consists of the BSS, solar, and wind energy. Through a unique converter, each of these energy sources is linked to the DC-link capacitor. FOPID is in charge of the converters on the source side. The load side AC/DC converters are controlled by the suggested multi-level inverter-based technique. Algorithms that track

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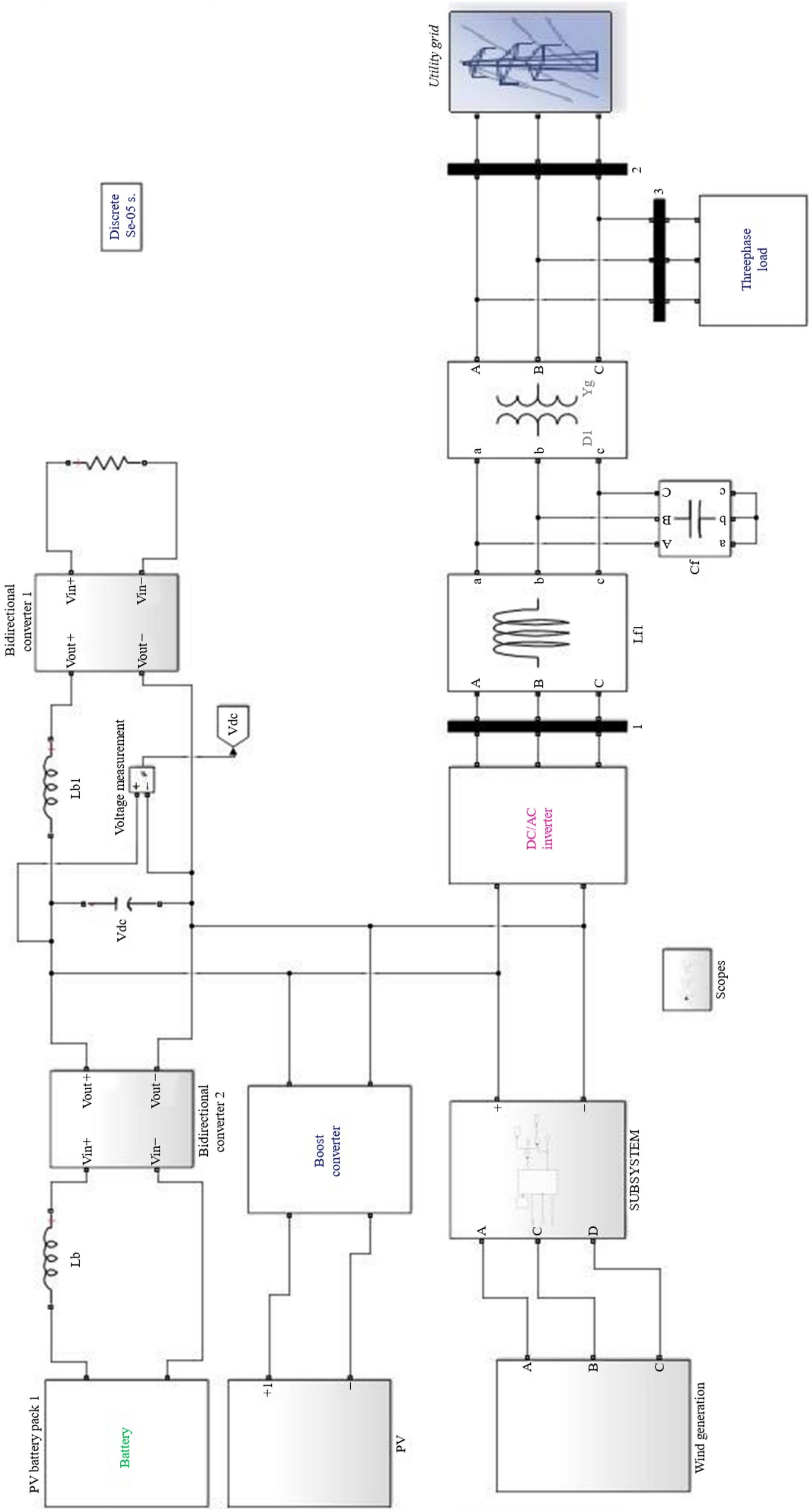

Figure 1. MATLAB/SIMULINK circuit diagram of hybrid energy configuration system.

