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A Strategy for Managing Energy in Standalone DC microgrid with PV and Dual Battery System

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Abstract: The incorporation of energy storage technologies and renewable energy sources in standalone DC microgrid has becoming more significant for meeting the power requirements of critical and non-critical loads in remote and isolated areas. This study proposes an approach to managing energy in a standalone DC microgrid equipped with photovoltaic (PV) panels and a dual battery system, incorporating state of charge measurements to efficiently supply both critical and non-critical loads. The system proposed is simulated using MATLAB Simulink software to evaluate the performance. The results demonstrate its effectiveness in efficiently providing power to both critical and non-critical loads.

Keywords: *Solar PV, DC microgrid, Energy management strategy, Dual battery*

1. Introduction

Due to the depletion of conventional resources and the damaging effects of greenhouse gases on our planet's ecosystem, the usage of renewable energy sources (RESs) has increased recently. Additionally, the rising energy demand has prompted the widespread adoption of RESs. To form a power system and to enhance their reliability, it is also possible to combine various renewables together so that they can be included in existing non-renewable systems[1]. Among RESs, photovoltaic (PV) technology is particularly appealing. However, PV power generation is heavily influenced by environmental factors like sunlight intensity and temperature [2]. Therefore, the incorporation of energy storage systems (ESSs), such as flywheels, supercapacitors, batteries, and hydrogen storage systems, is necessary [3]. Integrating RESs systems with ESSs is crucial for overcoming the intermittent characteristics of wind and solar power, particularly in stand-alone applications [4].

Utilizing DC microgrids (MGs) has received increased focus in recent times because of their advantages over AC microgrids. The main reason is that DC power sources such as batteries and PV generators can be easily integrated into DC microgrids. This removes the necessity for numerous power converters, a common requirement in AC microgrids to adjust power for end users. As a result, DC microgrids provide a substantial decrease in the quantity of power converters required. Additionally, DC microgrids demonstrate higher efficiency compared to AC MGs, as evidenced in [5].

Nevertheless, there exist multiple issues that necessitate attention in photovoltaic/battery systems. The primary objective is to harness the highest attainable energy from the PV generator by utilizing methods for tracking the maximum power point (MPPT). In recent years, a variety of MPPT algorithms have been proposed in scholarly works for tracing the peak power point (MPP) of photovoltaic modules. While these MPPT algorithms have a common goal, they vary in terms of effectiveness, intricacy of design, and hardware realization. In a study conducted by the authors in [6], different MPPT algorithms were investigated, and suggestions were given regarding appropriate embedded boards for each technique. The research underscored the significance of selecting a cost-efficient and robust microcontroller for MPPT integration in order to reduce the overall system expenses. The perturb and observe (P&O) algorithm and the incremental conductance (IC) algorithm stand out as the most widely used MPPT techniques. [7]. To extend the durability of the battery, which is a valuable element within a photovoltaic/battery setup, it is essential to appropriately adjust the battery's charging and discharging patterns. This involves preventing overcharging and deep discharging, as it helps to enhance the battery's longevity [8]. In an islanded microgrid (MG) with a PV/battery hybrid system, droop control method is used. This strategy ensures that the demand of load is met efficiently handling the processes of battery charging and discharging. The control strategy, proposed in [9], focuses on standalone PV systems. Its primary goal is to maximize the battery's lifespan while meeting demand of the DC load. A comparable system was displayed in [10], which

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combines a PV array with two energy storage devices. The control approach suggested in [11] manages the distribution of power within the microgrid's various elements. It ensures the durability of the battery by imposing restrictions on its charge and discharge currents as well as its state of charge (SoC).

The energy management (EMS) for DC MG with PV/ Dual Battery system supplying critical and non-critical DC demand is suggested in this study. The following requirements must be met by the control strategy: (i) the PV module should be used as the major source of energy to satisfy the load needs (ii) ensure battery's functioning remains within predefined limits and (iii) employ the backup battery to supply power to critical loads in situations where the main battery is below a specific threshold and the power generated by PV is inadequate.

