VISVESVARAYA TECHNOLOGICAL UNIVERSITY

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A Project Report

On

"SMART HYBRID RENEWABLE ENERGY MANAGEMENT SYSTEM FOR REMOTE VILLAGES"

A Project report submitted in partial fulfillment of requirement for the award of 7th Semester B.E Course during the academic year 2024-25

Bachelor Of Engineering

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Certificate

*This is to certify that the Project entitled **"SMART HYBRID RENEWABLE ENERGY MANAGEMENT SYSTEM FOR REMOTE VILLAGES"** is a bonafide work carried out by **MD UZAIR KASHIF (3GN21EE020), SYED RIYAN (3GN21EE038), SYED SHOAIB UMAR ALI (3GN21EE040), ATIFA NAUSHEEN (3GN22EE402)** in partial fulfillment of the requirements for the award of degree of Bachelor of Engineering in Electrical and Electronics Engineering from Visvesvaraya Technological University, Belagavi during the academic year 2024-2025. It is certified that the mini project report satisfies the academic requirement in respect of mini project work described for the Bachelor of Engineering degree.*

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ABSTRACT

A **Smart Hybrid Renewable Energy Management System for Remote Villages (SHRE)** integrates multiple renewable energy sources with energy storage solutions to provide reliable electricity, especially in rural and remote areas where conventional grid power is unreliable or unavailable. This project aims to design an optimized hybrid system that combines photovoltaic (PV) solar panels, wind turbines, grid power, and battery storage. The inclusion of grid connectivity serves as a backup to ensure uninterrupted power supply. By leveraging locally available solar and wind resources, the system minimizes reliance on fossil fuels, contributing to a cleaner and more sustainable energy ecosystem.

The proposed SHRE harnesses solar energy during the day through PV panels and wind energy when conditions are favorable, creating a complementary power generation profile. Excess energy produced during periods of high renewable generation is stored in batteries. This stored energy can then be utilized during low production periods, such as nighttime or windless days, ensuring a continuous and reliable power supply. Such a setup is particularly advantageous for small villages where energy demand fluctuates and consistent access to electricity is crucial for economic and social development.

Moreover, integrating grid power as a backup ensures that energy demands are met even during extended periods of low renewable energy production. By effectively reducing dependence on the grid, the system lowers overall energy costs for the community. The smart management aspect includes monitoring and control systems to optimize energy usage, enhance efficiency, and reduce wastage.

This project not only addresses the immediate energy needs of remote villages but also contributes to broader environmental goals by reducing greenhouse gas emissions and promoting renewable energy adoption. The SHRE is scalable and can be adapted to meet the needs of various rural communities, making it a sustainable and forward-thinking solution for global energy challenges.

Keywords: *Photovoltaic (PV) Solar Panels, Wind Turbines, Battery Storage, Grid Integration, Energy Sustainability, Renewable Energy Adoption.*

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CHAPTER 1

INTRODUCTION

1.1 Background

Energy is the basic need for development and the requirement of energy is more due to the rapid increase in world population, technology and other political and economic condition.

Now a day’s electrical energy is generated by the conventional energy resources like coal, diesel, and nuclear etc. and these are depleting day by day. So, there is an urgent need to switch onto non-conventional energy resources. This in turn has given rise to the smart hybrid renewable energy (SHRE) Management system for remote villages. Smart hybrid renewable energy (SHRE) Management system for remote villages is the combination of the two or more energy systems. Here, two sources are used solar and wind energy. In order to control the hybrid system IOT can be used. IOT (Internet of Things) is the inter-networking of physical devices embedded with electronics, software, sensors and network connectivity that enable objects to collect and exchange data.

IOT is used to switch the power supply i.e., wind energy and solar energy of a house through secure website when the grid supply is off. A prototype is designed to control the switching between these two sources of energy. With the advancement in technology provide sensors, metering, transmission, Distribution, and flexibility to consumers of electricity, it can be possible to control the sources of energy of a house by this prototype

1.2 Overview of SHRE

The Internet of Things (IoT) enables efficient monitoring of hybrid power generation systems that combine renewable sources like solar and wind with conventional mains power. This project implements an IoT-based hybrid power system using a GPRS network. It features sensors to monitor solar panels with sun trackers, wind turbines, batteries, and grid connectivity. The system automatically switches between power sources based on sunlight or wind availability, defaulting to the grid when needed.
Data from the sensors is transmitted wirelessly to a central monitoring station, equipped with a microcontroller and GPRS communication, for real-time and historical data analysis. A user-friendly interface allows performance monitoring and optimization.

Designed to be modular, scalable, and energy-efficient, the system minimizes power consumption and supports additional components.

1.3 Importance of SHRE

Many are looking at sustainable energy alternatives to protect the planet for future generations as worry over global warming and the depletion of fossil fuel supplies grows. Other than hydropower, photovoltaic and wind energy have the greatest potential to satiate our energy needs. Large amounts of power can be generated by wind energy alone, but it is highly unpredictable because it might appear one second and disappear the next. Similar to this, solar energy is available all day long, but the amount of solar irradiation varies due to the sun's intensity and the unpredictably shaped shadows created by clouds, birds, trees, etc. Both wind and photovoltaic systems have the inherent flaw of being intermittent, which renders them unstable. Nevertheless, by combining these two sporadic sources.

1.4 Current trends in SHRE

1. Renewable energy storage
2. Advanced nuclear reactors
3. Carbon capture, utilization and storage (CCUS)
4. Hydrogen energy
5. Advanced solar technologies
6. Smart grid and energy management systems
7. EV infrastructure
8. Energy-efficient buildings
9. Tidal and wave energy
10. AI and predictive analysis.

1.5 Objective

1. **Hybrid Power Generation Unit**: Generates power using solar, wind, and grid backup. Includes a solar tracker for optimal energy harvest by aligning panels with the sun.
2. **Energy Storage Unit**: Stores generated power in batteries or supercapacitors and supplies energy to the load as needed.

3. **IoT Monitoring & Control Unit**: Monitors and controls power generation and storage using sensors and a microcontroller. Sensor data is transmitted via GPRS to a cloud server for analysis.

1.6 Project Goal

The primary goal of a hybrid energy system is to combine multiple energy sources, like renewable sources like solar and wind, with potentially traditional sources like diesel, to achieve greater reliability, efficiency, and cost-effectiveness in energy generation, often by mitigating the fluctuations of renewable sources while reducing reliance on fossil fuels and minimizing environmental impact; essentially providing a more stable and sustainable energy supply by leveraging the strengths of different energy technologies.

1.7 Significance of the project

1. **Energy Security**: Hybrid systems ensure reliable power by combining renewable sources, compensating for weather-related output fluctuations.
2. **Reduced Emissions**: They lower greenhouse gas emissions and dependence on fossil fuels by integrating renewables.
3. **Cost-Effective**: Optimized energy production and use of existing infrastructure reduce energy costs.
4. **Grid Stability**: Provide consistent power, enhancing grid stability, especially with energy storage.
5. **Remote Flexibility**: Ideal for off-grid rural areas with limited access to traditional grids.

1.8 Limitations and Constraints

Hybrid energy systems face limitations including: high initial installation costs, complex system management due to integrating multiple energy sources, potential intermittency issues from renewable sources like solar and wind, challenges in energy storage capacity, space constraints for installation, technical complexity requiring specialized knowledge, and navigating regulatory hurdles depending on the location.

CHAPTER 2

LITERATURE REVIEW

A literature review surveys existing research to understand the current knowledge on a topic. It analyzes and synthesizes information from sources like journals and books, providing a foundation for new research, identifying gaps, and justifying further exploration. By evaluating past methodologies and findings, it ensures new research is relevant and contributes meaningfully to the field.

2.1 Literature Survey

2.1.1 Bahramara, S., M. Parsa Moghaddam, and M. R. Haghifa, "Optimal planning of hybrid renewable energy systems using HOMER: A review." RESE Reviews – 2016

This study reviews the application of the HOMER software for optimizing hybrid renewable energy systems (HRES). It highlights the increasing importance of hybrid systems in addressing energy demands sustainably, emphasizing solar, wind, and biomass energy sources. The authors analyze various case studies and configurations, identifying optimal solutions for technical, economic, and environmental performance. Key challenges include integrating diverse energy resources, policy gaps, and cost uncertainties. This review underscores HOMER's effectiveness in comparing design options, optimizing system sizing, and ensuring reliability. Future directions emphasize improving HOMER's capabilities to model larger-scale systems and its integration with other advanced simulation tools.

2.1.2 Ravi R. Kundankar, Dr. P. K. Katt, "Hybrid energy assessment for remote areas." IJETSR Volume 4, Issue 11, November 2017

The paper explores hybrid energy assessments tailored for remote areas, addressing energy poverty and sustainable development. It evaluates the feasibility of hybrid systems, combining renewable energy sources like solar and wind with conventional systems, to ensure energy reliability and cost-effectiveness. Using HOMER software, the study analyzes parameters like resource availability, load demand, and economic factors. Key findings show that hybrid systems reduce dependency on fossil fuels and minimize environmental impact. The authors advocate for government policies to promote hybrid systems in isolated regions. The research concludes with recommendations to enhance system efficiency through emerging technologies and better load management.

2.1.3 Rohit Sen, Subhas C. Bhattacharya, "Off-grid electricity generation with RE technology in India: An application of HOMER." Renewable Energy 2014

This research focuses on off-grid electricity generation in India using renewable energy technologies analysed through HOMER. It assesses the feasibility of hybrid systems for remote rural areas, considering resource potential and socio-economic factors. Results indicate that a mix of solar, wind, and battery systems provides optimal energy solutions, reducing reliance on diesel generators. The study highlights HOMER's utility in comparing various scenarios to determine the most cost-effective and environmentally friendly configurations. Recommendations include promoting localized renewable energy projects, improving financial incentives, and addressing technical challenges in remote electrification. The work contributes to India's renewable energy deployment goals.

2.1.4 Omar Hazem Mohammed, Adel A. Elbase, "Optimal Design of a PV/Fuel Cell Hybrid Power System for the City of Brest in France." Conference on Green Energy

This paper presents the design and optimization of a hybrid PV/fuel cell power system for Brest, France, using HOMER software. The study aims to develop a sustainable energy model that minimizes environmental impact while meeting local energy needs. It investigates system sizing, energy efficiency, and cost-effectiveness. Results demonstrate that hybrid systems significantly reduce carbon emissions compared to conventional setups. The authors highlight the importance of incorporating renewable sources like solar with fuel cells to ensure grid independence and reliability. The paper concludes by emphasizing policy support and technological advancements to improve the adoption of hybrid systems in urban areas.

2.1.5 Vivek kumar soni and Prof. Ranjeeta Khare, "Optimal Sizing of HRES for Small Sized Institute Using HOMER." IEEE 2nd International Conference on Electrical Energy Systems (ICEES)

This study uses HOMER to optimize hybrid renewable energy systems for small educational institutes. It evaluates solar, wind, and backup configurations to ensure reliable, cost-effective energy. Results show hybrid systems outperform standalone setups in sustainability and cost. The research highlights accurate load estimation, resource assessment, and smart technologies for efficient energy management and scalability, addressing institutional needs while supporting environmental goals.

2.1.6 Fathima A. H., Palanisamy K., "Optimization in microgrids with hybrid energy systems" — a review. Renew Sustain Energy Rev 2015

This review discusses optimization techniques in microgrids featuring hybrid energy systems, emphasizing their role in achieving sustainability, reliability, and cost-efficiency. It explores diverse renewable energy sources, including solar, wind, and biomass, alongside storage systems for decentralized grids. The authors classify optimization approaches into mathematical, heuristic, and hybrid methods, analyzing their suitability for different energy scenarios. Key challenges include managing intermittency, integrating multiple resources, and addressing economic constraints. The study highlights the importance of tailored optimization strategies to enhance system performance. Future directions focus on advanced algorithms, real-time decision-making, and seamless integration with larger smart grid frameworks.

2.1.7 Banosa R, Manzano-Agugliarob F, Montoyab FG, Gila C, Alcaydeb A, Gómezc J. "Optimization methods applied to renewable and sustainable energy" — a review. Renew Sustain Energy Rev 2011

This paper reviews optimization methods applied to renewable and sustainable energy systems, addressing the growing demand for efficient energy solutions. It examines various techniques, including linear programming, genetic algorithms, and artificial neural networks, used to optimize system design, resource allocation, and operational efficiency. The authors emphasize integrating renewables like solar and wind while minimizing environmental impacts and costs. Challenges such as variability in resources and scalability are discussed. The study concludes that combining multiple optimization methods can better address complex energy scenarios. Recommendations include enhancing computational tools and promoting interdisciplinary approaches for advancing renewable energy optimization.