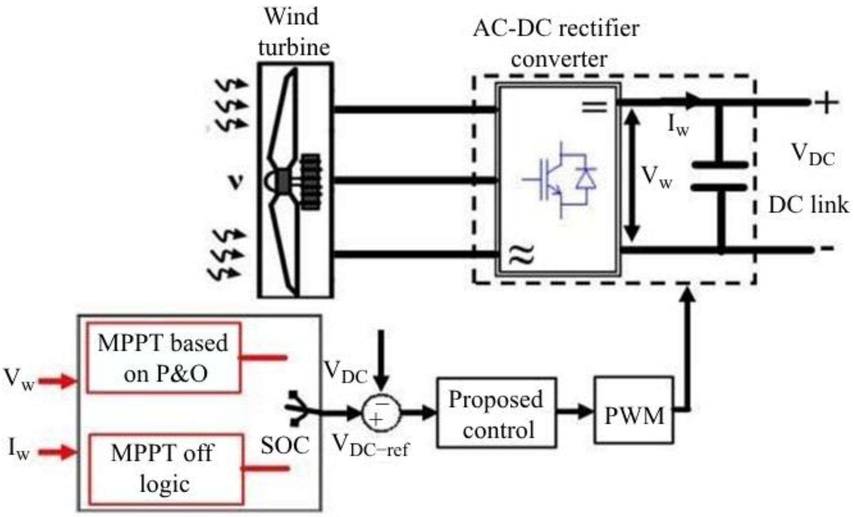

Figure 2. System for controlling of wind energy.

