ANALYSIS OF WIND AND SOLAR ENERGY EMBEDED TO DISTRIBUTION GRID FOR ACTIVE AND REACTIVE POWER SUPPLY TO GRID

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Abstract - Renewable energy sources have become a prominent alternative to traditional electrical energy sources in areas where conventional power generation is impractical. Photovoltaic (PV) and wind power generation have expanded dramatically in recent years. In this study, we present a hybrid energy system that combines solar panels and wind turbine generators as an alternative to traditional electrical energy sources, such as thermal and hydro power generation.To track the operational point at which maximum power may be extracted from the PV system and wind turbine generator system under continuously changing environmental conditions, a simple and cost-effective control technique has been developed. The complete hybrid system is described in detail, along with comprehensive simulation results that demonstrate the system's practicality. A software simulation model is developed in MATLAB/Simulink to analyze the performance and feasibility of the hybrid system

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***Key Words*:** PV System, Boost Converter, Wind Turbine, PMSG, Battery Charging

1. INTRODUCTION

Due to the critical state of industrial fuels such as oil and gas, the development of renewable energy sources is constantly improving. This increasing focus on renewable energy is driven by the need for sustainable and eco-friendly alternatives. Renewable energy sources are abundantly available in nature, eco-friendly, and recyclable, making them increasingly significant. Among the various renewable energy sources, solar and wind energy are the world's fastest-growing sectors. Other notable renewable sources include hydro and tidal energy, each contributing to a more sustainable energy future.

1.1 Solar PV System

In 1839, a French physicist named Edmund Becquerel discovered that certain materials could generate electricity when exposed to sunlight. However, it was not until 1905 that Albert Einstein elucidated the photoelectric effect and the nature of light, laying the groundwork for understanding how solar energy can be converted into electrical energy. This discovery became the fundamental basis for photovoltaic (PV) power generation technology. The first PV module was produced by Bell Laboratories in 1954, marking a significant milestone in the development of solar energy technology.

1.2 Wind Energy System

A wind turbine converts the kinetic energy of the wind into mechanical power through the rotational motion of the turbine blades. This mechanical power can then be utilized to power a machine or generate electricity. The power captured by a wind turbine blade is influenced by several factors, including the blade's shape, pitch angle, rotational speed, and rotor radius. These factors determine the efficiency and effectiveness of the wind turbine in harnessing wind energy.

2. SYSTEM CONFIGURATION

Hybrid generating systems that use more than one power source can considerably improve the consistency of load needs. A hybrid system can achieve even higher generating capacities. We can offer fluctuation-free output to the load in a stand-alone system regardless of weather conditions. To convert the PV system's energy output to storage energy and deliver consistent power from the wind turbine, an efficient energy storage method is necessary, which the battery bank can provide.

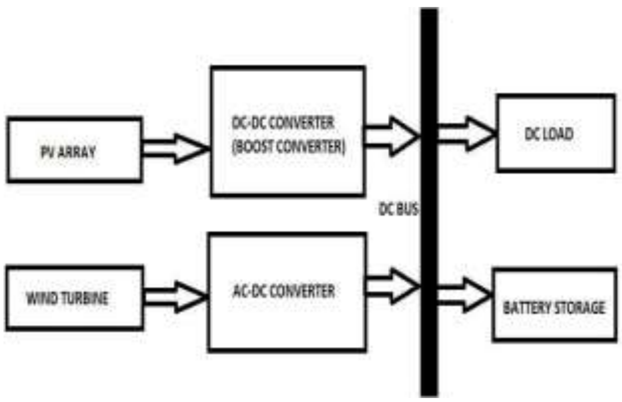

Fig.1 : Block Diagram of Hybrid System[7]

3. DETAILED DESCRIPTION

Solar panels and wind turbines are combined in hybrid systems. This combination's output is utilised to charge batteries, and the stored energy can be sent to nearby power stations.