2. Microgrid Configuration

The standalone DC microgrid simulated in this study is shown in Fig.1.

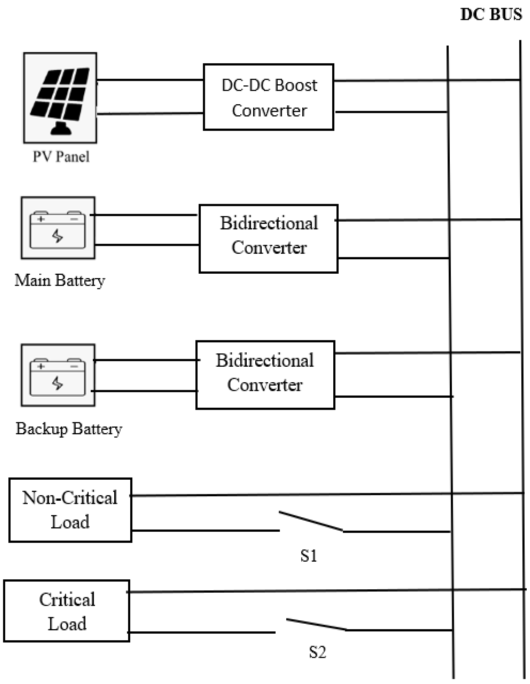

Fig 1: Proposed standalone DC microgrid structure.

It is consisting of a PV array, DC loads, and Lithium-ion batteries. The solar photovoltaic (PV) module is connected to the DC bus via a boost converter, while the battery is attached to the DC bus using a bidirectional buck/boost converter. The switch facilitates the connection of the load to the DC bus. The primary purpose of the boost converter is to capture the maximum power produced by the PV module, which serves as the primary energy source for the load. To control this converter, a PWM technique is employed to regulate the MOSFET gate.

In the proposed standalone DC microgrid, the main battery and backup battery are involved in the charging and discharging processes. During the charging phase, the main battery and backup battery are linked to the microgrid to receive electrical energy. To prevent overcharging and over-discharge of batteries, the higher and lower level of SoC is defined as 90% and 40% respectively for both the batteries. The strategy for managing two batteries is outlined as follows:

When the energy source output is more than the load demand and the main battery SoC is greater than 90%, the backup battery is charged if its SoC is lower than 90%.

In situations where the power generated is insufficient to satisfy the load demand, and the SoC of the main battery is greater than 40%, the main battery discharges to fulfil the requirements of both critical and noncritical loads.

When the load demand is more than power generated and the SoC of the main battery is below 40%, all noncritical loads are disconnected. The back up battery then discharges to supply the demand of critical load if its SoC is greater than 40%.

In cases where the generated power is insufficient to meet the load demand, and the SoC of both the main battery and back up battery is below 40%, every load is detached from the microgrid.

3. Result and Discussion

MATLAB SIMULINK software is used to simulate the proposed system. MPPT techniques play a crucial role in maximizing the efficiency and energy output of solar PV systems. In this study perturbation and observation (P&O) algorithm is used to track maximum power.

Table I shows specification of the studied standalone DC microgrid.

Table I: DC Microgrid Specification

Sl. No	Subsystem	Specification
1	PV array at STC	P_{max}=248.77W, V_{oc}=38.4V, I_{sc}=8.8A, Vmp=30.7V, I_{mp}=8.11A
2	Main Battery	220V, 50Ah
	Backup Battery	220V ,70Ah
3	DC Bus	240V
4	Noncritical Load	10kW
5	Critical Load	5kW

In the first scenario, from 0 to 3 sec P_{source} is less than P_{load} and the main battery SoC is lower than 40%, so all non-critical loads are disconnected. Critical loads are supplied by the backup battery. The waveforms are shown in Fig 2. From 3 to 6 sec P_{source} is greater than P_{load} which charges the main battery and supplies both the loads.