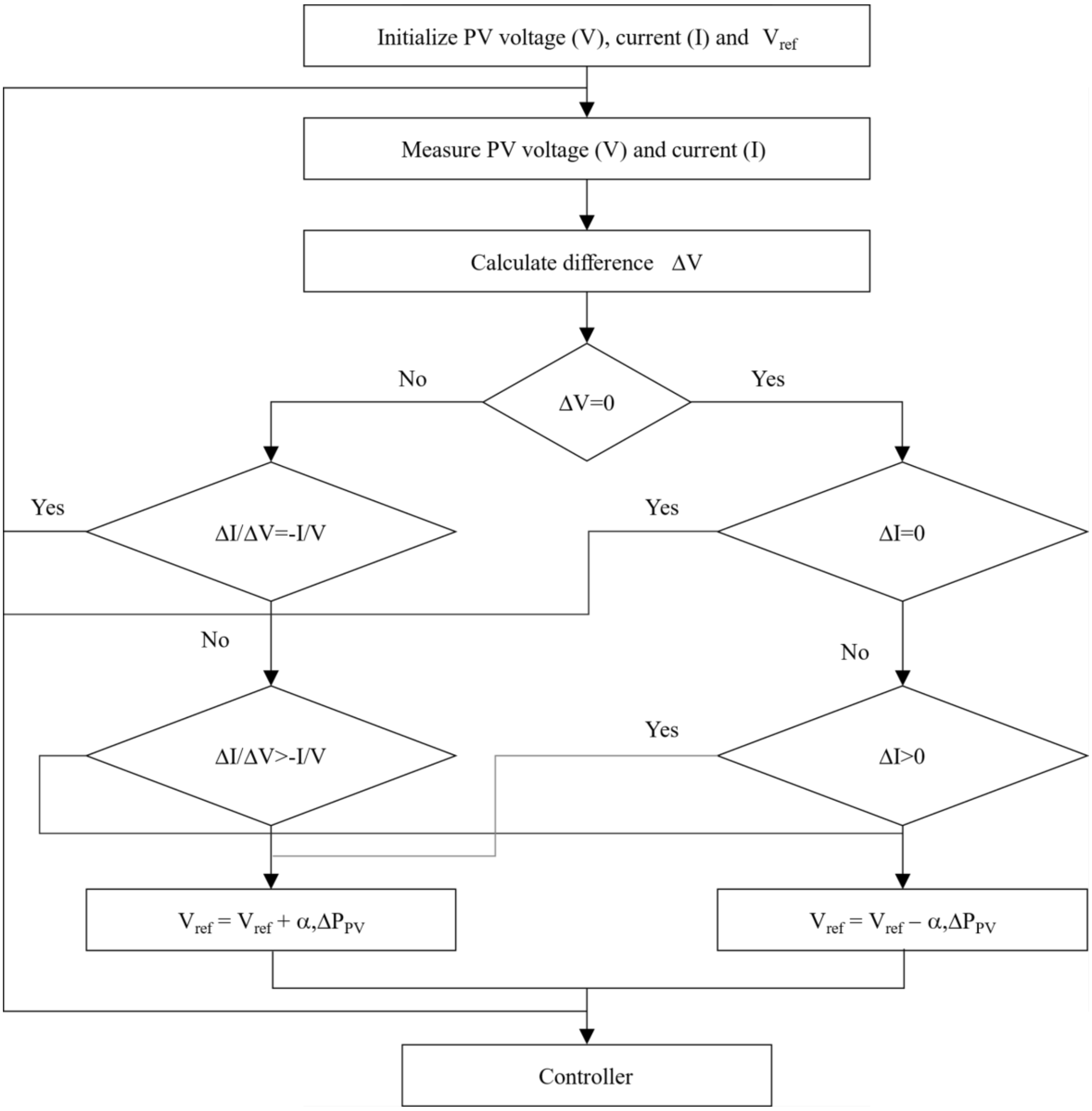

Figure 3. Flowchart of MPPT photo voltaic power generation.

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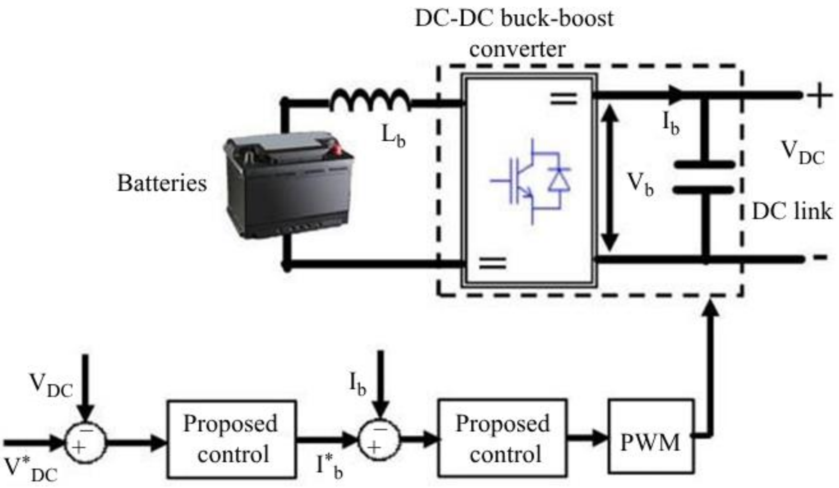

Figure 4. Battery with control system.

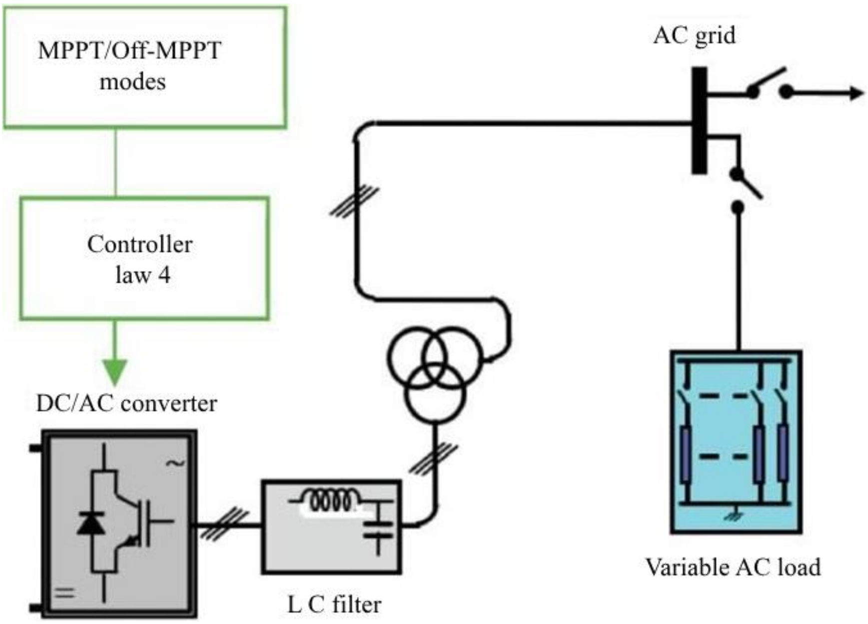

Figure 5. Representation of AC load system.