3.1 Solar PV System

PV modules or arrays convert solar energy in the form of solar irradiation into electrical energy. The DC-DC converter modifies the voltage level to match the requirements of the electrical appliances supplied by this system. Depending on the required and available voltage levels, the DC-DC converter can function as a buck, boost, or buck-boost converter.

The core principle underlying the operation of a single PV cell is the photoelectric effect. This effect states that when a photon strikes a PV cell, it stimulates the electrons of the semiconductor material, causing them to jump from the valence band to the conduction band. This movement allows the electrons to move freely, generating positive and negative terminals and creating a potential difference across these terminals. This potential difference is what generates the electric current used to power devices.

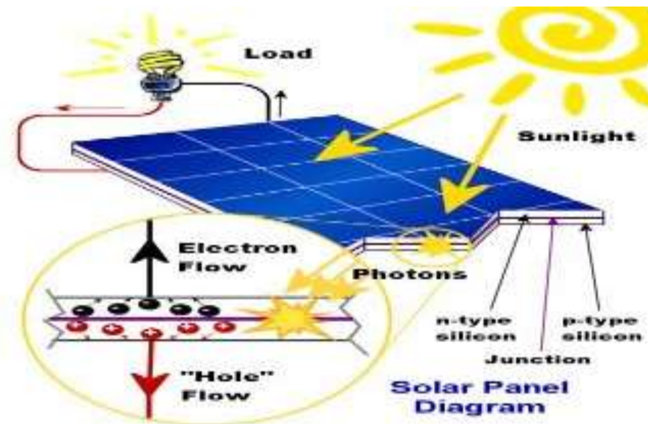

Fig: 2 PV cell, PV module and PV array [2]

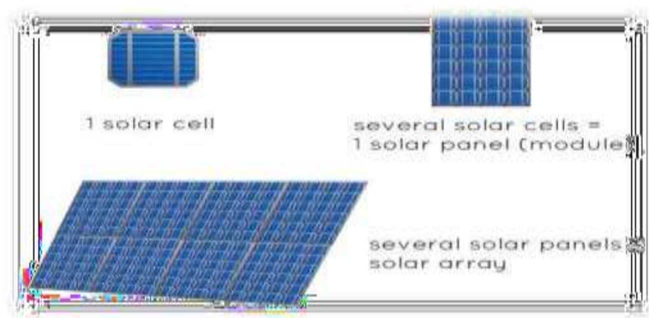

Fig.3 : Photovoltaic effect [2]

3.2 Wind Energy System

Wind is a renewable energy source. A wind turbine converts the kinetic energy of the wind into electrical energy. The generator, which is attached to the shaft of the blades, turns mechanical energy into electrical energy. The vertical axis wind turbine and the horizontal axis wind turbine are the two types of wind turbines based on the rotational axis of the blade..[8]

Fig.4 Vertical Axial wind turbine

Fig.5 : Horizontal Axial Wind Turbine [3]

The turbine's output is determined by the wind speed. In nature, the power generated by the turbine fluctuates. To ensure a continuous supply of power, electricity is first stored in a battery unit and then delivered to the load. Wind energy systems are more efficient than solar PV systems[7].

3.2.1 Components of Wind Turbine

The list of components which are used in wind energy system are given below :

1) Rotor and Rotor Blade
2) Hub
3) Main Shaft
4) Gearbox
5) Generator
6) Anemometer
7) Controller
8) Nacelle
9) Yo Motor Mechanism
10) Tower

