HYBRID SOLAR-WIND POWER GENERATION SYSTEM FOR RURAL ELECTRIFICATION

Project Reference No.: 49S_BE_6710

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Keywords:

Renewable energy, wind, solar, hybrid system, Rural electrification.

Introduction:

Hybrid solar–wind power generation is an emerging solution that provides reliable, clean, and affordable electricity to rural and remote areas. Many rural regions face frequent power shortages or lack grid connectivity due to difficult terrain and the high cost of extending transmission lines. A hybrid renewable energy system combines the strengths of both solar and wind resources, ensuring continuous power supply throughout the year. Solar energy is abundant during the daytime and in summer seasons, while wind energy is often available during evenings, nights, and monsoon periods. By integrating these two sources, the system compensates for the fluctuations of each resource and maintains a stable energy output. In a typical hybrid setup, solar panels convert sunlight into DC power, and wind turbines generate electricity from wind. This power is managed through charge controllers, inverters, and battery storage to supply usable AC power to homes, schools, farms, and small businesses. Hybrid systems reduce dependence on diesel generators, lower electricity costs, and minimize carbon emissions. They also support rural development by enabling irrigation, lighting, communication, and small-scale industries.

Fig 1: Hybrid Solar- Wind power Generation system for Rural Electrification

Objectives

- Provide reliable and continuous electricity for rural areas
- Combine solar and wind energy for efficient power generation
- Ensure uninterrupted power supply under varying weather conditions
- Support agriculture by powering irrigation systems and farming equipment
- Reduce dependence on diesel generators and lower energy cost
- Promote eco-friendly and sustainable energy solutions

Methodology:

- Solar Panel –12V, 2A, 20W Captures sunlight and converts it into DC electricity.
- Windmill (Wind Turbine) – Harnesses wind energy and generates AC power.
- Charge Controller– 12V to 24V, 20A (min input and max output)
- Lead acid Battery –12V, 7AH, Stores the energy generated from solar and wind for later use.
- Voltage Sensor – 0-25V DC Measures the generated voltage and sends data to the Arduino.
- Current Sensor (ACS712)– 10A Measures the generated current and sends the readings to Arduino.
- Arduino UNO –processes sensor data, controls the servo motor, and manages system functions.
- Servo Motor (MG995) – 360 deg rotation, used for solar panel tracking to adjust the angle based on sunlight.
- LCD Display(I2C) – 16X2 Shows real-time system values like voltage, current, and power status.
- Power Supply Module – Provides regulated power to Arduino.
- Inverter (Auto cutoff) – Converts stored 12V DC power from the battery into 230V AC power for load use.
- Step-Up Transformer – 12V I/P, 230V O/P. Increases the AC voltage output to a usable level for household or rural loads.
- MCB (Miniature Circuit Breaker) – Ensures protection by cutting off power during overloads or short circuit faults.
- Load – 220V-230V, represents appliances or systems (lighting load) that consume the generated electricity.