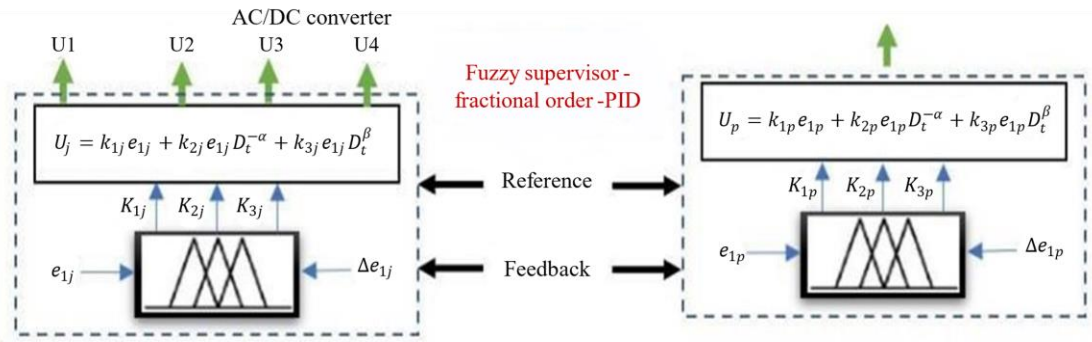

Figure 6. Fuzzy supervisor fractional order PID controller.

the maximum power point are used in solar and wind power (PV) systems to guarantee optimal efficiency. To determine the best control techniques, the energy management system computes the total energy produced and consumed.

Case 1: Under Step Change in Wind Speed

Figure 7 displays the wind profile at 8–13 m/s. In Figure 8 PV power is created at 3000 watts, while the amount of energy generated by wind varies from 4000 to 10000 megawatts, SSC power ranges from 7000 to 13000 watts, according on the current response. Figures 9 demonstrate how the suggested energy management control supplies a steady 8300 watts of power to the loads at a 240-volt load voltage. Figure 10 displays the SOC (80%) and load voltage is kept between 200 and 300 V.

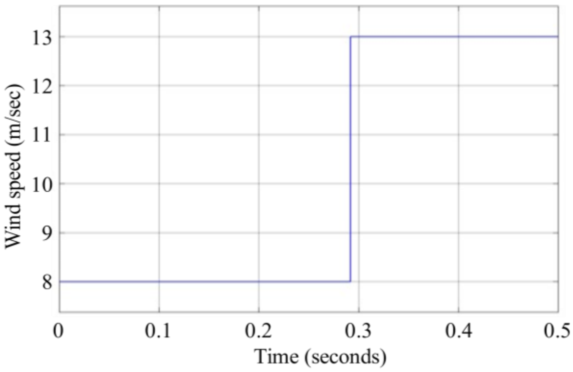

Figure 7. Step change in wind speed.