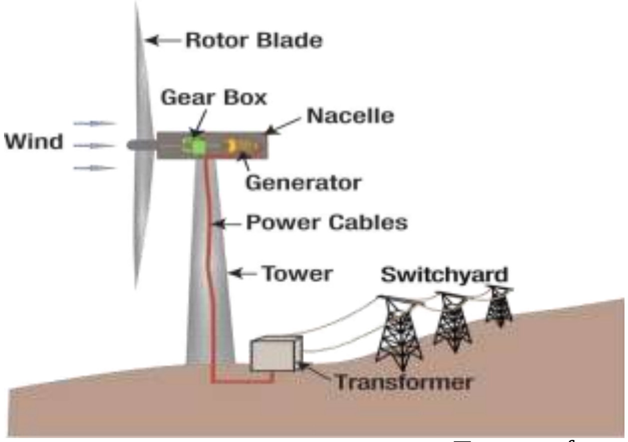

Fig 6 Wind Power Diagram[12]Types of Generator

Generators are classified based on the type of current they produce, namely alternating current (AC) generators and direct current (DC) generators. In both cases, the initial voltage produced is alternating, which can be converted to direct current using a commutator. For convenience and practicality, AC generators are typically used.

AC generators can be further classified based on the rotor speed. There are synchronous generators, which operate at a constant speed, and asynchronous generators, also known as induction machines, which operate at variable speeds. A wind turbine can be equipped with any type of three-phase generator. Today, the demand for grid-compatible electric current can be met by connecting frequency converters, even if the generator supplies alternating current (AC) of variable frequency or direct current (DC). This flexibility allows for the integration of various generator types into the electrical grid, ensuring a stable and consistent power supply.

.Asynchronous (induction) generator :

11) squirrel cage induction generator (SCIG)
12) wound rotor induction generator (WRIG)

- OptiSlip induction generator (OSIG)
- Doubly-fed induction generator (DFIG)

➢ Synchronous generator :

1) wound rotor generator (WRSG)

2) permanent magnet generator (PMSG)

In this project work, permanent magnet generator (PMSG)is use for wind power generation.

Permanent Magnet Generator (PMSG)

Because excitation is delivered without any energy supply, the efficiency of the permanent magnet machine is higher than that of the induction machine. However, the materials utilised to make permanent magnets are expensive and difficult to work with during the production process. Furthermore, using PM excitation necessitates the employment of a full scale power converter to match the voltage and frequency of generation to the voltage and frequency of transmission, respectively. [7] This is an additional cost. The advantage is that electricity can be created at any pace to suit the existing conditions.

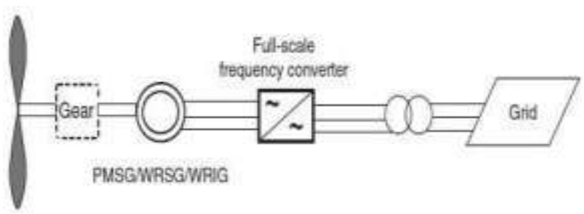

Fig.7 : Wind turbine with PMSG[6]

PMSGs have a winding stator and a permanent magnet pole system on the rotor. The PMSG's synchronous nature may pose issues during starting, synchronization, and voltage regulation. It is difficult to provide a consistent voltage. Another problem of PMSGs is that the magnetic materials are temperature sensitive. Therefore, the rotor temperature of a PMSG must be supervised and a cooling system is required.[15]

3.3 Batteries

The batteries are used to store the electricity generated by wind and solar energy. The capacity of the battery varies according to the size of the wind turbine or solar power plant. Battery maintenance should be minimal, and charge leaking should be minimal as well. Considering all of these factors, the free discharge type is the best option.[9]

4. Proposed Simulink model

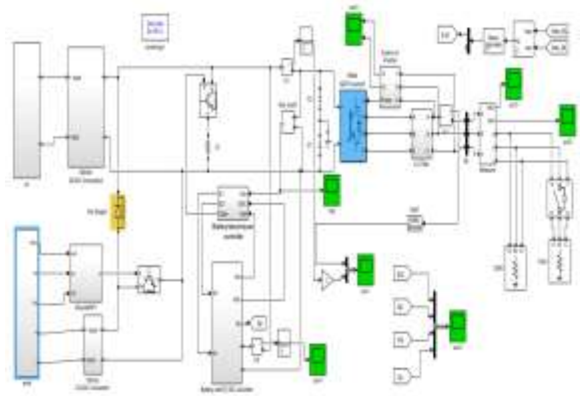

Fig 8: Simulink Model of Hybrid PV-Wind Energy System

Figure 8 depicts a grid-connected Hybrid PV-Wind energy device. The grid is a supply that acts as a backup device for renewable energy in the event of a power outage. When renewable energy systems generate surplus strength, the grid operates as a parking system. If there is a shortage of electricity from solar or wind, or if these sources are unable to meet the burden needs, the grid will automatically cover the entire demand.