2.1.8 Performance analysis of an off-grid wind-PV (photovoltaic)-diesel-battery hybrid energy system feasible for remote areas. A. Shezan, S. Julai – 2016

This study evaluates the performance of an off-grid wind-photovoltaic (PV)-diesel-battery hybrid energy system designed for remote areas. The research analyzes the feasibility and efficiency of integrating multiple renewable sources with traditional systems to address energy access challenges. Using simulation tools, the authors assess the system's reliability, cost-effectiveness, and environmental impact under varying load demands and resource conditions. Results reveal that hybrid configurations significantly reduce diesel dependency, lowering operational costs and carbon emissions. The study underscores the importance of proper sizing and resource assessment for optimal performance. Recommendations highlight policy support and advanced storage technologies for wider implementation.

2.1.9 Modeling and optimization of battery less hybrid PV (photovoltaic)/Diesel systems for off-grid energy applications - Tsuanyo D, 2015.

This paper focuses on the modeling and optimization of battery less hybrid photovoltaic (PV)/diesel systems for off-grid applications. The study investigates system configurations that eliminate the need for batteries, aiming to reduce costs and maintenance challenges while maintaining reliability. Using optimization techniques, the research analyzes energy production, fuel consumption, and system efficiency under diverse conditions. Results show that battery less hybrid systems can achieve significant cost savings and environmental benefits when properly designed. The authors emphasize the importance of load management and resource forecasting. The study concludes with recommendations for enhancing system robustness through advanced control strategies and efficient component integration.

2.2 Previous Work

Prior to the widespread use of fossil fuels, early civilizations utilized various forms of renewable energy, including wind power for sailing boats, water wheels to grind grain, and solar heat for cooking, with documented examples from ancient China, Persia, Greece, and Rome, where windmills pumped water for irrigation and early solar collectors were used for heating purposes; essentially, harnessing the power of the sun, wind, and water for basic needs was a significant part of pre-industrial energy systems.

2.2.1 Evolution of SHRE

The evolution of energy management systems (EMS) for microgrids has focused on optimizing hybrid wind-solar-battery systems for remote and off-grid areas, enhancing energy efficiency and sustainability. Advanced EMS designs address power balance challenges caused by renewable energy variability and fluctuating demand through dynamic control algorithms. These algorithms use optimization techniques, predictive modeling, and machine learning to manage energy flow, maximize resource utilization, and reduce reliance on external grid power.

2.2.2 IoT in SHRE

In a hybrid energy system, IoT (Internet of Things) technology enables real-time monitoring and optimization of multiple renewable energy sources like solar and wind, by utilizing sensors and data analytics to collect information on energy production, storage levels, and consumption patterns, allowing for efficient management and grid integration of the combined energy sources, ultimately leading to better energy utilization and cost savings.

2.2.3 IoT software

Arduino IDE

Arduino is a type of computer software and hardware company that offers open-source environment for user project and user community that intends and fabricates microcontroller based inventions for construction digital devices and interactive objects that can sense and manage the physical world. For programming the microcontrollers, the Arduino proposal provides an software application or IDE based on the Processing project, which includes C, C++ and Java programming software. It also support for embedded C, C++ and Java programming software. Arduino is an open-source computer hardware and software company, project and user community that designs and manufactures microcontroller-based kits for building digital devices and interactive objects that can sense and control the physical world. The boards feature serial communications interfaces, including USB on some models, for loading programs from personal computers. For programming the microcontrollers, the Arduino platform provides an integrated development environment (IDE) based on the Processing project, which includes support for C, C++ and Java programming languages.

Fig 2.1 Arduino IDE

2.2.4 Real world applications

Fig 2.2 Blynk Application

Blynk was designed for the Internet of Things. It can control hardware remotely, it can display sensor data, it can store data, visualize it and do many other cool things.

There are three major components in the platform:

Blynk App - allows to you create amazing interfaces for your projects using various widgets we provide.

Blynk Server - responsible for all the communications between the smartphone and hardware. You can use our Blynk Cloud or run your private Blynk server locally. It's open-source, could easily handle thousands of devices and can even be launched on a Raspberry Pi.

Blynk Libraries - for all the popular hardware platforms - enable communication with the server and process all the incoming and outcoming commands.

2.3 Proposed system

The **Smart Hybrid Renewable Energy (SHRE) Management System for Remote Villages** integrates **solar panels**, **wind turbines**, **battery storage**, and **grid connectivity** to provide a reliable and sustainable electricity supply in rural areas. The system generates power using solar and wind resources, stores excess energy in batteries, and uses grid power as a backup during low renewable generation periods. The **charge controller** ensures optimal battery charging, while a **relay switch** automatically selects the active energy source based on availability. **IoT-based monitoring** enables real-time tracking of system performance, optimizing energy usage, reducing dependence on fossil fuels, and ensuring uninterrupted power supply for economic and social development.

CHAPTER 3

METHODOLOGY

3.1 Block diagram

The block diagram illustrates a hybrid energy system that integrates renewable energy sources and grid power for efficient energy management. It features a stepdown transformer and regulator to convert grid voltage to 12V and 5V for system use. Renewable energy is harnessed through a solar panel and a windmill dynamo, with the generated AC power converted to DC by a rectifier filter. A relay switch manages the selection between power sources, while a charge controller regulates the charging of a 12V battery. The system is controlled by an ATMega328P R3 microcontroller, which coordinates operations, interfaces with sensors, a servo motor, and cloud connectivity for real-time monitoring. The load represents the devices powered by the system, ensuring uninterrupted operation and optimized use of renewable energy.

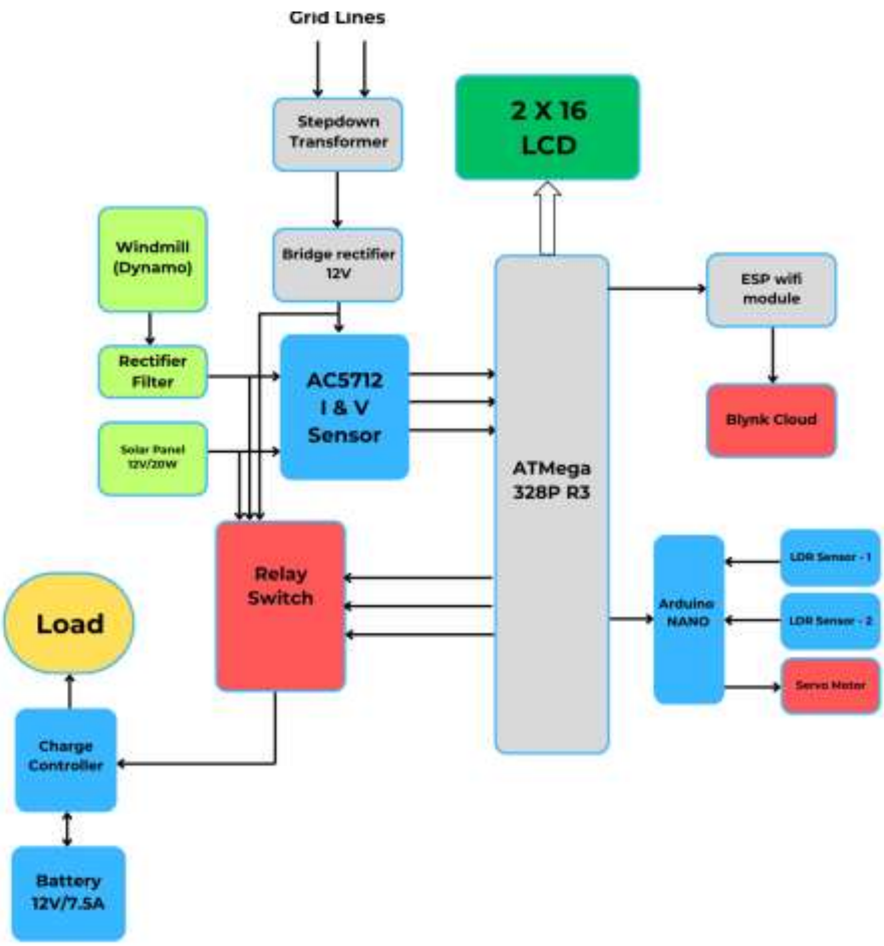

Fig 3.1 Block diagram of System

3.1.1 Block diagram working

1. Energy Generation

a) Solar Panel

The solar panel generates DC electricity when sunlight is available.

b) Windmill/Dynamo

The windmill generates AC electricity when wind is available. The generated AC is converted to DC through the Rectifier and Filter for compatibility with the system.

2. Power Regulation and Storage

a) The DC power from the solar panel and windmill is fed to the Charge Controller.
b) The charge controller regulates the voltage and current, ensuring the 12V/7.5Ah Battery is charged optimally and safely.

3. Power Source Selection

a) The Relay Switch monitors the availability of Solar energy, Wind energy, Grid power (if renewable energy is insufficient)
b) Based on availability and priority Renewable energy sources (solar/wind) are prioritized. Grid power acts as a backup.

4. Load Monitoring

The ACS712 Current and Voltage Sensor continuously measures current drawn by the load and voltage level at the output. This data is sent to the ATMega 328P R3 Microcontroller for analysis.

5. Microcontroller Operations

The ATMega 328P R3 acts as the system’s brain and Processes data from the sensors. Controls the Relay Switch to optimize power usage. Sends instructions to the Servo Motor (for solar tracking using LDR Sensors). Updates the LCD Display with system status. Interfaces with the IoT Module for remote monitoring and control.

6. Solar Tracking (Optional Sub-System)

LDR Sensors measure sunlight intensity from different directions. The microcontroller determines the optimal solar panel angle and adjusts it using the Servo Motor to maximize energy generation.

7. IoT Integration

The IoT module transmits real-time data (e.g., power source, battery level, load status) to a remote server or mobile app. Users can monitor or control the system remotely.

8. Power Supply to Load

The regulated power (from the battery or selected source) is supplied to the Load for operation. If renewable energy is insufficient and grid power is unavailable, the system may enter a low-power mode to preserve energy.

3.2 Description of Components

3.2.1 Solar Panel (12V/20W)

The 12V/20W solar panel captures sunlight and converts it into electrical energy using photovoltaic cells. It's ideal for small-scale power generation in hybrid systems, particularly in remote areas. It powers loads or charges batteries, reducing reliance on grid power and contributing to sustainability by maximizing renewable energy use.

Fig 3.2 Solar Panel

3.2.1.1 Working

A solar panel works by converting sunlight into electricity through a process known as the **photovoltaic (PV) effect**. It is composed of multiple photovoltaic cells made from semiconductor materials, typically silicon, which are arranged in layers. Here’s a step-by-step explanation of its working

1. **Absorption**: Photovoltaic cells absorb photons from sunlight.
2. **Excitation**: Photon energy excites electrons, creating free electrons and holes.
3. **Electric Field**: The p-type and n-type silicon layers create an electric field to direct electron movement.
4. **Current Flow**: Electrons generate direct current (DC) through metallic contacts.
5. **Power Output**: The DC is converted to alternating current (AC) by an inverter for use or grid feeding.

3.2.1.2 Applications: Charging mobile phones, home lighting Other types of low power, science project, solar power water pump, small solar power system etc.

3.2.2 Windmill (Dynamo)

The windmill, equipped with a dynamo, converts kinetic energy from the wind into electrical energy. This energy supplements the power generated by the solar panel, especially during periods of low sunlight. The dynamo produces alternating current (AC), which is then rectified to direct current (DC) for compatibility with other system components. By leveraging wind energy, the system enhances reliability and ensures a consistent power supply in varying environmental conditions. This dual-energy approach strengthens the system’s sustainability and efficiency.

Fig 3.3 Windmill

3.2.2.1 Working

1. Wind Energy Captured by Blades

The wind turbine blades capture wind energy by rotating as wind creates a pressure difference. Energy capture depends on wind speed and blade size.

2. Rotation of the Rotor

The rotating blades spin a rotor shaft, transferring mechanical energy to the wind dynamo. Rotation speed depends on wind speed.

3. Inside the Wind Dynamo

The wind dynamo consists of:

a) **Rotor (Armature)**: A coil of wire wound around a core.
b) **Stator (Magnet)**: Permanent magnets or electromagnets that create a magnetic field around the rotor.
c) **Bearings and Gears**: Gears may be used to increase the rotor's speed to enhance energy production.

4. Electromagnetic Induction

As the rotor spins in the stator's magnetic field, changing flux induces an electric current in the coil. Faster rotation results in a stronger induced current.

5. Alternating Current (AC) Generation

The dynamo generates alternating current (AC) as the magnetic flux changes direction with rotor spin. This AC can be used directly or converted to DC using a rectifier.

6. Power Output and Storage

The electricity produced by the wind dynamo is sent to a load or a charge controller for regulated storage in batteries. The energy can then be used during times of low wind availability.

3.2.3 Rectifier Filter

A rectifier filter is used in power supply circuits to convert alternating current (AC) into stable direct current (DC). It is commonly found in devices powered by AC sources like mains electricity, generators, or renewable energy systems (e.g., wind and solar). The system consists of a rectifier to convert AC to DC and a filter to smooth the output, ensuring a stable DC supply.