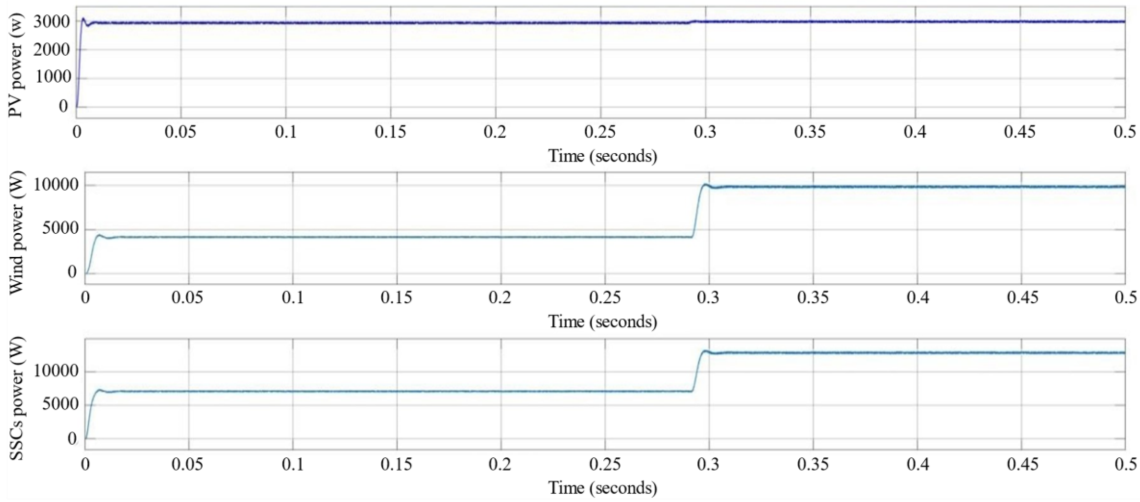

Figure 8. PV power, wind power, SSC's power.

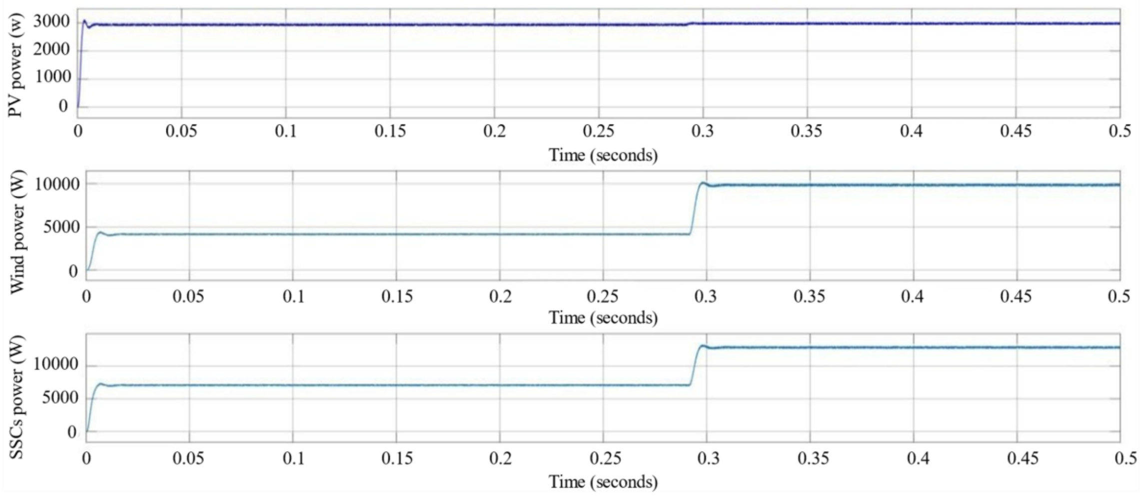

Figure 9. Load voltage, load power, battery power.