5. SIMULATION RESULTS

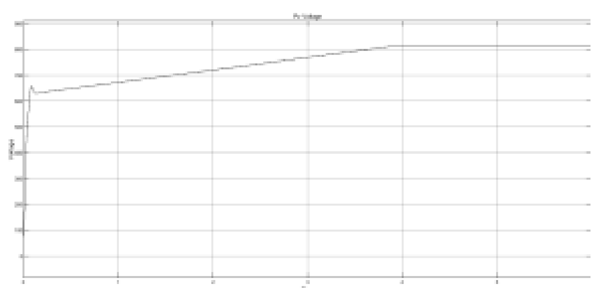

Fig 9: Voltage of the PV Module

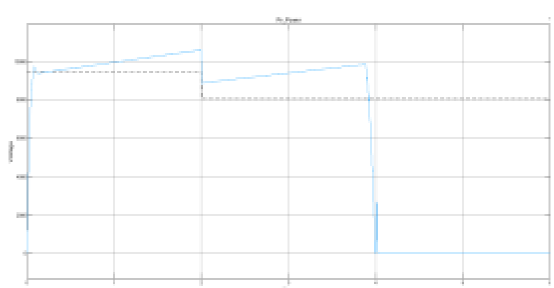

Fig 10: Power Curve of PV Module

The figures 9 and 10 represent the P-V (Power-Voltage) and I-V (Current-Voltage) characteristics for a PV module under standard test conditions of 25°C temperature and 1000W/m² solar irradiance. In Figure

5.8, the y-axis shows the voltage values in volts, and the x-axis indicates the power values in watts. While in Figure 5.9, the y-axis indicates the voltage values in volts, and the x-axis shows the current values in amperes. From the figures, the short circuit current (Isc) is 74A, the open circuit voltage (Voc) is 360V, and the maximum power obtained is 20KW.

Observations were made by varying the solar irradiance values from 250W/m² to 1000W/m² at a constant temperature of 25°C. It was observed that as the irradiance value increased, the current also increased. Solar irradiance significantly influences the current value, while its effect on voltage is minimal. As the irradiance value increases, the power output also increases, primarily due to the increment in current.

Further observations were made by varying the temperature values from 25°C to 100°C while maintaining the irradiance value at 1000W/m². It was observed that as the temperature value increased, the voltage decreased, while the current value remained relatively constant. Temperature variation has a much more significant effect on voltage. As the temperature increases, the power output decreases, primarily due to the decrement in voltage.

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5.1 SIMULATION RESULT OF WIND ENERGY SYSTEMS