Fig 3.4 Rectifier Filter

3.2.3.1 Working

1. Rectification Process

The first stage of the rectifier filter involves **rectification**, which is the process of converting AC voltage into DC voltage. There are two common types of rectifiers used:

a) **Half-Wave Rectifier**: Uses a single diode to allow only one half of the AC waveform to pass through, blocking the other half. This results in a pulsating DC output with high ripple.

b) **Full-Wave Rectifier**: Uses two or more diodes to convert both halves of the AC waveform into DC. This results in a smoother DC output with lower ripple than a half-wave rectifier.

The rectifier allows only the positive part of the AC waveform to pass, converting the AC into a unidirectional flow of current.

2. Filtering the Rectified Signal

After rectification, the output is still a **pulsating DC**, meaning it has ripples or fluctuations. To make the DC output smoother and more constant, a **filter** is used.

The most common types of filters used are:

a) **Capacitor Filter**: A capacitor placed in parallel with the output smooths ripples by charging when the output voltage rises and discharging when it drops, filling gaps and providing a more consistent DC voltage.

b) **Inductor Filter**: An **inductor** can be used to filter high-frequency ripples in the DC output. Inductors resist changes in current, and thus, they help smooth out the pulsating DC by filtering out high-frequency noise.

The final output from the rectifier filter is a **smooth DC voltage** suitable for use by electronic circuits or for charging batteries. This output is typically free from large fluctuations, making it usable in a wide range of electronic devices like power supplies for computers, LED lights, motors, and more.

3.2.4 Battery (12V/7.5Ah)

A **battery** is a device that stores and releases electrical energy through chemical reactions. It serves as a crucial power source for various applications, from everyday devices to large-scale energy storage systems. The working of a battery involves **electrochemical reactions** that allow the conversion of chemical energy into electrical energy. Here's a detailed look at how batteries work, their types, and their diverse applications.

Fig 3.5 Battery

3.2.4.1 Working Principle of a Battery

A battery operates based on **electrochemical reactions**. It typically consists of **two electrodes** (an anode and a cathode), a **electrolyte**, and a **separator** that isolates the electrodes from each other while allowing the flow of ions.

1. **Anode**: The negative terminal where oxidation occurs (loss of electrons).
2. **Cathode**: The positive terminal where reduction takes place (gain of electrons).
3. **Electrolyte**: A substance that allows the flow of ions between the electrodes, completing the circuit.
4. **Separator**: Keeps the anode and cathode from direct contact while allowing ions to flow.

When a battery is connected to a circuit, a chemical reaction occurs at the anode, releasing electrons. These electrons flow through the external circuit to the cathode, generating electrical current. At the same time, ions move through the electrolyte to balance the charge. This flow of electrons and ions creates an electric current that powers devices.

3.2.5 Relay Switch

A relay is an electrically operated switch that allows you to control the flow of electricity in a circuit without directly interacting with it. Relays are widely used in control systems and automation, serving as a crucial component in various electrical and electronic applications. By using a small electrical current to control a larger current, relays enable circuits to be controlled remotely and safely.

Fig 3.6 Relay Switch

3.2.5.1 Working Principle of a Relay Switch

A relay works based on the principle of **electromagnetism**. It consists of several components that help control the flow of electricity in a circuit. The basic components include:

1. **Coil**: A coil of wire, which, when energized by a small current, creates a magnetic field.
2. **Armature**: A metal lever that moves in response to the magnetic field generated by the coil.
3. **Contacts**: These are the conductive parts that either open or close depending on the armature's position. The relay has at least two contacts: Normally Open (NO) and Normally Closed (NC).
4. **Spring**: The spring returns the armature to its original position when the coil is de-energized.

3.2.5.2 Step-by-step Working

1. **Coil Energization**: When a current flows through the coil, it generates a magnetic field.
2. **Magnetic Attraction**: The magnetic field attracts the armature, causing it to move.
3. **Contact Movement**: The movement of the armature causes the contacts to change position. For instance, a normally open (NO) contact will close, while a normally closed (NC) contact will open.
4. **Control of Larger Circuit**: The movement of the contacts can either complete or break a circuit in a larger load system, enabling remote control of high-voltage or high-current circuits.

When the current to the coil is turned off, the magnetic field collapses, and the spring returns the armature to its original position, reversing the state of the contacts.

3.2.6 Charge Controller

A charge controller regulates the charging process in renewable energy systems, such as solar and wind setups, by managing voltage and current flowing into the battery. It prevents overcharging, deep discharging, and damage to the battery, thereby extending its lifespan and ensuring efficient charging.

Fig 3.7 Charge Controller

3.2.6.1 Working of a Charge Controller

The primary function of a charge controller is to regulate the flow of electricity from the energy source (like solar panels or wind turbines) to the batteries. The controller continuously monitors the battery's voltage and adjusts the charging process accordingly.

1. **Charging Stage**: When the battery is undercharged, the controller allows the energy source to charge the battery at a higher rate, typically in stages (Bulk, Absorption, and Float charging modes).

    a) **Bulk Charging**: The controller allows the energy source to charge the battery at its maximum rate until the battery reaches a preset voltage.
    b) **Absorption Charging**: After reaching the preset voltage, the controller reduces the charge rate to maintain the battery's voltage without overcharging it.
    c) **Float Charging**: Once the battery is nearly fully charged, the controller maintains a low current to keep the battery at full charge.

2. **Overcharge Protection**: When the battery reaches full charge, the controller either stops charging completely or shifts to a maintenance mode to prevent overcharging, which could damage the battery or reduce its lifespan.

3. **Undercharge Protection**: When the battery voltage drops below a set threshold, the controller may disconnect the load to prevent deep discharge, which can also harm the battery.

4. **Temperature Compensation**: Some charge controllers feature temperature sensors that adjust the charging parameters based on the ambient temperature, ensuring efficient charging in varying environmental conditions.

3.2.7 AC5712 I & V Sensor

The current and voltage sensor enables real-time monitoring of energy flow, ensuring precise measurement of power consumption and production. It helps optimize performance, reduce waste, and detect inefficiencies early, supporting predictive maintenance. Its real-time data enhances system reliability, reduces maintenance costs, and plays a key role in energy management. Essential in smart grids, renewable energy systems, and industrial applications, the sensor boosts efficiency, reliability, and sustainability in modern energy systems.

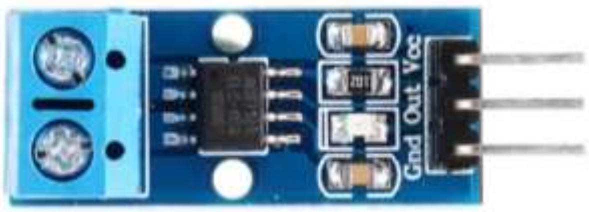

Fig 3.8 AC5712 I & V Sensor

3.2.8 Load

The load represents the devices or systems powered by the hybrid energy setup, such as appliances or lighting. It is the end-user of the energy generated and managed by the system. Proper load management ensures efficient use of energy and prevents system overloading.

Fig 3.9 Loads

3.2.8.1 Types of Loads

Electrical loads are broadly classified into three categories based on their behaviour and how they interact with the power supply:

1. Resistive Load

A **resistive load** is purely resistive and does not involve any inductive or capacitive components. The current and voltage in a resistive load are in phase, meaning they rise and fall simultaneously. Some examples of Resistive loads are

a) **Incandescent light bulbs**: They convert electrical energy into heat and light, with the current and voltage being directly proportional.

b) **Heaters**: Electrical resistance is used to produce heat.

c) **Electric stoves**: The resistive heating element converts electrical energy to heat for cooking.

2. Inductive Load

An **inductive load** contains components like coils, motors, transformers, or solenoids that create a magnetic field when current passes through them. In inductive loads, the current lags behind the voltage because of the energy stored in the magnetic field. Some examples of Inductive loads are

a) **Electric motors**: These are widely used in industrial machinery, pumps, fans, and more.
b) **Transformers**: Used to change voltage levels in AC circuits.
c) **Relays and solenoids**: Used for switching applications in circuits.

3. Capacitive Load

A **capacitive load** involves components like capacitors, which store energy in an electric field when voltage is applied. In capacitive loads, the current leads the voltage, meaning the current peaks before the voltage does. Some examples of Capacitive loads are

a) **Capacitor banks**: Used in power factor correction.
b) **Capacitors in power supplies**: They smooth the voltage in DC circuits.

4. Complex (Non-linear) Load

A **complex load** is a combination of resistive, inductive, and capacitive components. These types of loads exhibit more complicated characteristics and are commonly found in modern electronic devices, which contain both resistive and reactive elements. Some examples of complex loads are

a) **Computers and electronics**: These devices often contain motors, transformers, and sensitive circuitry.
b) **LED lights with drivers**: Often contain both resistive and inductive components.
c) **Switch-mode power supplies**: These are used in many electronic devices and can create non-linear current waveforms.

3.2.8.2 Load in Electrical Circuits

In any electrical system, the **load** determines the current and voltage that need to be supplied by the power source. Here's a basic understanding of how a load functions within an electrical circuit:

1. **Power Consumption**:

   The load draws current from the power source based on its resistance (or impedance, in the case of inductive and capacitive loads). The amount of current is determined by Ohm’s Law for resistive loads ($I = V/R$) or by more complex equations for reactive loads. The electrical energy consumed by the load is converted into other forms of energy (heat, light, mechanical work, etc.).

2. **Load Impedance**:
   For resistive loads, the impedance is purely resistive (R), while for inductive and capacitive loads, impedance is a function of both resistance (R) and reactance (X). The total impedance determines how much current flows through the load for a given applied voltage.
3. **Power Factor**:
   Power factor is a measure of how efficiently the load uses the supplied power. For resistive loads, the power factor is 1, indicating all the power is being used for work. For inductive or capacitive loads, the power factor is typically less than 1, indicating some of the power is reactive and not used for performing work.
4. **Load Variability**:
   Loads can be **constant** or **variable**. Constant loads, like a light bulb, consume the same amount of power consistently. Variable loads, like motors or industrial equipment, may change their power consumption based on factors such as speed, load, or operating conditions.

3.2.9 Arduino UNO R3

The Arduino UNO R3 is an 8-bit microcontroller from Atmel (now Microchip Technology), commonly used in electronics and embedded systems. It features the ATMega328P as the central processing unit, making it suitable for tasks like data processing, control systems, and communication. The R3 version refers to the third revision of the Arduino board.

Fig 3.10 Arduino

3.2.9.1 Key Features of Arduino UNO R3

The Arduino UNO R3 is equipped with several important features that make it highly versatile for various embedded system projects. Key features include

1. **Architecture**:

   8-bit AVR RISC (Reduced Instruction Set Computing) Architecture: It is designed to execute instructions in a single clock cycle, making it efficient in processing tasks.

2. **Memory**:
   a) **32 KB Flash Memory**: Used for storing the program code (with 0.5 KB reserved for the bootloader).
   b) **2 KB SRAM**: Used for storing data during program execution.
   c) **1 KB EEPROM**: Non-volatile memory used for storing data that must persist even when the device is powered off.

3. **Clock Speed**:

   It operates at a clock speed of **16 MHz**, which balances performance and power consumption for most small to medium applications.

4. **I/O Pins**:

   It has **23 general-purpose I/O pins** that can be used for both input and output tasks. Some of these pins have additional functionality like PWM (Pulse Width Modulation) and ADC (Analog to Digital Conversion).

5. **Analog to Digital Converter (ADC)**:

   The ATMega328P includes a **10-bit ADC** with 6 input channels, allowing it to interface with analog sensors or other analog devices for digital processing.

6. **Timers**:

   It has **3 timers** (two 8-bit and one 16-bit) that allow precise control over timing and waveform generation. These are essential for applications like PWM control, generating signals, or measuring time intervals.

7. **Communication Interfaces**:
   a) **USART (Universal Synchronous and Asynchronous Receiver-Transmitter)**: Used for serial communication (RS-232 or USB).
   b) **I2C (Inter-Integrated Circuit)**: For communication with sensors or other microcontrollers.
   c) **SPI (Serial Peripheral Interface)**: Used for high-speed communication with peripherals like memory cards or displays.

8. **Power Supply**:

   It can operate on a voltage range of **1.8V to 5.5V**, but is most commonly powered by a 5V supply. This allows flexibility in power management for different applications.

9. **Low Power Consumption**:

   The ATMega328P features several low-power modes, including sleep modes, which are critical for battery-powered applications, making it ideal for portable devices or IoT projects.

3.2.9.2 Working with Arduino

The **Arduino** is commonly used as a widely popular open-source platform that simplifies microcontroller programming for both beginners and experienced developers. Here's how it works:

1. **Programming**:

   The Arduino is typically programmed using the **Arduino IDE (Integrated Development Environment)**. The Arduino board provides a simplified environment for writing code (sketches) and uploading them to the microcontroller via USB.