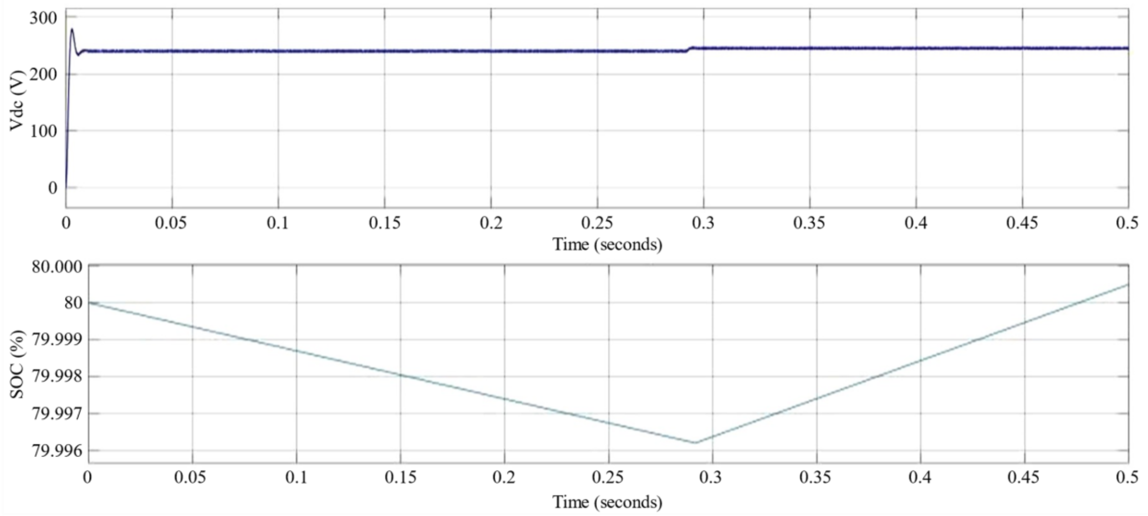

Figure 10. Vdc and SOC (%).

Case 2: Random Variations

Figure 11 depicts erratic wind speed variations, whereas Figures 12 display V dc between 200V and 800V and solar radiation between 200 w/m^2 and 300 w/m^2. Figures 13 demonstrate that while wind and SSC power fluctuate randomly, PV power is kept at a consistent value of 3000W. The proposed energy management control is shown in Figure 14 to transfer a constant power of almost 8000W to the load, which is also the same as in the first case.

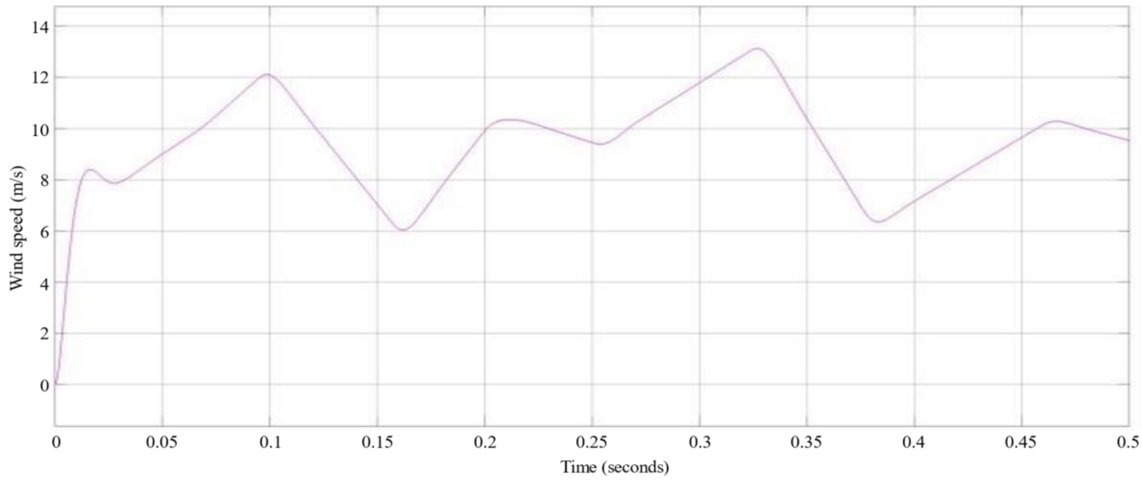

Figure 11. Random wind speed.

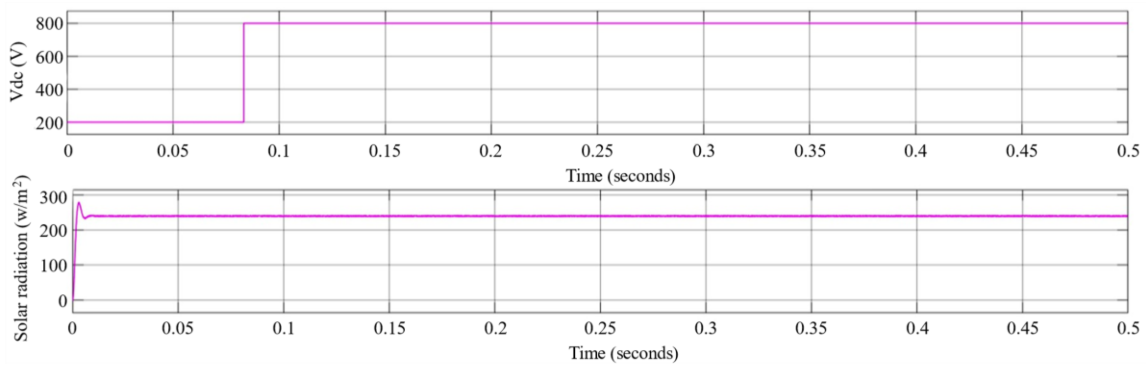

Figure 12. Vdc (V), solar radiation (w/m^2).