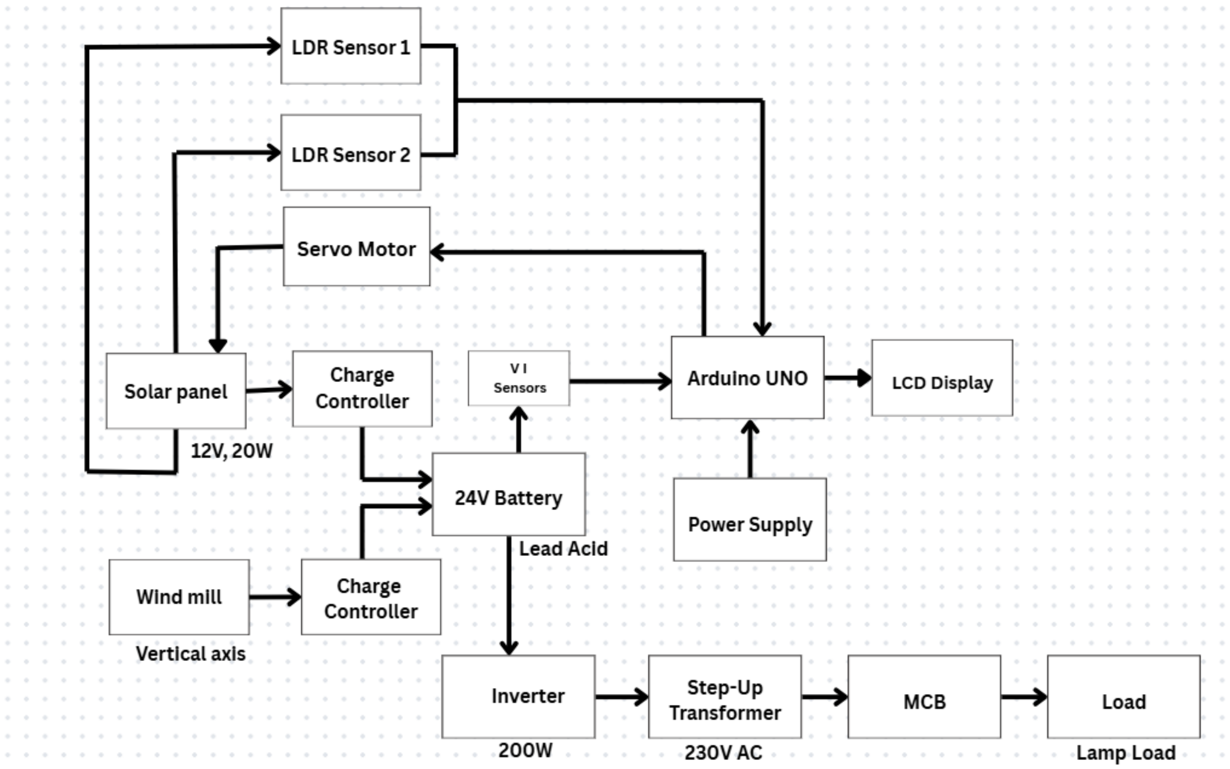


Fig 2: Project block diagram

Result and Conclusion:

The hybrid renewable energy system combining a VAWT and a solar PV panel was successfully tested under standard conditions and produced a combined 12 V output, making it suitable for charging 12 V battery systems in small-scale renewable applications.

Energy Source Output Voltage (V)
Solar Panel Only ~ 10-12 V (varied with sunlight)
VAWT Only ~ 2-5 V (varied with wind speed)
Hybrid Output 200-220 V AC (stable output with load)

The VAWT produced a variable voltage depending on wind speed, which was stabilized by the solar panel, especially during low-wind conditions. The hybrid system delivered more stable and reliable power, demonstrating improved efficiency under changing weather conditions.

Project Outcome & Industry Relevance:

1. The project successfully demonstrates a hybrid solar-wind power system capable of generating reliable and continuous electricity. The integration of two renewable energy sources improves efficiency and reduces power fluctuations. The system provides a low-cost and eco-friendly solution for rural electrification. The prototype shows practical implementation of energy storage, power conversion, and real-time monitoring using sensors and Arduino. It reduces dependence on fossil fuels and diesel generators, promoting sustainable energy usage.
2. This project contributes to the field of renewable energy and electrical engineering by providing a scalable hybrid power solution. It enhances knowledge in power systems, automation, and embedded systems.
3. In real-world applications, the system can be used in remote villages, farms, and off-grid areas. It can support agriculture, small industries, and household electricity needs. The design can be further expanded into smart microgrids and integrated with IoT for advanced monitoring. It has strong potential for adoption in renewable energy industries and government rural electrification programs.

Working Model:

1. This project is based on a physically developed working model rather than a simulation or theoretical study. The system was practically implemented using real components to demonstrate hybrid power generation.
2. The prototype integrates both solar and wind energy sources for continuous power generation. A solar panel converts sunlight into electrical energy, while a wind turbine generates power from wind.
3. Both sources are connected through charge controllers to regulate the power flow. The generated energy is stored in a lead-acid battery for later use.
4. An Arduino UNO is used as the control unit to monitor and manage system operations. Voltage and current sensors are used to measure real-time electrical parameters.
5. The solar tracking system is implemented using LDR sensors and a servo motor to maximize energy generation. The servo motor adjusts the solar panel position based on light intensity.
6. The stored DC power is converted into AC power using an inverter. A step-up transformer increases the voltage to 230V for practical usage.
7. An MCB is used to provide protection against overloads and short circuits. The output is connected to a lamp load to verify the working of the system.
8. The entire setup was assembled and tested under real-time conditions. The performance of the system was observed for different environmental variations.

9. Circuit diagrams and prototype designs were developed and implemented successfully. The results confirm the feasibility and reliability of the hybrid system.
10. Thus, the project represents a complete working model with practical implementation and testing.