2. **Bootloader**:

   The Arduino comes with a pre-installed bootloader, allowing it to be programmed via serial communication, usually through a USB connection. The bootloader allows the user to upload new programs without needing an external programmer.

3. **I/O Operations**:

   You can interface the Arduino with sensors, LEDs, motors, displays, and other peripherals using its I/O pins. For example, you could use an analog input to read sensor data and then output the results to a display or control an actuator.

4. **Debugging**:

   The board provides serial communication, which can be used for debugging and monitoring program status by sending information to a connected computer or terminal.

3.2.10 LCD (2 X 16)

A **2x16 LCD** (Liquid Crystal Display) is a type of alphanumeric display that can show two rows of 16 characters each. It is commonly used in electronic projects to display information such as sensor readings, status messages, and other text data. The "2x16" designation indicates the display has two rows (lines) with 16 characters on each line. It is typically used with microcontrollers such as the **ATMega328P** (Arduino) and other embedded systems. These displays are popular due to their ease of use, low power consumption, and relatively simple integration with microcontroller-based systems.

Fig 3.11 LCD (2 X 16)

3.2.10.1 Key Features of 2x16 LCD

1. **Display Size**:
   The LCD has **2 lines** and **16 columns**, allowing it to display 32 characters at once. Each character is represented by a 5x8 dot matrix, where the character's pattern is formed using a grid of pixels.
2. **Interface**:
   Most 2x16 LCDs use a **16-pin interface** for communication with the microcontroller. However, only **6-8 pins** are used in a typical application, as many of the pins control specific functionalities like data or control signals (RS, RW, EN, and Data lines).
3. **Backlight**:
   Many 2x16 LCDs have a **backlight** feature, which illuminates the display, making it visible in low-light conditions. The backlight is usually powered separately from the data lines.
4. **Low Power Consumption**:
   The 2x16 LCDs are low power devices, making them ideal for battery-powered applications, where efficiency is crucial.

5. **Text-based Output**:

   The display is **monochrome** and is designed to output alphanumeric text, meaning it can display letters, numbers, and some special characters, but not images or graphics.

6. **Control Lines**:
   a) **RS (Register Select)**: Determines whether the data being sent to the display is command or character data.
   b) **RW (Read/Write)**: Specifies the direction of data flow (read or write).
   c) **EN (Enable)**: Used to latch the data into the LCD.

7. **Character Font**:

   The characters displayed on a 2x16 LCD are generated by a **5x8 dot matrix**, which can display standard alphanumeric characters. Some LCDs also allow users to define custom characters.

3.2.10.2 Working of 2x16 LCD

The operation of a 2x16 LCD is driven by a controller, often the **HD44780** or its compatible chips, which manage the data flow to the screen. Here's how the LCD operates:

1. **Initialization**:

   When powered on, the microcontroller sends commands to initialize the LCD. This includes setting the display mode (e.g., 2 lines, 16 characters), enabling the display, and configuring the cursor settings.

2. **Data Communication**:

   Communication between the microcontroller and the LCD is usually done via a parallel interface. The microcontroller sends commands and character data to the LCD through the data and control pins.
   a) **Command Mode**: The microcontroller sends commands for display settings, cursor movements, clearing the display, etc.
   b) **Data Mode**: The microcontroller sends character data, which is displayed on the screen. Each character corresponds to a specific binary value that the LCD interprets and displays as a pattern of dots on the screen.

3. **Displaying Text**:

   The text is displayed in a 16x2 grid, where each position can hold one alphanumeric character or special symbol. The data is written to the display in a left-to-right sequence, filling one line after the other. Once one line is filled, the next line is automatically used.

4. **Control Operations**:
   a) **Clear Display**: To clear the screen, the controller sends a command to clear all characters.
   b) **Cursor Movement**: The cursor can be moved to any position on the screen using control commands. It can be used to create dynamic updates or modify existing text.

3.2.11 Stepdown Transformer

A step-down transformer reduces voltage from a higher value to a lower value while maintaining the same frequency. It works on electromagnetic induction, with the primary coil having more turns than the secondary coil, reducing voltage and increasing current. Step-down transformers are essential in power distribution, making high voltage safer for use in homes, industries, and other low-voltage applications.

Fig 3.12 Stepdown Transformer

3.2.11.1 Principle of Operation

The working of a step-down transformer is based on the principle of **electromagnetic induction**, discovered by Michael Faraday. The basic components of a transformer are:

1. **Primary Coil**: This is the coil connected to the input power supply. It receives the AC voltage and generates a magnetic field.
2. **Secondary Coil**: The coil from which the output voltage is taken. It is linked magnetically to the primary coil.

3. **Core**: The core is usually made of laminated silicon steel, which provides a low-resistance path for the magnetic field and helps to transfer the energy efficiently between the coils.

When an alternating current (AC) flows through the primary coil, it creates a time-varying magnetic flux. This magnetic flux is transferred to the secondary coil, where it induces a voltage (due to Faraday's law of induction). The magnitude of the induced voltage in the secondary coil is determined by the **turns ratio** between the primary and secondary coils.

3.2.11.2 Working Process

1. **AC Current in Primary Coil**: When an AC voltage is applied to the primary coil, it creates an alternating magnetic field around the coil.
2. **Magnetic Induction**: This magnetic field is transferred to the secondary coil, where it induces an alternating voltage due to electromagnetic induction.
3. **Voltage Reduction**: Because the secondary coil has fewer turns than the primary coil, the induced voltage in the secondary coil is lower than the input voltage (step-down operation).
4. **Current Increase**: According to the principle of conservation of energy (assuming negligible losses), the current in the secondary coil increases as the voltage decreases.
5. **Output Voltage and Current**: The step-down transformer provides the desired lower voltage and higher current on the secondary side, suitable for use in appliances, homes, or industrial equipment.

3.2.12 Regulator

A regulator maintains a constant output voltage or current despite variations in input voltage or load conditions. It ensures stable performance of electrical devices, preventing damage from voltage fluctuations. Regulators are used in power supplies, audio equipment, communication systems, and industrial machinery, where stable power is essential.

Regulators can be classified into two main types based on the method they use to regulate the output:

1. **Linear Regulators**: These provide a constant output voltage by dissipating excess energy in the form of heat.
2. **Switching Regulators**: These use a more complex method of switching on and off to convert excess voltage into usable power with higher efficiency.

Fig 3.13 Regulator

3.2.12.1 Working Principle of Voltage Regulators

Voltage regulators control the voltage delivered to a load by monitoring input voltage and adjusting the output to maintain a set value. They sense voltage variations and compensate for fluctuations, ensuring a constant output.

1. **In Linear Regulators**: Voltage regulators drop excess voltage as heat, making them less efficient than switching regulators. However, they offer a clean and stable output with minimal ripple, which is crucial for sensitive electronic devices.
2. **In Switching Regulators**: Switching regulators use high-frequency techniques like Pulse Width Modulation (PWM) to convert excess voltage efficiently, minimizing energy loss by storing and releasing the excess voltage.

3.2.13 LDR'S

An **LDR (Light Dependent Resistor)** is a variable resistor whose resistance changes based on light intensity. It operates on photoconductivity, where the electrical conductivity of the material increases with light exposure. Typically made from semiconductor materials like cadmium sulfide (CdS), the resistance decreases in brighter light, allowing more current to flow. In low light, resistance increases, reducing current flow. LDRs are ideal for light detection and light-sensitive switching applications.

Fig. 3.14 Light dependent resistor

3.2.13.1 Working Principle of LDR

The working of an LDR is based on photoconductivity, where light absorbed by a semiconductor increases the number of charge carriers (electrons and holes), leading to a decrease in the material's resistance.

1. **In the dark**, the LDR has high resistance because there are fewer free charge carriers available for conduction.
2. **When light hits** the LDR, photons excite electrons in the semiconductor material, moving them from the valence band to the conduction band. This generates free charge carriers (electrons and holes), reducing the resistance of the LDR.

As the intensity of the light increases, more charge carriers are generated, and the resistance of the LDR decreases. This change in resistance can be measured and used to control various electronic circuits.

3.2.14 Servo Motor

A servo motor is a motor designed for precise position, velocity, and acceleration control. It moves to a specific position and holds it with high accuracy, unlike ordinary motors. Servo motors operate in closed-loop control systems with feedback mechanisms for precision. They are commonly used in robotics, CNC machinery, conveyor systems, and radar antenna positioning.

Fig. 3.15 Servo motor

3.2.14.1 Components of a Servo Motor

A typical **servo motor** is composed of three main parts:

1. **DC Motor**: A small electric motor inside the servo that provides the rotational force (torque).

2. **Gearbox**: A set of gears that reduce the speed of the motor and increase the torque. This makes the servo motor capable of producing precise movements and holding positions.
3. **Feedback Device (Encoder or Potentiometer)**: A feedback sensor monitors the motor's output shaft position and sends this data to the controller. This allows the system to adjust the motor's operation, ensuring it reaches and maintains the desired position accurately.

3.2.14.2 Working Principle of Servo Motors

The operation of a servo motor is based on the principle of **closed-loop control**, where the motor's position is continually monitored by a feedback device. The typical working mechanism of a servo motor is:

1. **Command Signal**: A PWM signal is sent to the servo motor, determining the desired position based on pulse duration.
2. **Controller**: The controller compares the desired position with the actual position using feedback, calculating the error signal.
3. **Motor Activation**: The controller adjusts the motor's input based on the error signal, driving the motor toward the desired position.
4. **Feedback**: The feedback device (e.g., potentiometer or encoder) confirms the motor's position, allowing the controller to make real-time adjustments.
5. **Torque and Position Holding**: The motor maintains the set position with feedback control, adjusting torque to prevent oscillation or drifting.

3.2.15 Arduino Nano

The Arduino Nano is a small, versatile microcontroller board based on the ATmega328P. It is popular among hobbyists and engineers for its compact size and strong performance, making it ideal for space-constrained projects. While it offers similar functionality to the Arduino Uno, its smaller form factor is more suitable for embedded applications.

Fig. 3.16 Arduino nano

3.2.15.1 Key Features of Arduino Nano

1. **Microcontroller**: ATmega328P (8-bit AVR RISC architecture).
2. **Operating Voltage**: 5V.
3. **Input Voltage (Recommended)**: 7-12V.
4. **Digital I/O Pins**: 14 (of which 6 support PWM output).
5. **Analog Input Pins**: 8.
6. **Flash Memory**: 32 KB (2 KB used by the bootloader).
7. **SRAM**: 2 KB.
8. **EEPROM**: 1 KB.
9. **Clock Speed**: 16 MHz.
10. **USB Connectivity**: Mini-USB for programming and power.
11. **Dimensions**: 18mm x 45mm.

3.2.15.2 Working of Arduino Nano

The Arduino Nano operates as a programmable logic board, allowing users to create and control electronic circuits. Its microcontroller runs user-written code uploaded through the Arduino IDE, which interacts with connected sensors, actuators, and other components. The board supports communication protocols like I2C, SPI, and UART for versatile interfacing with peripherals.

3.2.16 ESP wifi module

The **ESP Wi-Fi module** is a compact and low-cost microcontroller with built-in Wi-Fi capabilities, widely used for IoT and wireless communication projects. Manufactured by Espressif Systems, the most popular version is the **ESP8266** and its successor, the **ESP32**, which offer powerful performance, multiple GPIOs, and support for communication protocols like SPI, I2C, and UART.

Fig. 3.17 ESP wifi module

3.2.16.1 Key Features

1. **Wi-Fi Connectivity**: Supports 802.11 b/g/n standards for connecting to wireless networks.
2. **Processor**: ESP8266 (Tensilica L106) or ESP32 (dual-core Xtensa).
3. **Operating Voltage**: 3.3V.
4. **GPIO Pins**: Supports digital and analog inputs/outputs.
5. **Programming**: Compatible with Arduino IDE, MicroPython, and other development platforms.
6. **Power Efficiency**: Sleep modes for energy conservation.

3.2.17 Arduino I/O Shield

An **Arduino I/O shield** is an extension board designed to simplify connections and expand the functionality of Arduino boards. It provides additional input/output (I/O) interfaces and is often equipped with pre-configured connectors for sensors, actuators, communication modules, and other peripherals.