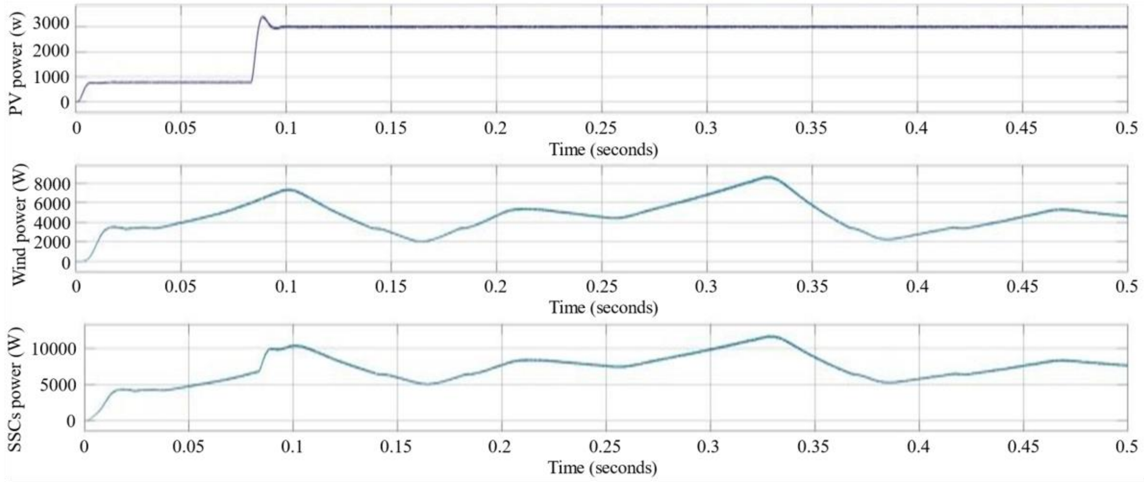

Figure 13. PV power (W), wind power (W), SSC's power (W).

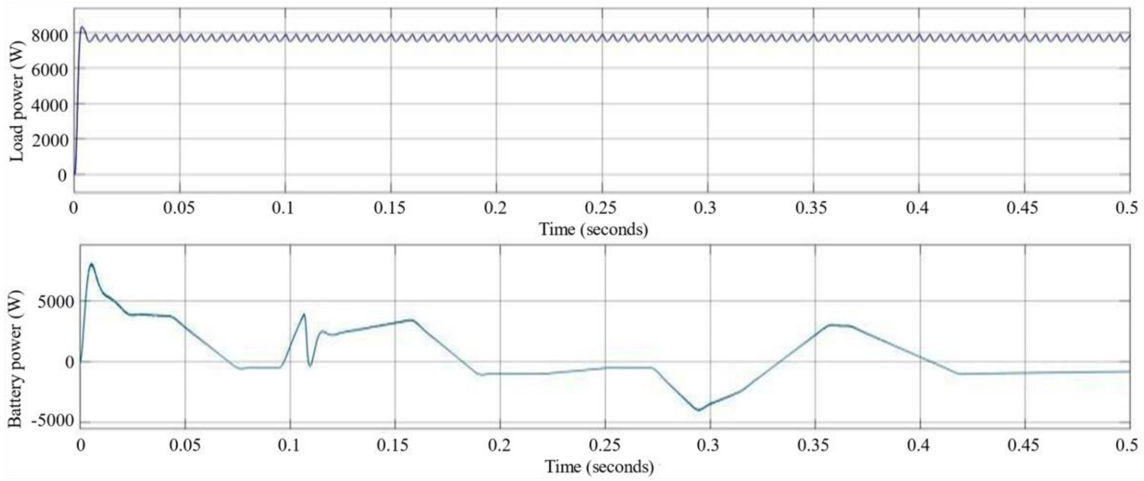

Figure 14. Load power (W), battery power (W).

