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Hybrid Electricity Generation Model using Wind Energy and Solar Energy

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Abstract

Reliable and continuous electricity supply is a fundamental requirement for the sustainable development of any nation. In recent years, electrical energy has become a key driver for economic growth and improved living standards. Due to the increasing demand for power and the depletion of conventional energy resources, there is a strong need to shift towards renewable and eco-friendly energy sources.This paper presents the design and implementation of a hybrid electrical power generation system that combines solar and wind energy to ensure efficient and uninterrupted power supply. The system integrates photovoltaic (PV) solar panels and a wind turbine to harness energy from both sunlight and wind under varying environmental conditions. By combining these two renewable sources, the reliability and overall efficiency of power generation are significantly improved.The proposed system consists of PV modules, a wind generator mounted on a suitable structure, charge controllers, battery storage units, and an inverter to convert DC power into usable AC power. This hybrid approach not only minimizes dependency on a single energy source but also reduces operational costs and environmental impact.The developed hybrid solar-wind power generation system is suitable for both domestic and industrial applications, especially in remote and off-grid areas. It offers a sustainable, cost-effective, and environmentally friendly solution to meet the growing energy demands without disturbing the ecological balance.

1.INTRODUCTION

Electrical energy plays a vital role in both human life and economic development. It is one of the primary driving forces behind social progress and is considered a basic necessity for any nation. With rapid technological advancements, the demand for energy is continuously increasing, which has led to the exploration of alternative and renewable energy sources. Initially, research in renewable energy focused on solar power and later expanded to include wind energy. The efficiency of solar energy conversion systems is approximately 18%, while wind energy systems can achieve efficiencies of around 55%. These efficiencies can be further enhanced through advanced techniques such as solar tracking, beam focusing, and adaptive wind direction control methods.

Renewable energy sources are clean, sustainable, and environmentally friendly. They produce minimal emissions and contribute to improved air and water quality. Among these, wind energy has emerged as one of the most economical options for new power generation, competing effectively with conventional sources like coal, gas, and nuclear energy. Similarly, solar energy has significant potential to meet global energy demands. For instance, regions like the United States possess vast wind resources capable of

generating multiple times their current energy requirements.

In recent years, solar installations have seen remarkable growth, with capacity exceeding thousands of megawatts and powering hundreds of thousands of homes. The solar industry has also experienced rapid expansion, supported by a continuous decline in the cost of solar panels. In India, renewable energy capacity has grown significantly, with wind power contributing a major share, followed by solar energy.

Hybrid systems combining solar and wind energy, along with efficient storage solutions, have gained considerable attention in recent times. These systems offer reliable and continuous power generation by compensating for the variability of individual energy sources. Solar power output depends on daily and seasonal sunlight variations, while wind energy depends on wind speed and atmospheric conditions. By integrating both sources, a more stable and efficient energy supply can be achieved.

This paper focuses on the development of a solar-wind hybrid power generation system designed for sustainable and reliable electricity production. The system is compact, user-friendly, and suitable for large-scale implementation at an affordable cost. Additionally, integration with the grid ensures uninterrupted power supply, eliminating issues such as power failure and load shedding. Therefore, this hybrid system presents a cost-effective, dependable, and eco-friendly solution for meeting future energy demands.

A. Energy Sources

1. Hydroelectric-Potential of water stored at higher altitudes is utilized as it is passed through water turbines which drive the alternators.
2. Wind Power- High velocities of wind are utilized in driving wind turbines coupled to alternators. Wind power has an advantage of zero production cost. The cost of the equipment and the limit of generating unit rating is suitable for a particular location are the important constraints. The method has exclusive advantages of being pollution free and renewable.
3. Solar Cell/Photo Voltaic Cell- These directly convert solar energy into electrical energy through a chemical action taking place in solar cells. These operate based on the photo voltaic effect which develops an emf on absorption of ionizing radiation from the sun.
4. Fuel cell- These are devices which enable direct conversion of energy chemically into electrical form. This is an upcoming technology with a special merit of being pollution free.
5. Nuclear Energy- Towards the end of the Second World War, it was discovered that a large amount of heat energy is liberated by the fusion of uranium and other fissionable materials. It is estimated that heat produced by 1kg nuclear fuel is equal to that produced by 4500tonnes of coal. There are some difficulties in the use of nuclear energy. The principals are

a) high cost of nuclear plant, b) problem of disposal of radioactive waste and dearth of trained personnel to handle the plant.