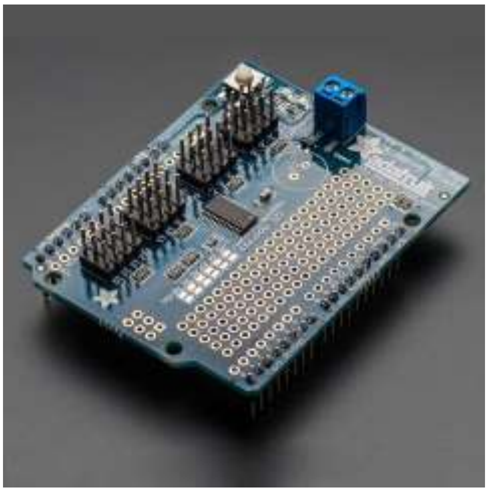

Fig. 3.18 ESP Arduino I/O shield

3.2.17.1 Key Features

- **Expanded I/O**: Breakout pins for easier connection to external devices.
- **Built-in Connectors**: Includes headers for sensors, relays, motors, and more.
- **Compatibility**: Designed to fit seamlessly on Arduino boards like Uno, Mega, and Nano.
- **Additional Features**: Some shields include LEDs, buttons, and debugging tools.

3.3 Circuit diagram

The circuit diagram represents a hybrid renewable energy system integrating solar and wind energy with a tracking mechanism and load management. The **solar panel** and **wind turbine** generate renewable energy, which is regulated and directed through a power supply system. An **Arduino board** acts as the central control unit, processing inputs from components like **LDR sensors** for solar tracking and interfacing with a **servo motor** to optimize solar panel positioning. The system also incorporates a **Wi-Fi module** for remote monitoring, a **2x16 LCD display** for status updates, and an **ACS712 sensor** to measure current flow. Power supply regulation is achieved using a **regulated power supply**, and relay drivers ensure seamless control of connected loads and devices. This integrated setup enables efficient renewable energy generation and usage.

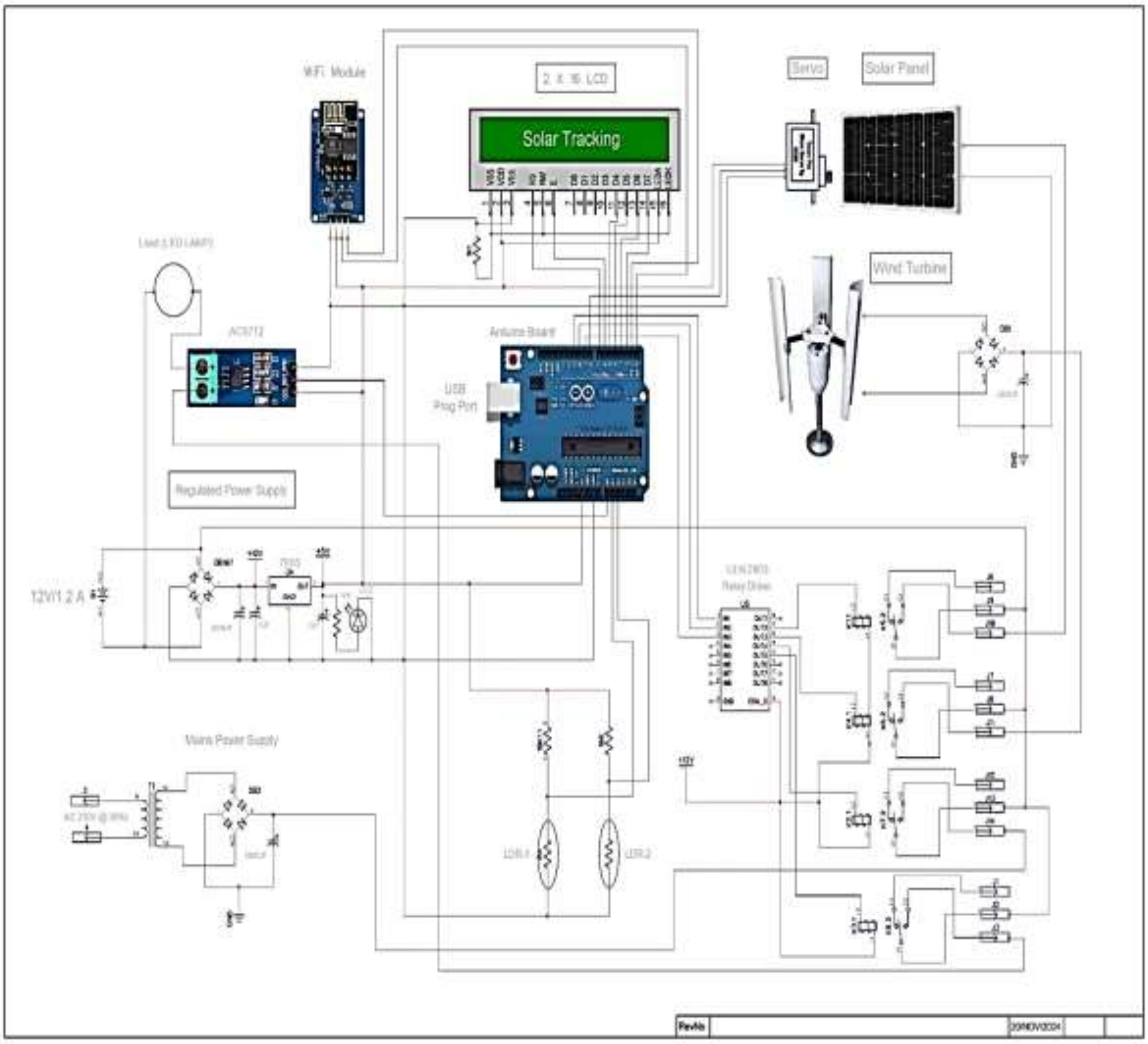

Fig. 3.16 Circuit diagram

CHAPTER 4

IMPLEMENTATION AND DESIGN

4.1 Flow Chart

The flowchart represents the operational sequence of a hybrid renewable energy system that combines solar and wind energy sources. The process begins with energy generation from the **solar panel** and **wind turbine**, which is regulated and directed through a **power management system**. Inputs from **LDR sensors** are processed by the **Arduino board**, which controls a **servo motor** to adjust the solar panel's position for maximum sunlight capture. The system continuously monitors energy flow using an **ACS712 current sensor** and updates the user through a **2x16 LCD display**. Additionally, a **Wi-Fi module** facilitates remote monitoring and control of the system. The energy generated is stored in a battery or supplied to the load as required, ensuring efficient and uninterrupted power delivery.

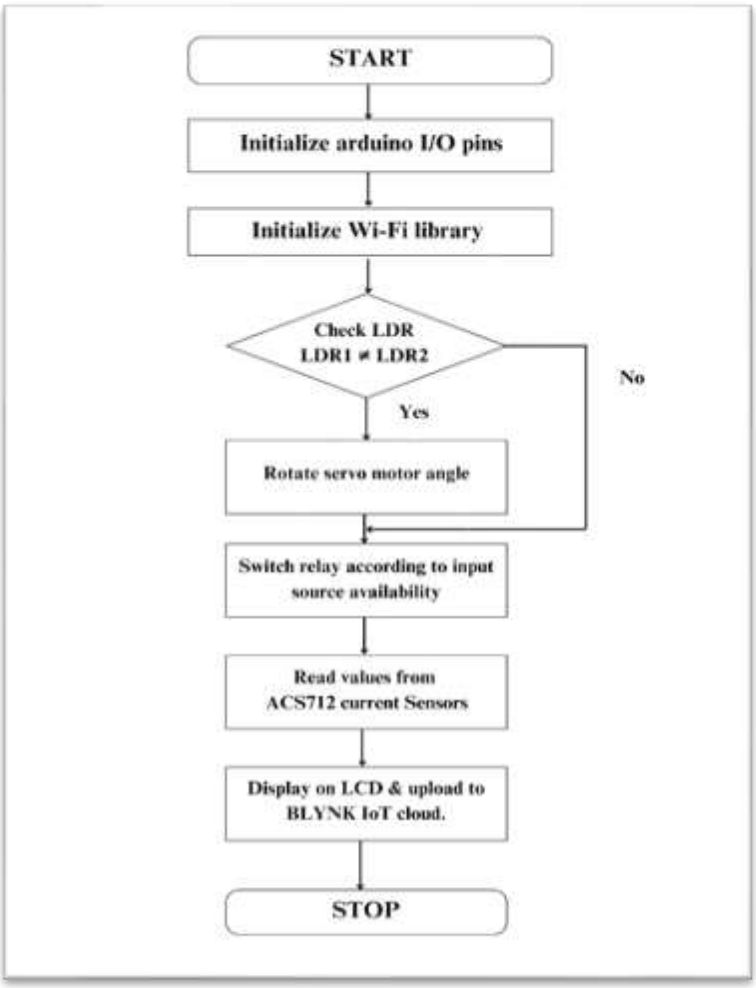

Fig. 4.1 Flow chart

4.2 Program

```
#define BLYNK_PRINT Serial
#define BLYNK_TEMPLATE_ID "TMPL3qnkUNdrM"
#define BLYNK_TEMPLATE_NAME "Hybrid Energy"
#define BLYNK_AUTH_TOKEN "64XeCQ3mI_faAQlAXRS4LGDL5qO8AJOG"

#include <LiquidCrystal.h>     // include the library
LiquidCrystal lcd(7, 6, 5, 4, 3, 2);  // datapin, latchpin, clockpin
#include <ESP8266_Lib.h>
#include <BlynkSimpleShieldEsp8266.h>
BlynkTimer timer;
char auth[] = BLYNK_AUTH_TOKEN;
char ssid[] = "Peterparker";  // type your wifi name
char pass[] = "0987654321";  // type your wifi password

#define EspSerial Serial
#define ESP8266_BAUD 115200
ESP8266 wifi(&EspSerial);
int mvAmp_sol20  = 148;
int offset_sol20 = 1935;

const int I_in = A0;    //  Current
const int v_in = A1;    //  Voltage
const int v_in2 = A2;    //  Voltage
const int v_in3 = A3;    //  Voltage
const int G_rly = 9;
const int W_rly = 8;
const int S_rly = 10;
const int L_rly = 11;

//Measuring DC Voltage Using voltage divider n/w
float Vout = 0.00;
float Vin = 0.00;
float R1 = 32600.00; // resistance of R1 (100K)
float R2 = 6650.00; // resistance of R2 (10K)
int val = 0;

//Measuring DC Voltage Using voltage divider n/w
float Vout2 = 0.00;
float Vin2 = 0.00;
float R11 = 32600.00; // resistance of R1 (100K)
float R22 = 6650.00; // resistance of R2 (10K)
int val2 = 0;
float Power_Value = 0.00;
int RawValue  = 0;
float sen_v = 0;
float Amps = 0;

void setup()
{
  // Debug console
   EspSerial.begin(ESP8266_BAUD);  delay(10);
   lcd.begin(16, 2);  lcd.clear();
   lcd.home ();
   pinMode(G_rly, OUTPUT); digitalWrite(G_rly, HIGH);
   pinMode(W_rly, OUTPUT); digitalWrite(W_rly, HIGH);
   pinMode(S_rly, OUTPUT); digitalWrite(S_rly, HIGH);
   pinMode(L_rly, OUTPUT); digitalWrite(L_rly, HIGH);
```

```
   pinMode(v_in, INPUT); pinMode(v_in2, INPUT); pinMode(v_in3,
  INPUT);
   pinMode(I_in, INPUT);
   lcd.setCursor (0, 0);  lcd.print ("  Smart hybrid  ");
   lcd.setCursor (0, 1);  lcd.print ("renewable energy");
   delay(3000);
   lcd.clear();
   Blynk.begin(auth, wifi, ssid, pass);
   timer.setInterval(500L, send_I);    //send_I();  send_V();
  send_V2();
   timer.setInterval(1000L, send_V);
   timer.setInterval(1500L, send_V2);
   delay(200);
}
/
void loop()
  {
   Blynk.run();  timer.run();
   if(Vin >= 10)
    {
     lcd.setCursor(9, 0);  lcd.print("L-on:So ");
     digitalWrite(G_rly, HIGH);
     digitalWrite(W_rly, HIGH);
     digitalWrite(S_rly, LOW);
    }
   else if(Vin2 >= 3)
     {
      lcd.setCursor(9, 0);  lcd.print("L-on:Wi ");
      digitalWrite(G_rly, HIGH);
      digitalWrite(W_rly, LOW);
      digitalWrite(S_rly, HIGH);
     }
   else
     {
      lcd.setCursor(9, 0);  lcd.print("L-on:Gr ");
      digitalWrite(G_rly, LOW);
      digitalWrite(W_rly, HIGH);
      digitalWrite(S_rly, HIGH);
     }
  }
 void send_I()
  {
    int average = 0;
    for(int i = 0; i < 15; i++)
     {
      average = average + analogRead(I_in);
      delay(20);
     }
    RawValue = average/15;
    sen_v = (RawValue / 1023.0) * 5000;       // Gets you mV
    //Serial.println(sen_v);
    Amps = ((sen_v - offset_sol20) / mvAmp_sol20);
    if(Amps <= 0.06)  { Amps = 0.00; }
    lcd.setCursor(0, 0);
    lcd.print("I:");
    lcd.print(Amps);
    lcd.print("  ");
    Blynk.virtualWrite(V0, Amps);
    delay (50);
  }
void send_V()
  {
```

```
    int average2 = 0;
    for(int i = 0; i < 10; i++)
     {
      average2 = average2 + analogRead(v_in);
      delay(20);
     }                                     //reads the analog input
    val = average2/10;
    Vout = (val * 5.00) / 1023.00;  // formula for calculating
  voltage out i.e. V+, here 5.00
    Vin = Vout / (R2/(R1+R2));      // formula for calculating
  voltage in i.e. GND
    if(Vin < 0.10)  { Vin = 0.00; }
    lcd.setCursor(0, 1);   lcd.print("SV:");
    lcd.print(Vin,1);   lcd.print("  ");
    Blynk.virtualWrite(V1, Vin);
    delay (100);
  }
void send_V2()
  {
    int average3 = 0;
    for(int i = 0; i < 10; i++)
     {
      average3 = average3 + analogRead(v_in2);
      delay(20);
     }                                     //reads the analog input
    val2 = average3/10;
    Vout2 = (val2 * 5.00) / 1023.00;  // formula for calculating
  voltage out i.e. V+, here 5.00
    Vin2 = Vout2 / (R22/(R11+R22));      // formula for calculating
  voltage in i.e. GND
       if(Vin2 < 0.10) { Vin2 = 0.00; }
    lcd.setCursor(9, 1);   lcd.print("WV:");
    lcd.print(Vin2,1);   lcd.print("  ");
    Blynk.virtualWrite(V2, Vin2);
    delay (100);
  }

BLYNK_WRITE(V3)
 {
   int Sw1 = param.asInt();
   if(Sw1 == 1) { digitalWrite(L_rly,LOW); }
   else   { digitalWrite(L_rly,HIGH);  }}
```

