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Enhancing Off-Grid Hybrid Renewable Energy System

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A B S T R A C T

Abstract- In India, most people live in villages, some of them living in remote areas segregated from grid regions. Extending the grid connection to supply those communities with electricity is not practical or cost-effective; however, installing an independent hybrid renewable energy system may be a good alternative. PV energy is appropriate for hybrid systems since it is ecologically beneficial and readily available in India. However, the hybrid power system that primarily relies on intermittent renewable energy sources provides a variable output voltage, which leads to harm to equipment functioning on a constant supply. A continuous power supply is possible by renewable energy with storage devices like batteries. This paper focused on the Simulation of a Hybrid renewable energy system (PV/Battery/Diesel). The diesel generator and battery serve as a backup energy source, while the PV systems serve as the main energy source. When the power output of the hybrid PV system is less than the power required by the load, the battery storage system is utilized to store excess power from the system and provide continuous electricity. When the battery runs empty, electricity is additionally provided by the diesel generator. The complete hybrid system is modeled, simulated, and analyzed using MATLAB/Simulink software.

Keywords: *Off-grid, PV system, Battery, HRES, Diesel generator*

1. INTRODUCTION

Electrical energy plays a significant part in modern life because of its efficiency and adaptability. Even in India, where there is 100% access to energy, many remote communities still need the power to suit their needs. They deal with a lot of issues as a result, which lowers their standard of living in areas like agriculture and the economy.

To create electricity for rural regions, microgrids are offered as a solution to such issues. A distributed energy system that links small communities and the electricity grid is called a micro-grid. It responds quickly and calls for more nuanced decision-makers. The drawbacks of renewable energy sources are their high price, lack of fuel costs, and ecological nature; also, their supply is contingent upon accessibility. Solar energy production usually depends on radiation levels; in the event of rain or cloud cover, supply will be at a minimum, therefore using only renewable energy sources will not be able to provide stability to a continuous flow of power in all climate conditions.

To provide a consistent flow of energy, a hybrid microgrid generates electricity from both renewable and non-renewable energy sources. Solar energy is the best non-conventional energy source since it has great potential, is readily available, and can be stored when there is less irradiance. Batteries are also utilized for this purpose. Diesel generators, or DGs, are used in stand-alone systems because they provide a steady supply of electricity from conventional sources. Because of its dependability, the hybrid microgrid offers stand-alone areas a practical way to overcome the challenges. A hybrid microgrid including solar PV, batteries, a DC-DC boost converter, a three-phase inverter, load, and diesel generator is modeled in this paper.

2. System Background

When compared to coal-fired power plants, the majority of renewable energy systems require less maintenance and have lower operational costs. While renewable energy sources are unreliable when used alone, their reliability is greatly increased when used in hybrid mode [2]. The two renewable energy systems, including battery storage, are described in the sections that follow. The utilization of various sources in a hybrid mode is the subject of the final section.

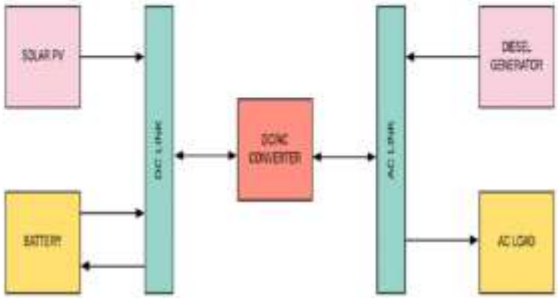

Fig:1 Hybrid System of PV/Diesel/Battery

A.1. Solar Energy

If and only if the sun's plentiful energy is effectively and correctly captured, it may be able to supply our energy needs. Solar radiation is converted to energy by a solar cell using the photovoltaic effect. Because it requires less computing and produces somewhat accurate results, the general solar cell model is thought to represent the solar cell. Maximum power is tracked by the PI controller.