B. Type of Load

A device that taps electrical energy from the electric power system is called a load on the system. The various types of load on the power system are-

1. Domestic Load- Domestic load consists of lights, fans, televisions, small motors, for pumping water etc. most of the residential loads occur only for some hours during the day (i.e.24 hours a day).
2. Commercial Load- Commercial load consists of lighting, for shops, fans, and electric appliances used in restaurants etc. this class loads for more hours during the day as compared to the domestic load. The commercial load has seasonal variation due to the extensive use of air conditioners and

space heaters.

3. Industrial Load- Industrial load consists of load demand by industries. The magnitude of industrial load depends upon the type of industry. Thus small scale industry requires load up to 25kW, medium scale Industry between 25kW and 100kW and large scale industry requires loads above 500kW.
4. Municipal Load- Municipal load consists of street lighting, power required for water supply, drainage purposes. Steer lighting load is practically constant throughout the hours of the night.
5. Irrigation Load- The type of load is the electric power needed for pumps driven by the motors to supply water to fields.
6. Traction Load- This type of load includes trams, cars, buses, railways etc. This class of load has wide variation. During the morning hours, it reaches peak value because people have to go to their work place. After morning hours, the loads start decreasing and again rise during evening since the people start coming to the homes.

C. Wind Power Generation

To extract energy from wind and to convert that energy into electrical power, we need a Wind Turbine setup which can convert the mechanical power into electrical power. The blades of the wind turbine are fixed to the rotor part of the generator set which is mounted on the turbine using gear-arrangement.

Wind with a speed of 5km/hr or more causes the rotation of the blades of the turbine. As the blades rotate, the mechanical power then converts into electrical power with the help of a generator set.

The amount of energy which the wind transfers to the rotor depends on the density of the air, the rotor area, and the wind speed. Block diagram representation of Wind power generation is shown in Fig 1.

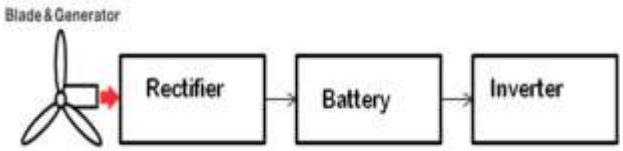

Fig 1. Block diagram representation of Wind power generation

D. Solar Power Generation

The sun gives us energy in terms of both heat & light. But we are using light energy for producing electrical energy. The system which converts sunlight to electrical energy is called Solar Cell. It is basically a photo-voltaic cell or PV cell which is photo sensitive

When sunlight falls on the N side, the free electrons flow from N to P. As the electron gets enough energy to break down the bond and flow through the load. So current flows in the opposite direction. This is the main operating principle of solar cells. Block diagram representation of Wind power generation is shown in Fig 2.

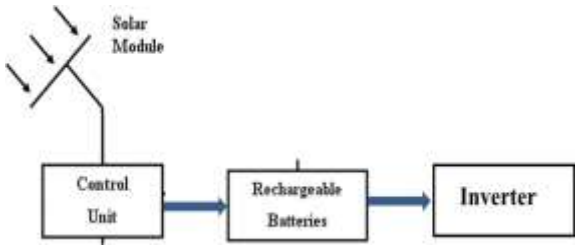

Fig 2. Block diagram representation of Solar power generation

The equivalent circuit of solar cells is given in Fig 3.