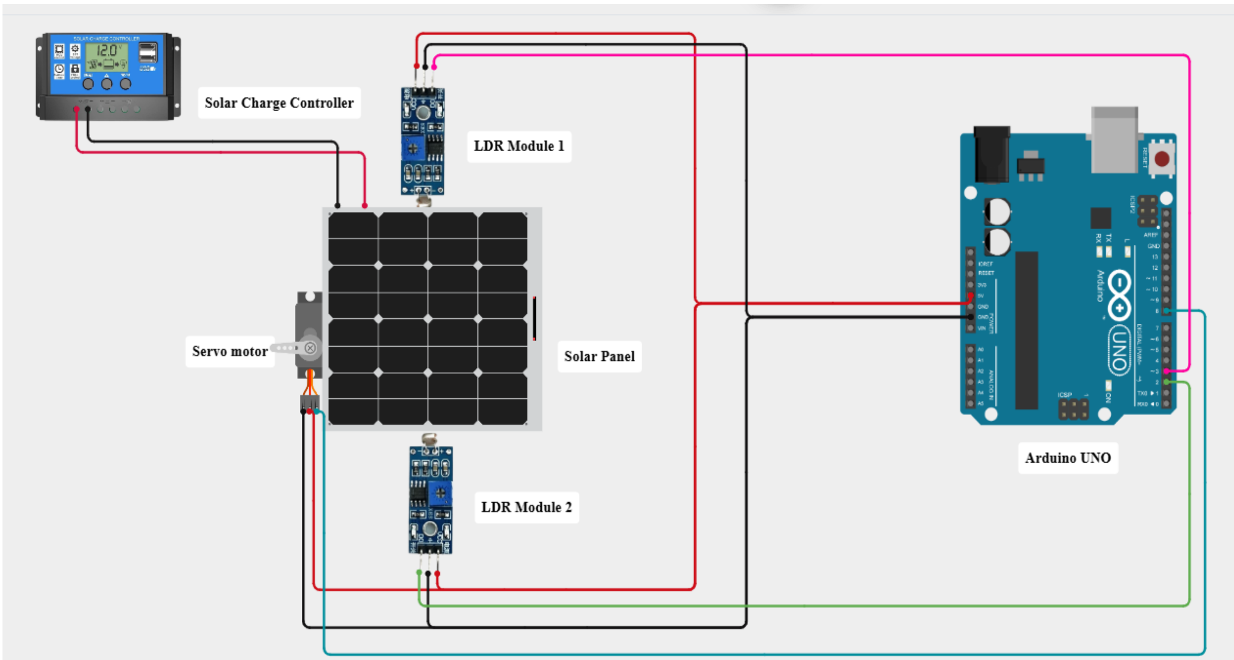


Fig 3: Solar Tracking Connections

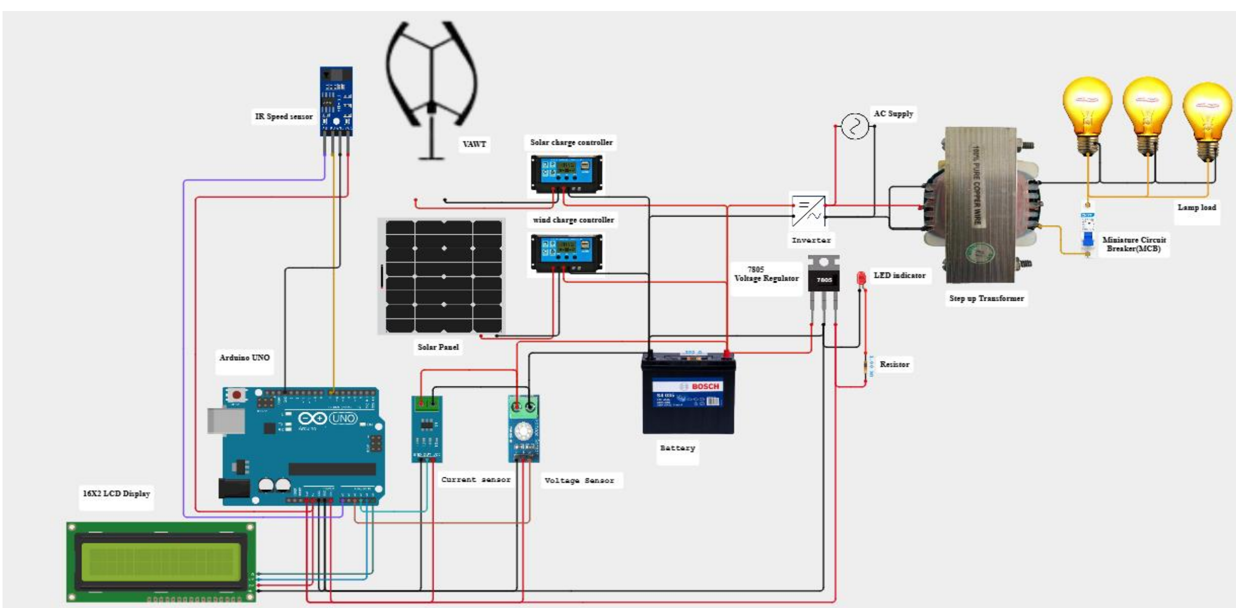
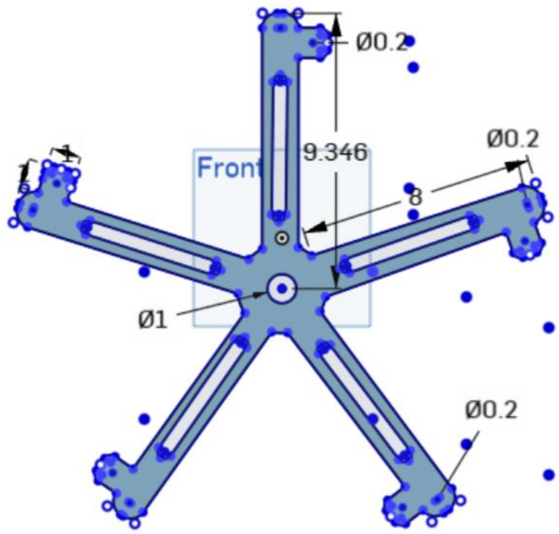
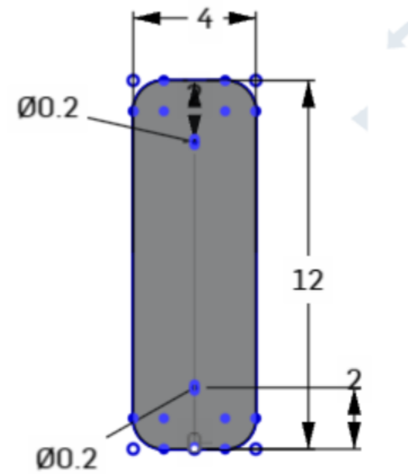