4.3 Software Requirement

4.3.1 Arduino IDE

Arduino is an open-source platform that combines hardware and software to help users create microcontroller-based projects. It offers a user-friendly environment for building digital devices and interactive objects that sense and control the physical world. The Arduino IDE, based on the Processing project, supports programming in C, C++, and Java, making it accessible for a wide range of applications.

An Arduino board features a microcontroller (typically an Atmel AVR series, like ATmega8 or ATmega168) and connectors for attaching shields, which expand functionality. These shields can communicate directly with the board or via an I²C serial bus, allowing multiple shields to work in parallel.

Arduino microcontrollers come pre-programmed with a bootloader that simplifies uploading programs from a computer, eliminating the need for an external programmer. This feature makes Arduino easy to use for both beginners and experts. The Arduino UNO, for example, uses the Optiboot bootloader for seamless programming.

Fig. 4.2 Arduino IDE

4.3.2 Blynk App

Fig. 4.3 Blynk software

Blynk was designed for the Internet of Things. It can control hardware remotely, it can display sensor data, it can store data, vizualize it and do many other cool things.

There are three major components in the platform:

1. **Blynk App -** allows to you create amazing interfaces for your projects using various widgets we provide.
2. **Blynk Server** - responsible for all the communications between the smartphone and hardware. You can use our Blynk Cloud or run your private Blynk server locally. It's open-source, could easily handle thousands of devices and can even be launched on a Raspberry Pi.
3. **Blynk Libraries** - for all the popular hardware platforms - enable communication with the server and process all the incoming and outcoming commands.

Now imagine: every time you press a Button in the Blynk app, the message travels to space the Blynk Cloud, where it magically finds its way to your hardware. It works the same in the opposite direction and everything happens in a blynk of an eye.

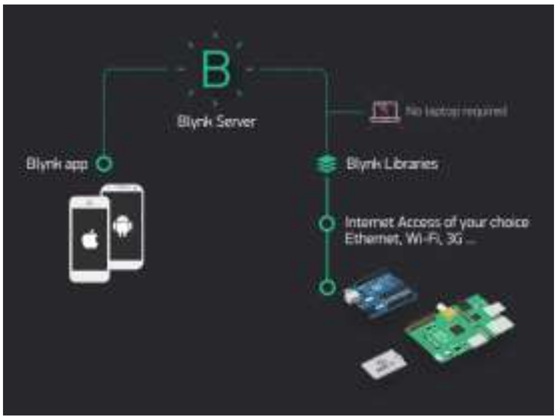

Fig. 4.4 Blynk cloud

4.3.2.1 Features

1. Similar API & UI for all supported hardware & devices
2. Connection to the cloud using:
   a) WiFi
   b) Bluetooth and BLE
   c) Ethernet
   d) USB (Serial)
   e) GSM
3. Set of easy-to-use Widgets
4. Direct pin manipulation with no code writing
5. Easy to integrate and add new functionality using virtual pins
6. History data monitoring via SuperChart widget
7. Device-to-Device communication using Bridge Widget
8. Sending emails, tweets, push notifications, etc.
9. New features are constantly added!

The Blynk app, available for free on Android and iOS, is an easy-to-use platform for creating and controlling IoT projects. It features a drag-and-drop interface for building custom controls for your devices. Upon starting a new project, users select their development board and connection method. The app then sends an authorization token for secure connection over the Blynk server. The app uses "Widgets" to interact with devices, offering buttons, sliders, joysticks, graphs, text displays, and specialized controls for components like LEDs and LCDs. It also includes widgets for posting to Twitter or sending notifications. While free, the app limits widget usage with an "Energy" cost, and users receive an initial balance of 2,000 energy units, with the option to purchase more.

Each widget can be customized with specific settings such as pin selection and value ranges. Blynk also allows for virtual pins to control multiple device actions with a single app button. Users can share projects via QR codes, making it easy for others with the Blynk app to access and interact with the project.

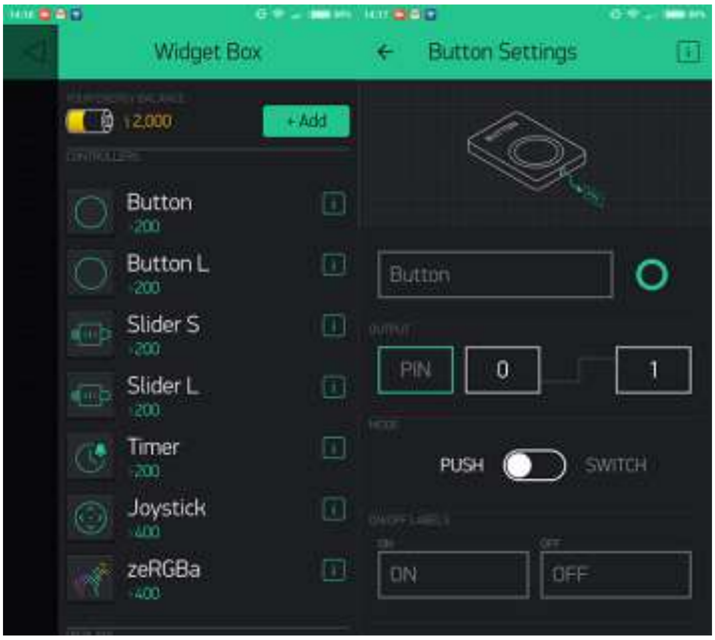

Fig. 4.5 Widget box

4.4 Setting Up Hardware with Software

4.4.1 Installing of Blynk application on smartphone

1. Blynk application is downloaded and installed from the Play Store.
2. Once the application is installed, a new account is created and logged in to it.
3. After logging in, a new project is created. The project is named, hardware is selected as Node MCU and the connection type is selected as Wi-Fi, and created.
4. At this point Blynk will sends an authentication token to email id. This authentication token will be used to identify the hardware in the Blynk server.
5. As the prototype uses 4 channel relay module, 4 buttons are added to the screen from the side bar.
6. All the 4 buttons are then customised by adding a name and selecting the digital pin it will correspond to. This section will actually affect the hardware connection as the relays will be physically connected to the digital pins corresponded here.
7. The setup of Blynk application is now complete.

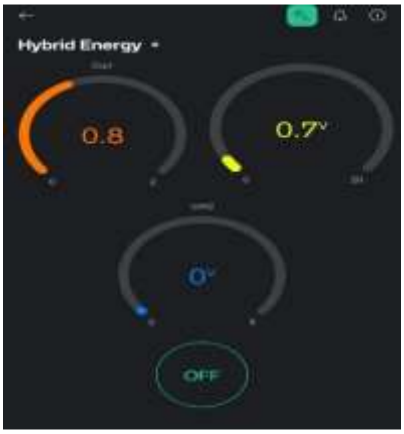

Fig. 4.6 Blynk app interface

4.4.2 Driver Installation for Hardware Interfacing

Most modern devices automatically download and install drivers. However, Windows may not automatically recognize the USB driver for Arduino Uno, making manual installation necessary.

1. **Arduino Uno Overview:**

   The Arduino Uno is a microcontroller board based on the ATmega328P. It features a USB interface for seamless connection to computers or USB host devices, along with a 6-pin ICSP header for programming. The board uses either the CH340 or ATmega16U2 chip as a USB-to-serial converter, enabling communication and programming via the USB-B port.

2. **Driver Installation:**

   To install the necessary USB-to-serial driver, users need to download the appropriate driver for their operating system.

3. **Driver Download and Connection:**

   After downloading and installing the driver, the system will establish a connection with the Arduino Uno.

4. **COM Port Identification:**

   Users need to note the COM port assigned to the newly connected USB device (Arduino Uno) in the system's Device Manager.

4.4.3 Interfacing Arduino Uno with Arduino IDE

1. **Install the Latest Arduino IDE Version:**

   Download and install the latest version of the Arduino IDE from the official Arduino website.

Fig. 4.7 installing Arduino Uno with Arduino IDE

2. **Setup Board Manager:**

   The Arduino Uno is supported natively by the Arduino IDE, so no additional board URLs are required.

Fig. 4.8 Setup Board manager

3. **Install Drivers (If Required):**

   If prompted, install drivers when connecting the Arduino Uno for the first time.

4. **Board Selection:**

   Open the Arduino IDE and select the Arduino Uno from the **Tools** > **Board** menu.

Fig. 4.9 Selecting the Board

5. **Connect Arduino Uno to Computer:**

   Use a USB-B cable to connect the Arduino Uno to the computer. Once connected, the system assigns a unique COM port, visible in the **Tools > Port** menu.

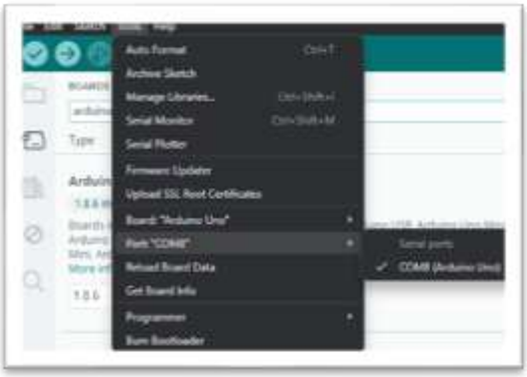

Fig. 4.10 Selecting the port

6. **Set Upload Speed:**

   Select the default upload speed of **115200** under **Tools > Port** if required.

4.4.4 Uploading Code to Arduino Uno

1. **Connect the Arduino Uno:**

   Plug the Arduino Uno into the PC using a USB-B cable.

2. **Configure the Arduino IDE:**

   Open the Arduino IDE, go to **Tools** > **Board**, and select **Arduino Uno**.

3. **Open Example Code:**

   Navigate to **Files** > **Examples** > **Basics** > **Blink**. This opens a new file with prewritten code to blink an LED.

4. **Modify the Code (Optional):**

   Customize the code as needed. For instance, adjust the delay values to change the blinking pattern of the LED.

5. **Upload the Code:**

   Click the **Upload** button in the Arduino IDE. The code is compiled and transferred to the Arduino Uno.

6. **Run the Code:**

   Once the upload is complete, the Arduino Uno automatically executes the code, blinking the onboard LED or performing the desired operation.

CHAPTER 5

RESULTS AND DISCUSSION

5.1 Result

The **result** of the project demonstrates the successful integration of a hybrid renewable energy system that efficiently utilizes both solar and wind power to meet energy demands. By incorporating solar tracking using LDR sensors and servo motors, the system optimizes the solar panel's exposure to sunlight, enhancing the overall energy production. The wind turbine contributes to the generation of additional power, particularly during periods of low sunlight.

The Arduino microcontroller serves as the central control unit, effectively managing inputs from various sensors, such as the LDRs and ACS712 current sensor, while also controlling the servo motor for solar panel adjustment. The system's real-time status is displayed on a 2x16 LCD screen, allowing users to monitor performance. The addition of the Wi-Fi module enables remote monitoring, providing flexibility in controlling and analyzing the system's performance from any location.