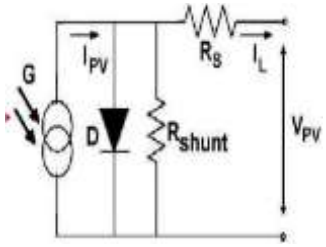

Fig 3. Circuit diagram representation of Solar cell

The PV cell is arranged in Fig 4.

Fig 4. Representation of PV Cell

WIND SOLAR HYBRID POWER SYSTEM MODEL

After successful power generation from both the power sources, we will combine the two power sources.

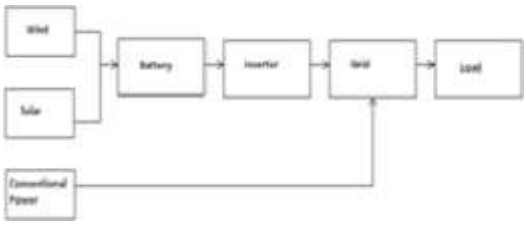

Fig 5. Block diagram representation of Hybrid Power System model.

A. Inverter

An inverter is an electronic device or circuitry that changes direct current (DC) to alternating current (AC). The input voltage, output voltage and frequency, and overall power handling depend on the design of the specific device or circuitry. The inverter does not produce any power; the power is provided by the DC source. A typical power inverter device or circuit requires a relatively stable **DC power source** capable of supplying enough current for the intended power demands of the system. The input voltage depends on the design and purpose of the inverter, e.g., 12VDC, for smaller consumer and commercial inverters that typically run from a rechargeable 12V lead acid battery[9][10].

B. Circuit Diagram

The necessary circuit diagram of the inverter is shown in Fig 6.

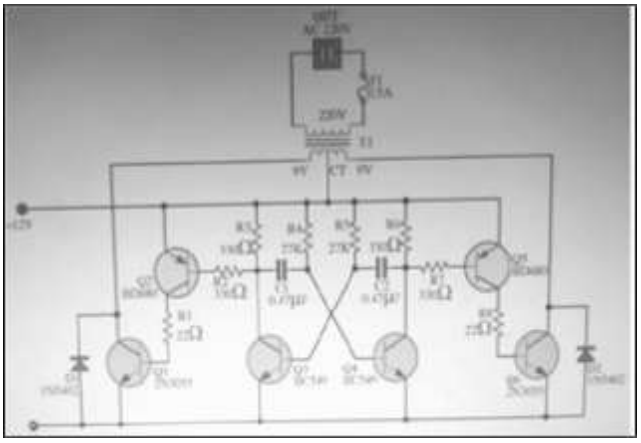

Fig 6. Circuit diagram of Inverter

I. Conclusion

Hybrid power generation models using solar and wind energy are more effective solutions for power generation than conventional energy resources. Its efficiency is always better. It can be used in remote areas where the government is unable to reach. So that the power can be utilized where it is generated so that it will reduce the transmission losses and cost. Although the initial cost for a solar-wind hybrid power system is high, it produces electricity at least cost. Due to distributed generation it eliminates installation cost transmission lines. It has many advantages that it produces no pollution and requires less maintenance. People should be motivated to use non conventional energy resources. It is highly safe for the environment as it doesn't produce any emission and harmful waste products like conventional energy resources. An initial investment is required for that purpose. So it is reliable for electricity generation.

Advantages of Hybrid Electricity Generation

- Continuous power supply
- Higher efficiency
- Eco-friendly (no pollution)
- Low operating cost
- Reliable system
- Low maintenance

Result:

The hybrid solar-wind power generation system successfully generated continuous and stable electricity. It showed better performance compared to using only solar or wind individually. The battery storage ensured power availability during low generation periods.

Discussion:

The system improves reliability by combining two renewable sources. Solar output varies with sunlight, while wind energy depends on wind speed, but together they balance each other. The overall efficiency and cost-effectiveness are improved. This system is suitable for both domestic and small-scale industrial use, especially in areas with unreliable grid supply.

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