A.2. Battery Storage

Despite the rapid advancement of technology, electrical power storage remains an issue. All standalone PV, wind, and hybrid systems require a battery system. The battery system resolves the inconsistencies produced by renewable energy. Because lithium-ion batteries are designed to last a long time, their efficiency is reduced throughout extended charging and discharging cycles, making them ideal for renewable energy systems and applications. Lithium-ion batteries have a 15-year life expectancy and a roundtrip efficiency of around 85-95%.

A.3. Diesel Generator

One of the key components for a steady supply of power is a diesel generator. When compared to other generators that use various fuels, such gas, the utilization of these diesel generators results in lower fuel costs and increased power output. Diesel generators generate electricity during times when the primary sources are unavailable. Hence, it provides the system as a whole with primary and secondary protection. Using non-renewable energy sources in addition to renewable energy sources provides a better answer for issues in rural areas.

Block Diagram Of PV, Battery, Diesel of HES

In this block, the PV cell is designed by a single-diode model. Irradiance and Temperature are the inputs of PV cells. The maximum power point is tracked by the PI controller. Taking the actual voltage from the PV cell and also creating one reference voltage through another PV cell. And comparing these voltages through the PI controller and finding maximum power. A controller is connected to the gate terminal of MOSFET. PV cells are connected to a boost converter to step up the voltage of PV cells. DC power from the PV cell is converted into AC using a bridge inverter.

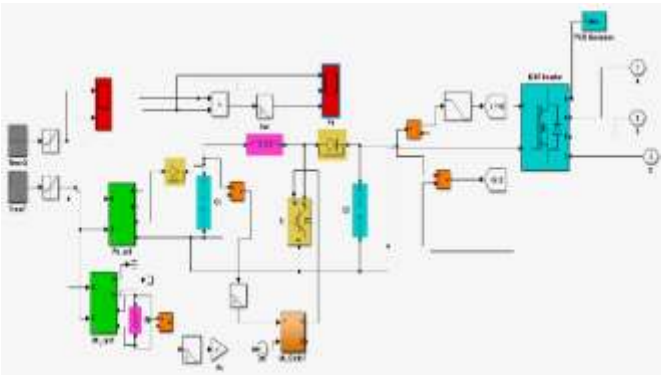

Fig:2 Simulation Model of PV System

The lithium-ion battery is used in this battery model. This block consists of two switches. When one is on another switch will be off. The two switches are complementary to each other. Vc Voltage across the load (possibly the PV system output). Vcn Voltage across the load in the previous time step. i_L Inductor current. i Current through the load. Vb Battery voltage. u0 A parameter that seems to represent a default output value. Vn Nominal voltage (assumed to be 240 volts). Duty cycle, calculated as the ratio of nominal voltage (Vn) to battery voltage (Vb). Switching frequency, set to 40 kHz. Inductance, set to 3×10^−4 Henries (H). Capacitance, set to 1×10^−3Farads (F).

s=vc-vcn+1.5*sqrt(L/C)*(i_L-i/D);

del=Vn*(vc-Vn)/(2*L*f*vc);

If s is greater than del, y is set to 1, suggesting some kind of switching action. If s is less than -del, y is set to 0, indicating another switching action. If s is neither greater than del nor less than -del, y is set to u0, possibly implying some default behavior or maintaining the current state.

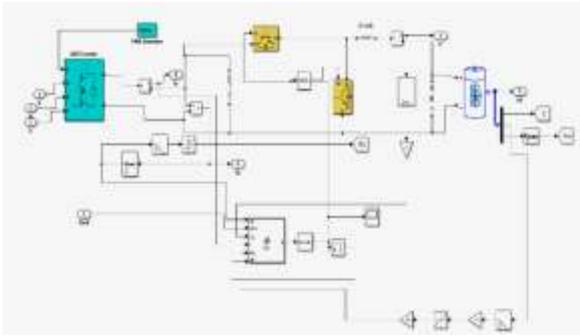

Fig:3 Simulation Model of Battery

A diesel generator system is simulated using MATLAB/SIMULINK, which includes a diesel engine, excitation system, and synchronous generator, as illustrated in Fig:4. To ensure system stability, the diesel generator can be run within the permitted range of 400 to 600 for steady fuel input. The DG system is directly linked to an isolated load and simulated in the MATLAB/SIMULINK environment.