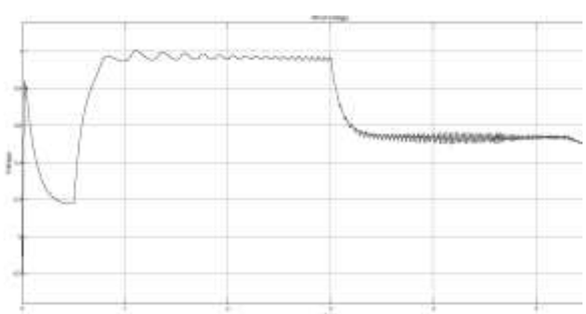

Fig 11: Output Voltage of Wind Power System

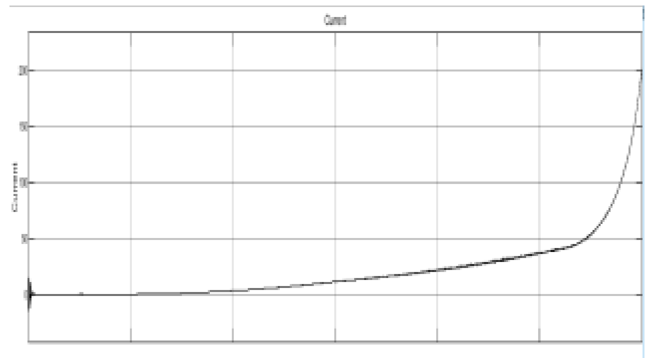

Fig 12: Output Current of Wind Power System

The figure 11 and 12 represents the output waveforms of wind power systems. The figure 5.10is the output graph of voltage and the figure 5.10 is the output graph of current. The x-axis indicatesthe time and the y-axis is the voltage and current.

5.2 SIMULATION RESULT OF HYBRID ENERGY SYSTEM

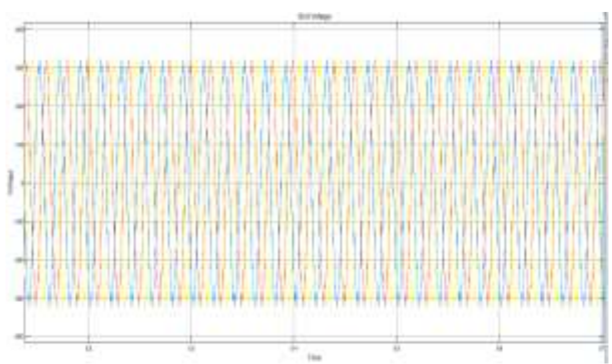

Fig 13 (a) Grid Voltage

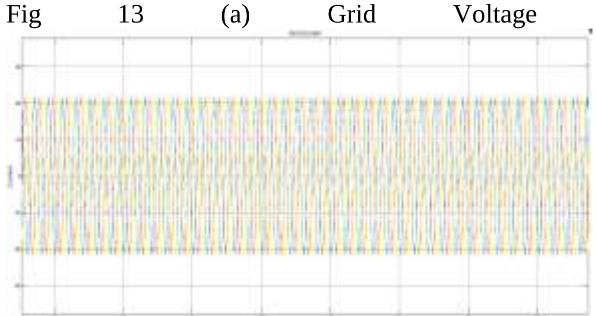

Fig 13 (b) Grid Current

The above figure 13 represents the output from the combined solar and wind energy system. The output for the hybrid system is the combined solar and wind power.

- The first set of graphs in the figure shows the output of Vrms and Irms, which are the DC equivalent output waveforms.
- The middle set of graphs represents the real power and reactive power of the power distribution in the hybrid energy system.
- The bottom set of graphs represents the sinusoidal voltage and current output from the hybrid energy system.

The hybrid system's output is used to supply power to the load, with any surplus power being fed back into the grid. By combining solar and wind energy to power the grid, the generated power from the wind system is connected in parallel and shared with the PV system.

However, there is a difference in power generation from wind and solar sources because they depend on varying climatic conditions. This variability can lead to an imbalance in the amount of power generated, even though the two systems are connected in parallel to the grid.

6. CONCLUSION

This dissertation focuses on modeling a hybrid wind/PV alternative energy system. The main part of the dissertation centers on the modeling of different energy systems. A hybrid wind/PV system is proposed, where wind and PV are the primary power sources, and a battery is used as a backup and long-term storage unit.

Using dynamic component models, a simulation model for the proposed hybrid wind/PV energy system has been successfully developed using MATLAB/Simulink. The overall power management strategy, which coordinates the power flows among the different energy sources, is presented in the dissertation.

Simulation studies have been conducted to verify the system's performance under different scenarios using practical load profiles and real weather data. The results demonstrate that the overall power management strategy is effective, and the power flows among the different energy sources and the load demand are balanced successfully.

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