In the second scenario, from 0 to 3 sec P_{source} is less than P_{load} and the main battery SoC is greater than 40% so both the loads are supplied by main battery. From 3 to 6 sec P_{source} is greater than P_{load} which charges the backup battery and supplies both the loads as shown in Fig 3.

Fig 4 shows the waveforms for the scenario when both the batteries are charged. From 0 to 3 sec P_{source} is less than P_{load} , so both the loads are supplied by main battery. From 3 to 6 sec P_{source} is greater than P_{load} which charges the main battery and supplies both the loads.

In the fourth scenario, P_{load} is greater than P_{source} and SoC of both the batteries less than 40% , so all loads are detached from the grid. It is shown in Fig 5.

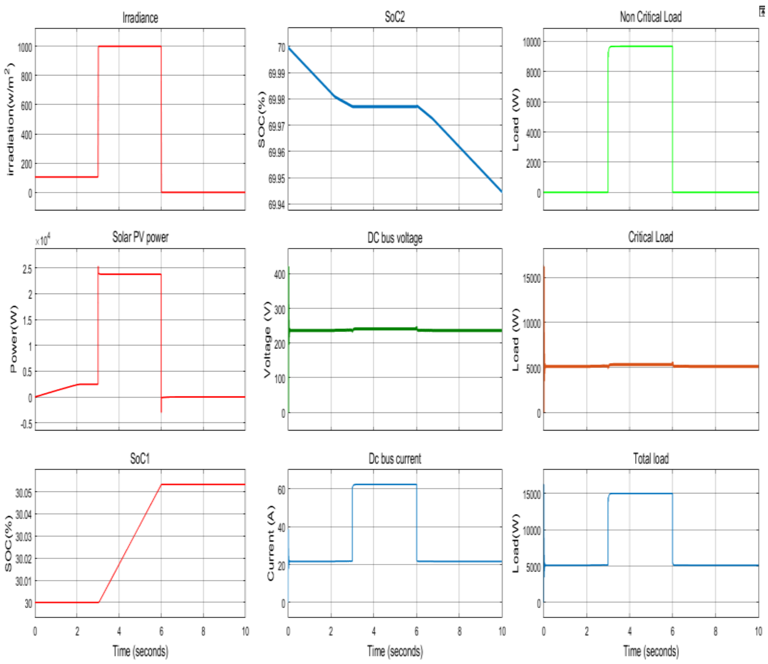

Fig 2: Waveforms when Main Battery SoC is less than 40%

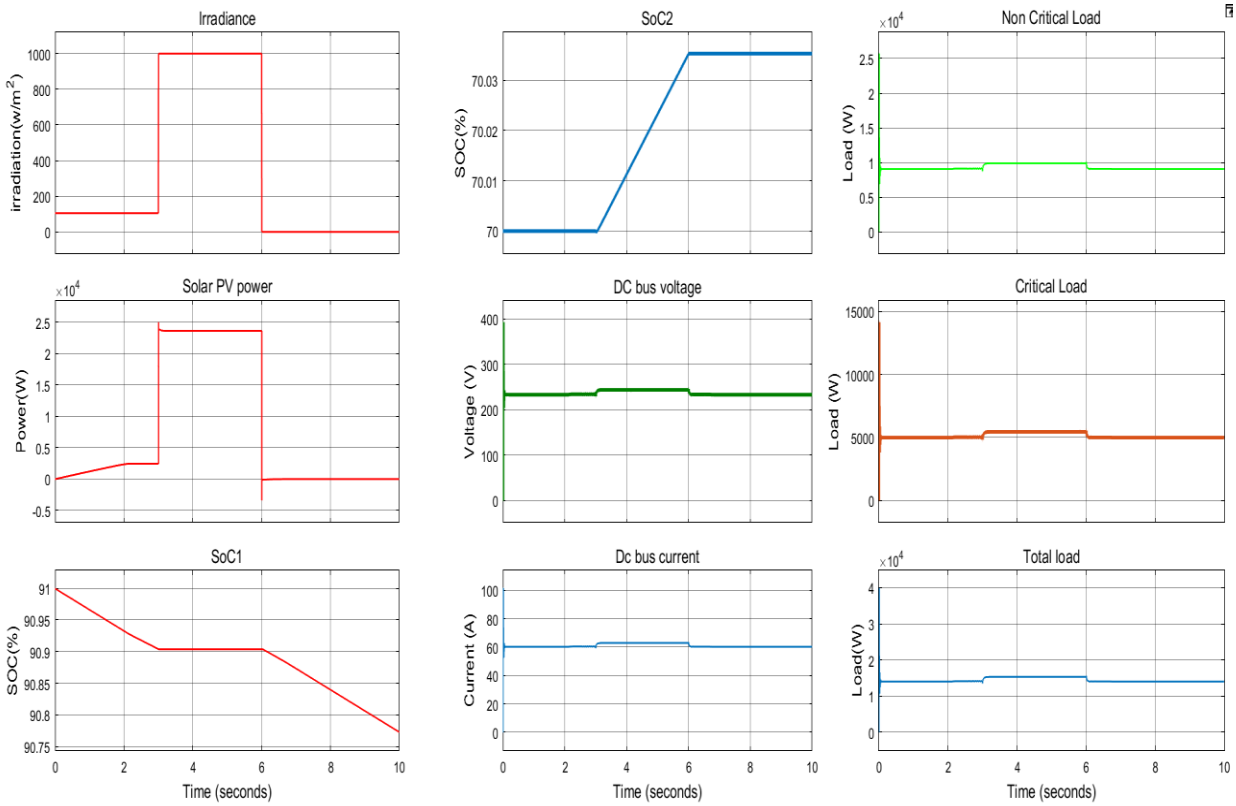

Fig 3: Waveforms when Backup Battery SoC is less than 90%

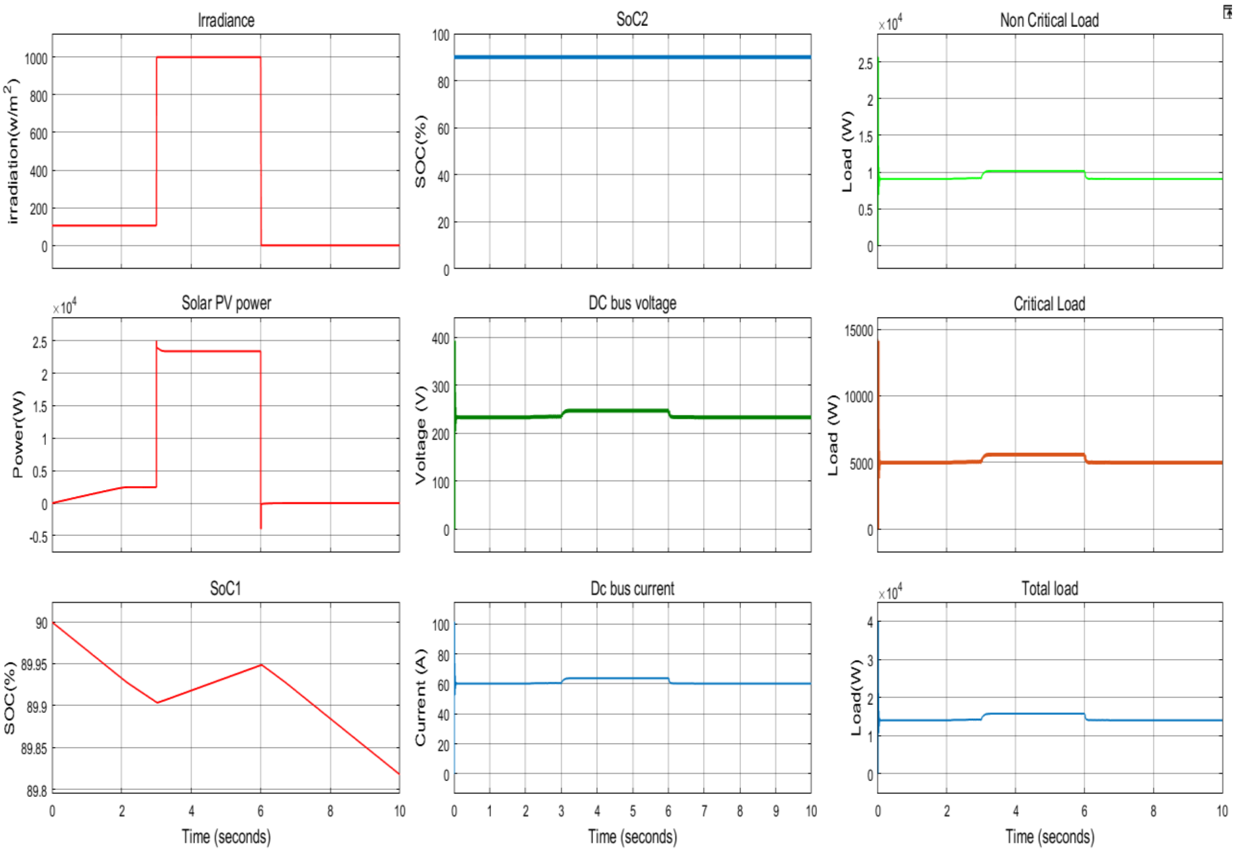

Fig 4: Waveforms when both batteries SoC is 90%

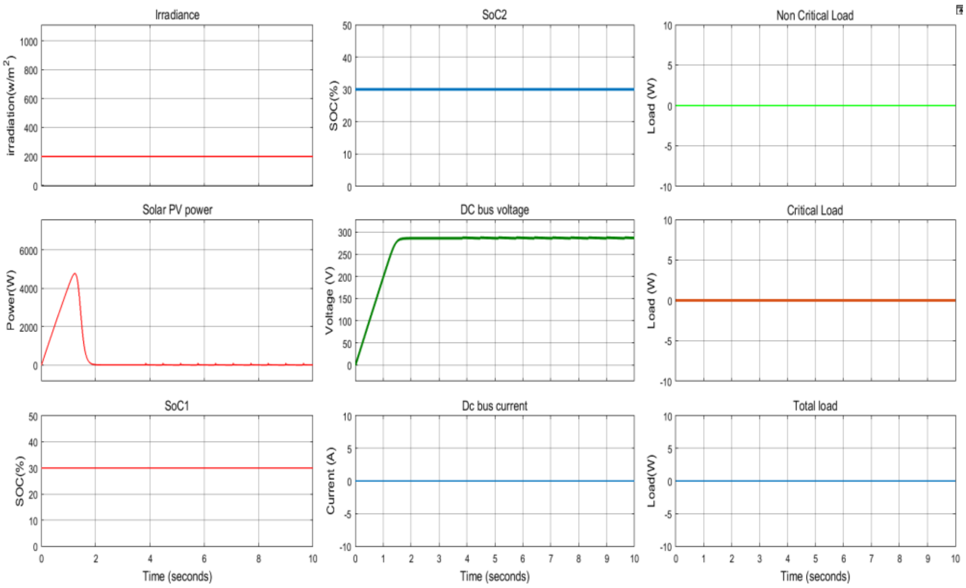

Fig 5: Waveforms when P_{source} is less than P_{load} and both batteries SoC less than 40%

4. Conclusion

Isolated DC microgrids are required to ensure a consistent and dependable power supply, which is even more crucial than in grid-connected microgrids. Hence, this study presents an energy management strategy by implementing dual battery system which ensures efficient utilization of energy resources and effectively addresses the power requirements of both critical and noncritical loads. The results of simulations performed using MATLAB Simulink software validate the effectiveness of the proposed system. Simulation results showed stable DC voltage waveforms in various operating scenarios. This system has important implications for remote and isolated places without access to reliable electricity grids, as it offers a reliable and sustainable solution for meeting their power requirements.

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