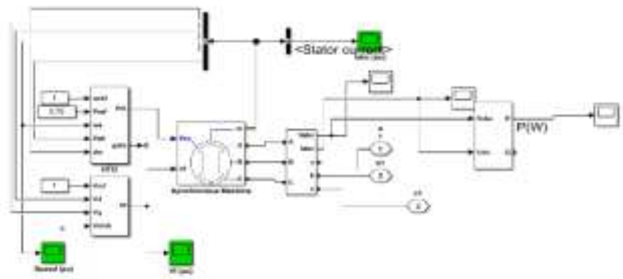

Fig:4 Simulation Model of Diesel Generator

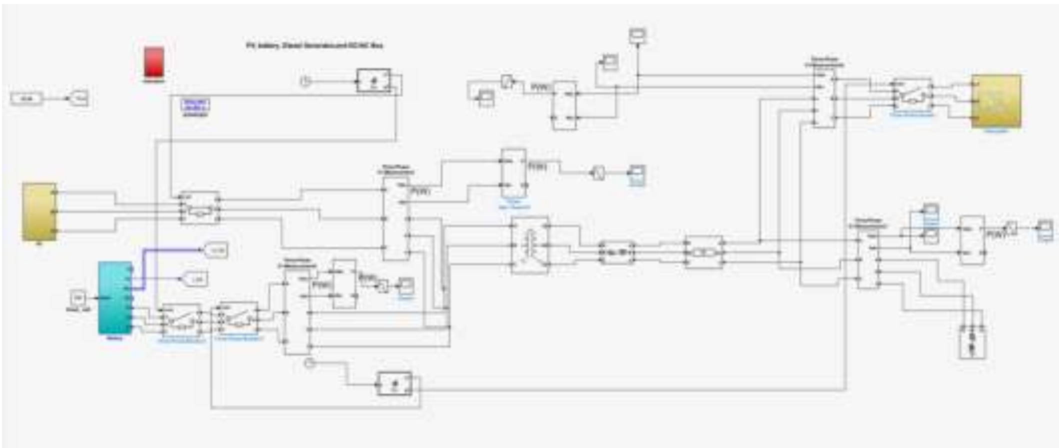

Fig:5 Simulink Model of Hybrid Micro Grid Connected PV, Battery, and Diesel Generator

3. Results and Discussions

In a hybrid microgrid connected PV battery diesel generator consists of a PV block, Battery block, diesel generator, transformer, three phase breakers, and Line parameter. When the PV generates power through irradiance and temperature. PV mainly depends on weather conditions. So in this simulation, PV will give power for up to 8 seconds shown in Fig:8. Whenever PV is disconnected then the battery will come into the picture and give supply up to 11 seconds shown in Fig:9. The battery also gives power for up to some time only. Whenever battery discharging is completed the diesel generator will supply the power to load for up to 15 seconds shown in Fig:10. Load is change continuously