The project achieves its goal of creating a reliable, renewable energy solution that efficiently combines solar and wind power, with real-time monitoring and control. The system's ability to track solar movement and optimize energy generation ensures maximum efficiency, making it a viable solution for off-grid or remote area power supply

Fig. 5.1 Prototype

5.2 System Performance

The hybrid renewable energy system, combining solar and wind power, enhances energy generation with automated solar tracking via LDR sensors and a servo motor. The wind turbine supplements solar power during low sunlight, ensuring continuous energy supply and reducing grid reliance. An Arduino microcontroller manages energy distribution, while the ACS712 current sensor monitors real-time energy data. The system's performance is displayed on a 2x16 LCD, and a Wi-Fi module allows remote monitoring and control. This system provides reliable, efficient, off-grid energy for remote areas with optimized generation, storage, and management.

5.3 Performance analysis

The performance analysis of the hybrid renewable energy system, consisting of solar and wind energy generation, has been conducted based on key parameters such as energy output, efficiency, reliability, and system integration.

1. **Energy Generation**: The system harnesses both solar and wind power. Solar tracking with LDR sensors and a servo motor maximizes solar output, while the wind turbine ensures energy supply during cloudy days.
2. **Efficiency**: The integration of solar and wind energy reduces grid dependence and enhances energy independence, with efficient storage in the battery for power availability.
3. **Reliability**: The Arduino microcontroller ensures smooth operation, while the ACS712 sensor monitors energy flow. The Wi-Fi module allows remote monitoring and control.
4. **Load Management**: Energy is efficiently distributed to the load (LED lamp) based on availability, preventing waste.
5. **Remote Monitoring**: The Wi-Fi module provides real-time tracking and cloud-based management, enabling remote troubleshooting and adjustments.

5.4 Challenges and solutions

The system combining solar and wind energy generation with monitoring via the Blynk app offers great potential, but also presents several challenges. These challenges primarily stem from the integration of various components, power management, and connectivity issues. However, with proper design and optimization, these challenges can be mitigated to ensure smooth operation and an efficient energy system. Below are some of the key challenges and their respective solutions:

5.4.1. Solar Tracking System Issues

1. **Challenge:** The solar panel's tracking may experience inaccuracies due to environmental factors like cloud cover or obstructions, affecting sunlight intensity and reducing energy collection.
2. **Solution:** Enhance LDR sensor and servo motor calibration for better tracking accuracy. Implement an algorithm to adjust tracking during cloudy or obstructed conditions to maintain optimal energy collection in varying weather.

5.4.2. Wind Turbine Output Fluctuations

1. **Challenge**: Wind turbine output can fluctuate with changing wind speeds, leading to inconsistent energy generation.

2. **Solution**: Incorporate battery storage to store excess energy during high wind speeds for use during low winds. Use a hybrid controller to balance the energy load between solar and wind sources for consistent power supply

5.4.3. Battery Life and Storage Capacity

1. **Challenge:** The battery may not store enough energy during peak generation, leading to energy loss or overcharging risks.
2. **Solution:** Use smart charge controllers with advanced algorithms to prevent overcharging and extend battery life. Consider increasing battery capacity or using multiple batteries for better energy storage efficiency.

5.4.4. Power Distribution to Load

1. **Challenge:** Efficiently distributing energy from both solar and wind sources to the load can be complex, especially with varying energy availability.
2. **Solution:** Integrate an automatic power switching system with a smart controller that prioritizes energy sources (solar first, then wind, and grid if necessary) for efficient energy management and dynamic allocation from the most available source.

5.4.5. Wi-Fi Connectivity and Remote Monitoring via Blynk App

1. **Challenge:** Ensuring stable Wi-Fi connectivity for remote monitoring via the Blynk app in areas with weak or unstable internet connections.
2. **Solution:** Implement a local server or offline mode to allow operation without constant internet access. Additionally, use long-range Wi-Fi modules or LoRa-based communication to improve connectivity in weak signal areas.

5.4.6. App Interface and User Experience

1. **Challenge:** The Blynk app interface may be too complex or unintuitive, especially for users unfamiliar with renewable energy systems.
2. **Solution:** Develop a more user-friendly interface with clear labels and intuitive buttons. Include real-time notifications and simple graphical data representations (e.g., solar output, battery charge level) for better user understanding. A help section or manual within the app can also assist users with troubleshooting common issues

5.4.7. Power Consumption by the System

1. **Challenge:** Components like sensors, Wi-Fi modules, and the Arduino board consume power, which could reduce the system's overall efficiency if not properly managed.
2. **Solution:** Use low-power components, such as the ESP32 for Wi-Fi connectivity and power-efficient sensors. Additionally, implement a sleep mode for the system during inactive periods to minimize power consumption.

By addressing these challenges with the proposed solutions, the system's performance and user experience can be greatly enhanced, ensuring reliable and efficient operation in both solar and wind-powered renewable energy systems while providing seamless remote control through the Blynk app.

CHAPTER 6

CONCLUSION AND FUTURE SCOPE

6.1 Conclusion

The Smart Hybrid Renewable Energy (SHRE) system successfully achieves its objective of providing a sustainable, reliable, and cost-effective energy solution tailored for remote villages. By integrating solar panels, wind turbines, and battery storage, the system ensures uninterrupted power supply, even in off-grid locations or areas with limited access to conventional electricity. The dual energy generation approach minimizes reliance on any single renewable source, enhancing system reliability and efficiency.

The inclusion of the Blynk app for real-time monitoring and remote control adds a significant layer of functionality, enabling users to track energy generation, monitor battery levels, and manage system performance from anywhere. This feature not only empowers users with better control and oversight but also reduces the need for on-site maintenance and troubleshooting, which is particularly valuable in remote and inaccessible areas. The integration of advanced components such as the Arduino UNO R3 microcontroller and sensors like LDRs and ACS712 current sensors for energy and environmental data collection further enhances the system's adaptability and optimization. By enabling real-time data analysis and dynamic adjustments, the SHRE system ensures efficient energy generation, storage, and consumption, even under fluctuating environmental conditions.

In addition to meeting energy demands, the SHRE system contributes to environmental sustainability by reducing dependence on non-renewable energy sources. Its innovative design not only promotes clean energy utilization but also encourages local communities to adopt greener energy practices, thus fostering a culture of environmental awareness and conservation. It offers a scalable and adaptable model for rural electrification, addressing the pressing energy needs of underserved communities while promoting energy independence and environmental conservation. With further refinements and broader implementation, the SHRE system has the potential to transform energy accessibility for remote and off-grid regions, fostering sustainable development and improving quality of life.

6.2 Future scope

Hybrid energy systems have a very promising future scope, expected to play a key role in the transition towards a sustainable energy grid by combining multiple renewable energy sources like solar and wind with energy storage technologies, offering increased reliability, efficiency, and grid stability compared to standalone renewable sources, making them a critical component in achieving a decarbonized future.

6.2.1 Key points about the future of hybrid energy systems

1. **Increased Adoption**

With growing environmental concerns and government policies promoting renewable energy, demand for hybrid systems is likely to rise significantly, especially in regions with fluctuating renewable energy availability.

2. **Technological Advancements**

Ongoing research and development will further improve the efficiency and cost-effectiveness of hybrid systems, including advancements in energy storage technologies like batteries and smart grid integration.

3. **Microgrid Applications**

Hybrid systems are well-suited for microgrids, providing localized power generation and resilience in remote areas or during grid disruptions.

4. **Optimized Energy Management**

Sophisticated control systems will enable better optimization of energy production from different renewable sources, maximizing their utilization and minimizing reliance on fossil fuels.

5. **Cost Competitiveness**

As technology matures, the cost of hybrid systems is expected to decrease, making them more accessible to a wider range of consumers.

6.2.2 Potential applications of hybrid energy systems

1. **Residential and Commercial Buildings**

Integrating solar panels, wind turbines, and battery storage for improved energy self-sufficiency.

2. **Industrial Facilities**

Utilizing hybrid systems to power large energy-consuming industries while reducing carbon emissions.

3. **Remote Communities**

Providing reliable electricity access in areas with limited grid infrastructure through hybrid systems combining solar, wind, and diesel generators.

6.2.3 Key challenges to address

1. **Grid Integration**

Ensuring seamless integration of hybrid systems with existing power grids to manage fluctuations in energy production.

2. **Cost Optimization**

Further reducing the upfront cost of hybrid systems to make them more widely adopted.

3. **Policy Frameworks**

Developing supportive regulatory frameworks to incentivize the deployment of hybrid energy systems.

Overall, hybrid energy systems are poised to play a vital role in the future of sustainable energy generation by providing a reliable, efficient, and flexible solution for meeting diverse energy needs while minimizing environmental impact.

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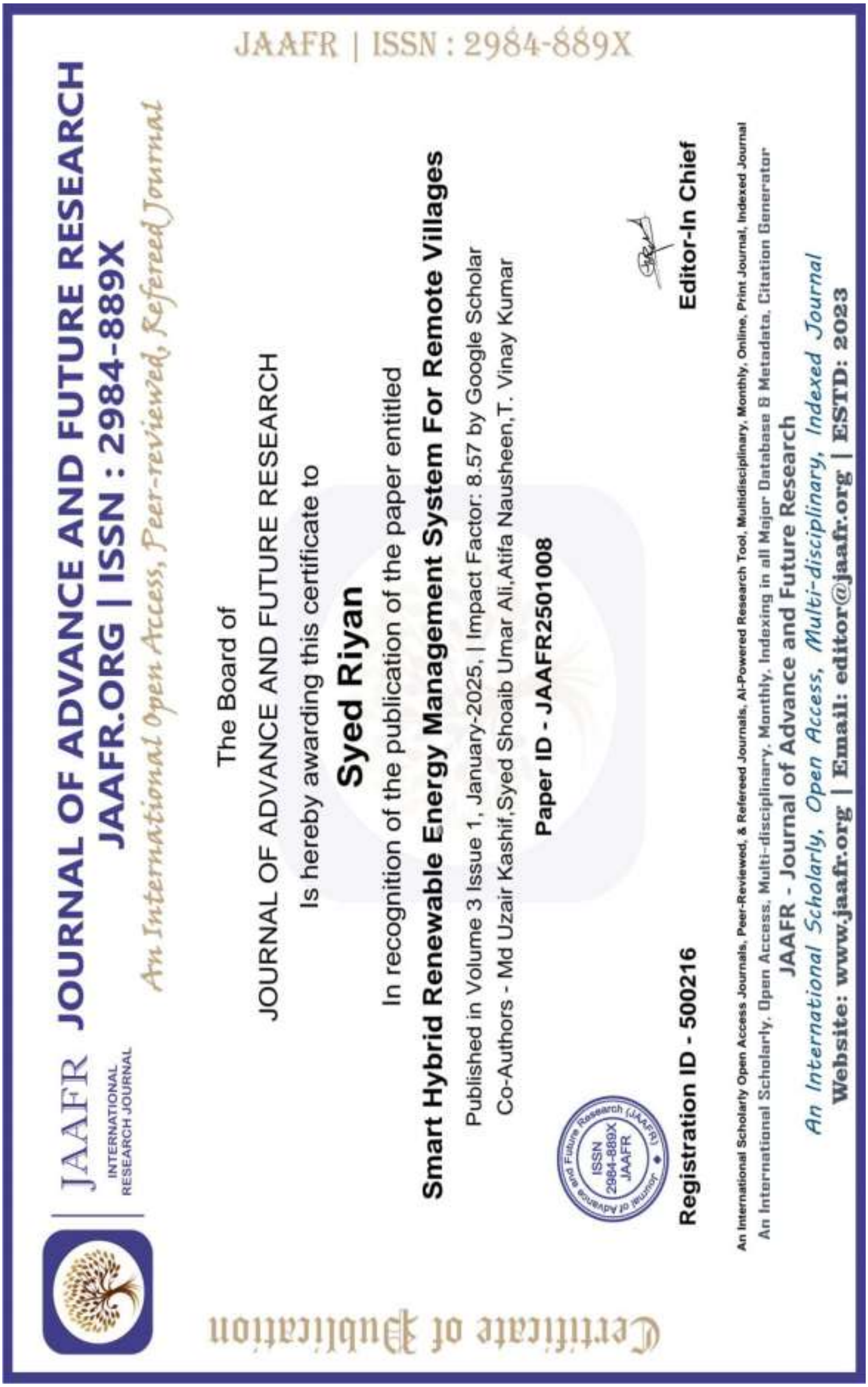
PHOTO GALLERY



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SMART HYBRID RENEWABLE ENERGY MANAGEMENT SYSTEM FOR REMOTE VILLAGES

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Abstract : A Smart Hybrid Renewable Energy Management System (SHRE) for remote villages integrates photovoltaic (PV) solar panels, wind turbines, battery storage, and grid connectivity to provide reliable electricity in rural and remote areas. The system leverages locally available solar and wind resources, storing excess energy in batteries to ensure uninterrupted power during low production periods, such as nighttime or windless days. Grid power acts as a backup to meet energy demands, enhancing system reliability and reducing energy costs. Smart monitoring and control optimize energy usage, minimizing wastage while contributing to sustainability by reducing fossil fuel dependence and greenhouse gas emissions. Scalable and adaptable, SHRE offers an efficient, cost-effective solution for rural electrification and energy sustainability.