RESULTS

The total harmonic distortion (THD) levels seen in conventional inverters are depicted in Figure 15, which highlights the degree of distortion produced by these conventional devices. On the other hand, Figure 16 shows the THD levels in a three-level inverter, which is significantly lower than in traditional inverters. Its ability to provide cleaner and more efficient electrical outputs has significantly improved, as seen by the three-level inverter's decreased THD.

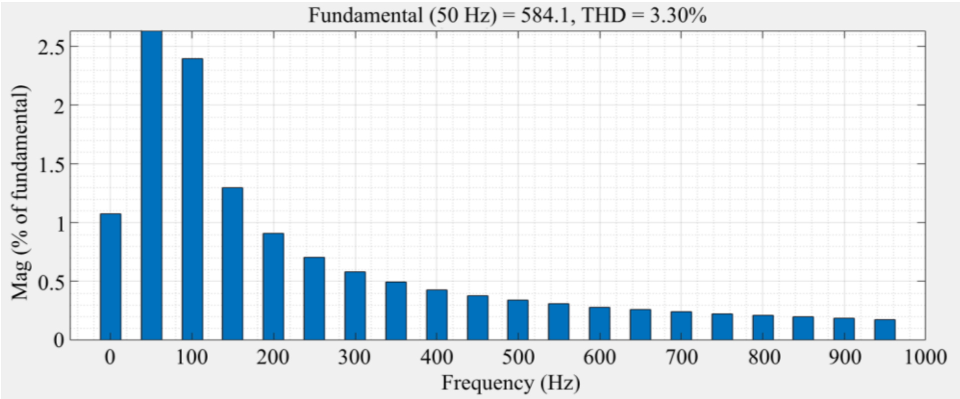

Figure 15. THD for conventional inverter based micro grid system.

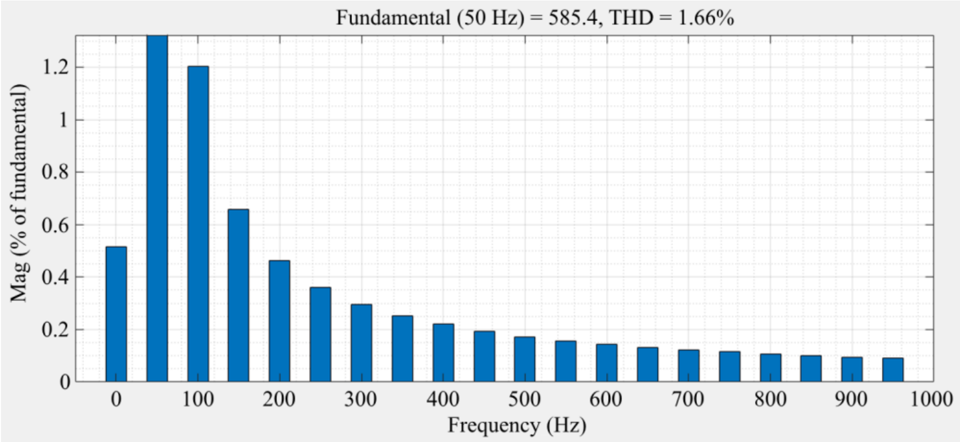

Figure 16. THD for proposed three level inverter based micro grid system.

CONCLUSION

As suggested in this work, FOPID controllers could be used to monitor hybrids of power sources that are part of the Smart Grid by way of DC link voltage. The energy source that DC hybrid micro grids rely on is battery, wind and solar power. The DC Micro grid will be able to generate as much energy from renewable sources and wind power as possible, thanks to its specific intelligent FOPID technique. Energy sources the most efficient way to build micro grids is through photovoltaic and wind energy. The FOPID technique is employed to regulate the load converters. In this paper, we propose an FOPID controller that provides stable output power and uninterrupted service. In order to implement the simulation results in MATLAB/Simulink, the proposed simulation method has been used. In this paper due to the usage of three level inverter the total harmonic distortion is decreased in terms of 3.30% to 1.66% as shown in fig.15 and fig 16 due to decrease in total harmonic distortion the power quality will be enhanced.

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