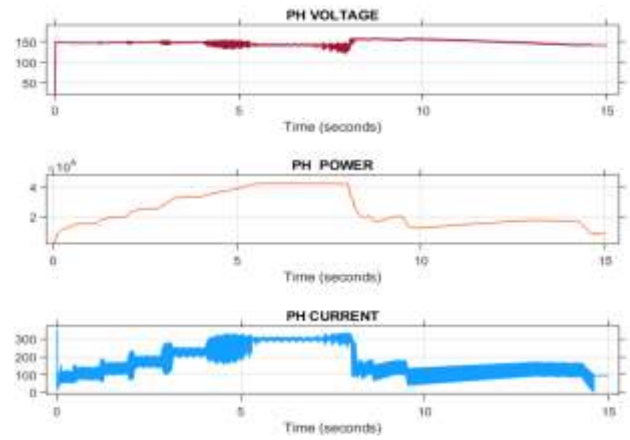

Fig:6 PV System power, voltage, current

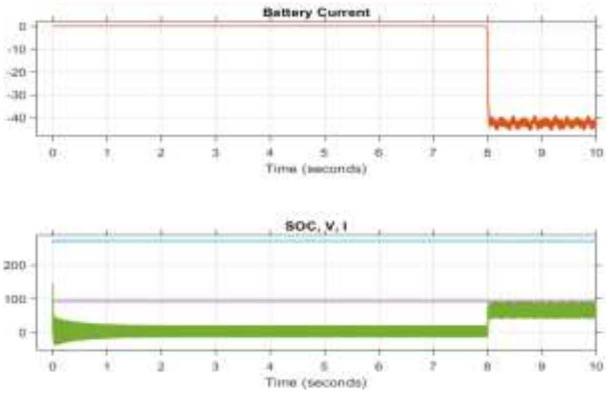

Fig:7 SOC , Voltage, Current of the Battery

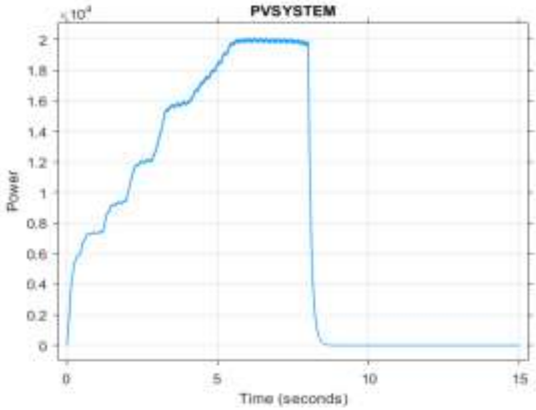

Fig:8 Output power of PV System

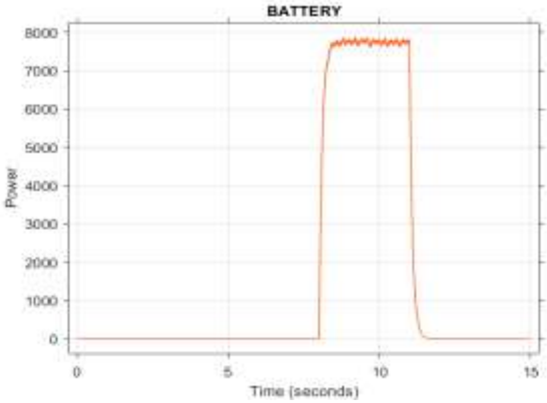

Fig:9 Output power of Battery

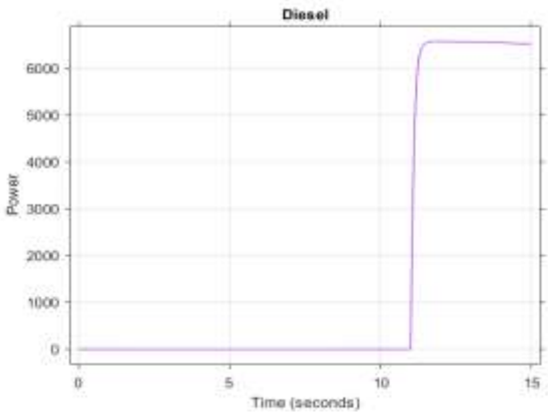

Fig:10 Output power of Diesel generator

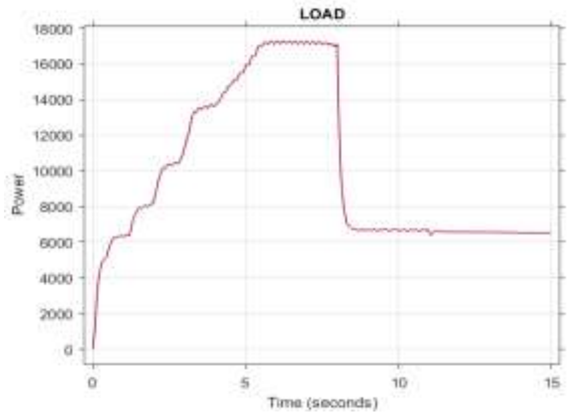

Fig:11 Power of Load

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