Fig 4: Solar-Wind Connection

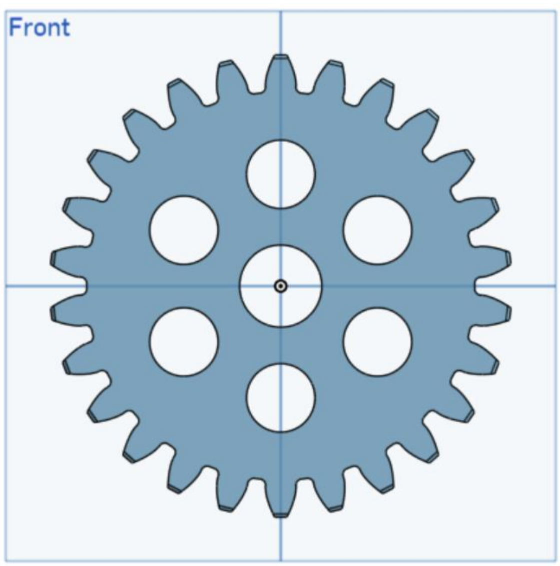
Material Design:



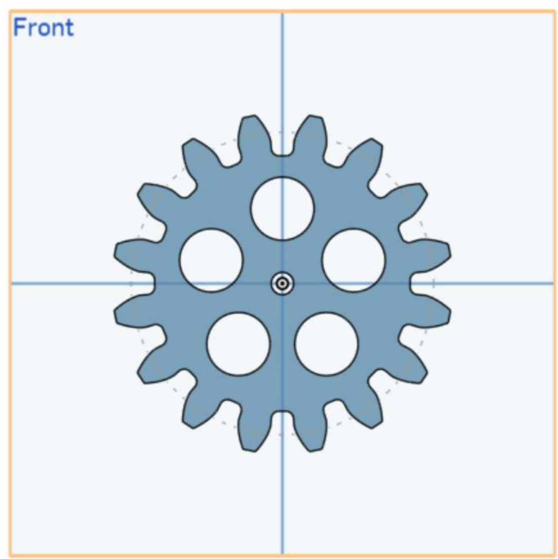
Turbine Blade Dimensions



Wing Blade Dimensions



28 Teeth Gear Design



16 Teeth Gear Design

Project Outcomes and Learnings:

- Successfully developed and tested a hybrid sol ar-wind working model for continuous power generation
- Achieved stable energy output using battery storage and power conversion system

- Gained practical knowledge of renewable energy systems and rural electrification concepts
- Learned Arduino programming, sensor integration, and real-time monitoring techniques Developed skills in circuit design, system integration, and troubleshooting

Future Scope:

- **Advanced Energy Storage Solutions:** Use high-efficiency batteries to improve storage and reduce long-term cost
- **Expansion to Remote & Off-Grid Areas:** Extend system to villages with no or limited electricity access
- **Smart Grid Integration:** Connect with grid to share excess energy and improve stability
- **Improved Efficiency with Better Materials:** Use advanced panels and turbine designs for higher output
- **Localized Manufacturing & Cost Reduction:** Develop low-cost components using local resources
- **IoT & Automation Enhancements:** Enable real-time monitoring, fault detection, and smart control
- **Hybrid Renewable Energy Expansion:** Integrate solar, wind, and other renewable sources
- **Community Participation & Ownership Models:** Encourage local involvement in system management
- **Sustainability & Environmental Protection:** Use eco-friendly methods to protect environment
- **Policy & Government Support:** Promote subsidies and policies for wider adoption