IndexTerms - *Renewable Energy, Photovoltaic Panels, Wind Turbines, Battery Storage, Grid Backup, Energy Management***.**

INTRODUCTION

Access to reliable electricity remains a significant challenge in rural and remote areas, where grid power is often unavailable or unreliable. The Smart Hybrid Renewable Energy (SHRE) management system for remote villages, integrating multiple renewable sources such as photovoltaic (PV) solar panels, wind turbines, battery storage, and grid connectivity, offers a sustainable and effective solution to this challenge. These systems harness solar energy during the day and wind energy under favorable conditions, creating a complementary power generation profile to ensure continuous energy supply. Excess energy generated during peak production periods is stored in batteries and utilized during low production times, such as nighttime or windless days.

The inclusion of grid power as a backup further enhances reliability, ensuring that energy demands are consistently met. The smart energy management aspect, supported by IoT-based monitoring and control, optimizes power generation, storage, and consumption, reducing energy costs and minimizing wastage. By decreasing reliance on fossil fuels, these systems contribute to sustainability goals and greenhouse gas emission reductions while promoting renewable energy adoption. Scalable and adaptable, the SHRE management system for remote villages provides an efficient and forward-thinking solution for rural electrification and energy independence .

LITERATURE REVIEW

Recent studies have explored various aspects of SHRE management systems for remote villages

A. Literature Survey

1. ***IoT Based Smart Power Grid Monitoring and Control Using Arduino Ch. Uday Sankar et al. - 2022***
   This Paper focuses on real-time monitoring and control of smart power grids. The system uses Arduino, sensors, and IoT technologies to track parameters such as voltage, current, and power usage. The paper highlights IoT's role in improving grid reliability, reducing losses, and enabling remote control for enhanced performance.

2. ***Review on Advancement in Solar Photovoltaic Monitoring Systems Fahad Saleh M. Abdallah et al. - 2021***
   This Paper provides a comprehensive review of recent developments in solar PV monitoring systems. The authors analyze sensor technologies, IoT platforms, and data processing techniques to improve the efficiency of solar energy systems. Key advancements include remote monitoring, fault detection, and performance optimization .

3. ***Solar Photovoltaic Remote Monitoring System Using IoT Kekre & Gawre - 2017***
   This Paper discuss about Solar Photovoltaic Remote Monitoring System Using IoT discusses an IoT-based monitoring

system for solar PV power plants. The paper highlights the use of real-time sensors and cloud platforms to collect and analyze solar power data. The system enhances energy management, enabling better decision-making and resource allocation.

4. ***Enhancement of Hybrid Power Systems Using IoT by Kalaiarasi et al. - 2016***
   This paper Proposes an IoT-based solution to optimize hybrid power systems that combine renewable sources like solar and wind. The system improves power efficiency through real-time monitoring, automated control, and data-driven performance analysis, ensuring continuous energy supply in hybrid setups.

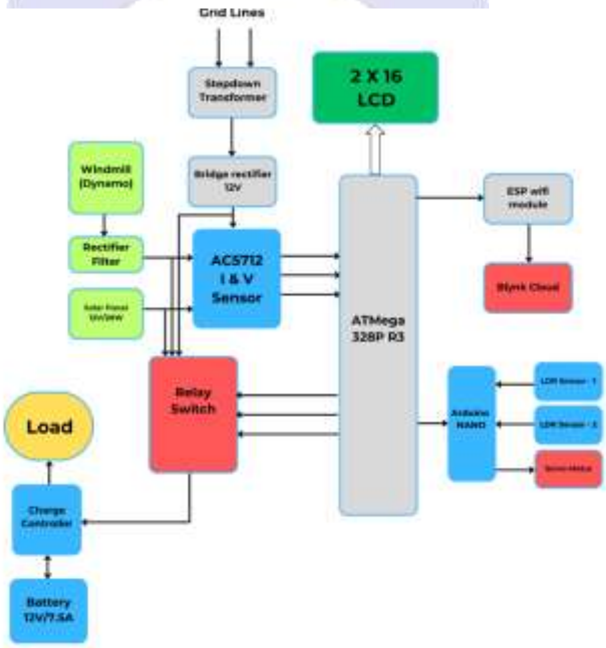
B. Proposed System

The Smart Hybrid Renewable Energy (SHRE) Management System for Remote Villages integrates solar panels, wind turbines, battery storage, and grid connectivity to provide a reliable and sustainable electricity supply in rural areas. The system generates power using solar and wind resources, stores excess energy in batteries, and uses grid power as a backup during low renewable generation periods. The charge controller ensures optimal battery charging, while a relay switch automatically selects the active energy source based on availability. IoT-based monitoring enables real-time tracking of system performance, optimizing energy usage, reducing dependence on fossil fuels, and ensuring uninterrupted power supply for economic and social development.

METHODOLOGY

A. Block Diagram

The block diagram illustrates a hybrid energy system that integrates renewable energy sources and grid power for efficient energy management. It features a stepdown transformer and regulator to covert grid voltage to 12V and 5V for system use.Renewable energy is harnessed through a solar panel and a windmill dynamo, with the generated AC power converted to DC by a rectifier filter. A relay switch manages the selection between power sources, while a charge controller regulates the charging of a 12V battery. The system is controlled by an ATMega328P R3 microcontroller, which coordinates operations, interfaces with sensors, a servo motor, and cloud connectivity for real-time monitoring. The load represents the devices powered by the system, ensuring uninterrupted operation and optimized use of renewable energy.



B. Working of Proposed System

The **SHRE management system for remote villages** combines renewable energy sources (solar and wind), battery storage, and grid power for reliable electricity supply. The block diagram consists of:

1. **Energy Generation**: Solar panels and wind turbines generate DC and AC power, respectively. The AC from the windmill is converted to DC via a rectifier.
2. **Power Regulation**: A **charge controller** manages energy flow to the battery, ensuring optimal charging.
3. **Storage**: A 12V battery stores excess energy for later use.
4. **Source Switching**: A **relay switch** prioritizes renewable energy and switches to grid backup during insufficient generation.
5. **Monitoring and Control**: The **microcontroller** processes data from sensors and controls energy flow.
6. **IoT Integration**: Real-time monitoring is enabled via an IoT module, transmitting system parameters to a cloud platform for remote access.
7. **Load Management**: The energy stored or directly generated is supplied to the load efficiently.

C. Components Description

1. Solar Panel (12V/20W):

Converts sunlight into DC electricity for immediate use or battery storage.

Fig. 2. Solar Panel

2. Windmill with Dynamo:

Captures wind energy, generating AC power that is rectified into DC for the system.

Fig. 3. Windmill with dynamo

3. Battery (12V/7.5Ah):

Stores excess energy from renewable sources to ensure continuous power supply during low generation periods.

Fig. 4. Battery

4. Charge Controller:

Prevents overcharging and deep discharging of the battery, ensuring safe energy regulation.

Fig. 5. Charge Controller

5. Relay Switch:

Automatically switches between solar, wind, and grid power based on availability, prioritizing renewable sources.

Fig. 6. Relay Switch

6. Microcontroller (ATMega328P R3):

Acts as the central controller, processing sensor data, managing power flow, and enabling IoT integration.

Fig. 7. Arduino

7. Current & Voltage Sensor (AC5712):

Monitors system voltage and current, providing data for energy management and analysis.

Fig. 8. V & I sensor

8. Wi-fi Module:

Enables real-time monitoring and control via cloud-based platforms or mobile applications.

Fig. 9. Wi-fi Module

9. LCD Display (2x16):

Displays system parameters such as power source status, battery level, and energy metrics.

Fig. 10. LCD display

10. Arduino Nano:

The **Arduino Nano** is a compact microcontroller board based on the **ATmega328P**, featuring 32KB Flash memory, 14 digital I/O pins (6 PWM), 8 analog inputs, and communication support for UART, SPI, and I2C. Operating at 5V with an input range of 7–12V, it is ideal for space-constrained applications such as IoT systems, robotics, energy management, and sensor-based automation projects.

Fig. 11. Arduino nano

C. Circuit Diagram

The circuit diagram represents a hybrid renewable energy system integrating solar and wind energy with a tracking mechanism and load management. The **solar panel** and **wind turbine** generate renewable energy, which is regulated and directed through a power supply system. An **Arduino board** acts as the central control unit, processing inputs from components like **LDR sensors** for solar tracking and interfacing with a **servo motor** to optimize solar panel positioning. The system also incorporates a **Wi-Fi module** for remote monitoring, a **2x16 LCD display** for status updates, and an **ACS712 sensor** to measure current flow. Power supply regulation is achieved using a **regulated power supply**, and relay drivers ensure seamless control of connected loads and devices. This integrated setup enables efficient renewable energy generation and usage. drivers ensure seamless control of connected loads and devices. This integrated setup enables efficient renewable energy generation and usage.

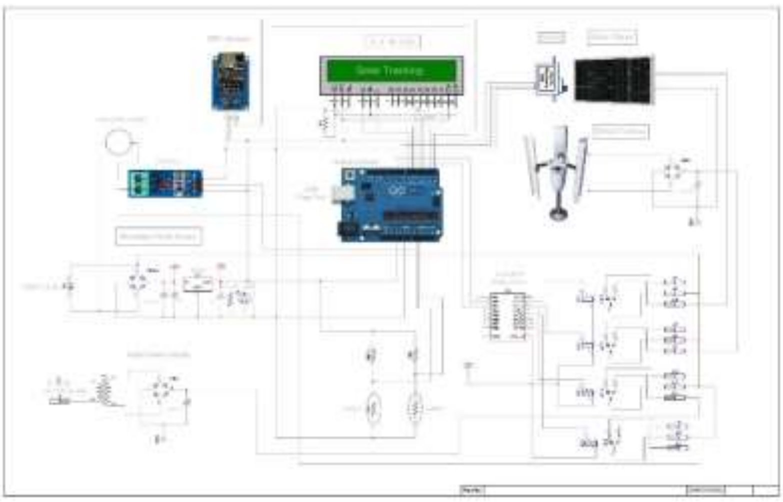


Fig. 12. Circuit diagram

IMPLEMENTATION AND DESIGN

A. Flow Chart

The flowchart represents the operational sequence of a hybrid renewable energy system that combines solar and wind energy sources. The process begins with energy generation from the **solar panel** and **wind turbine**, which is regulated and directed through a **power management system**. Inputs from **LDR sensors** are processed by the **Arduino board**, which controls a **servo motor** to adjust the solar panel's position for maximum sunlight capture. The system continuously monitors energy flow using an **ACS712 current sensor** and updates the user through a **2x16 LCD display**. Additionally, a **Wi-Fi module** facilitates remote monitoring and control of the system. The energy generated is stored in a battery or supplied to the load as required, ensuring efficient and uninterrupted power delivery.

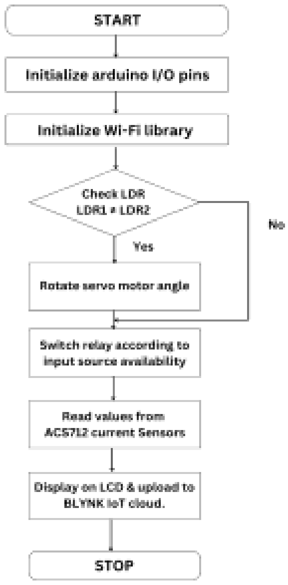


Fig. 13. Flow Chart

B. Setting Up the Arduino

1. **Arduino IDE**
   The **Arduino Integrated Development Environment (IDE)** is an open-source platform used to write, compile, and upload code to microcontroller-based boards like **Arduino Nano**. It supports programming languages such as **C** and **C++** and simplifies programming using built-in libraries and tools. The IDE allows direct interfacing with Arduino boards via **USB communication** and features an easy-to-use interface for development and debugging [1].
2. **Blynk Platform**
   Blynk is an IoT platform designed to monitor and control hardware remotely. It provides real-time visualization, data storage, and communication between hardware and mobile applications via **Blynk Cloud**.

RESULT AND ANALYSIS

A. Results

The project successfully integrates a **hybrid renewable energy system** combining solar and wind power. **Solar tracking** using LDR sensors and servo motors optimizes solar panel orientation, improving energy generation. The wind turbine supplements power during low sunlight conditions. The **Arduino Nano** serves as the central control unit, managing sensors and energy flow, while real-time system data is displayed on a **2x16 LCD** and monitored remotely via the **Wi-Fi module** and **Blynk app**. This setup ensures reliable, optimized energy production for off-grid applications.

Fig. 14. Prototype

B. System Performance

The system's performance was evaluated in terms of **energy generation**, **efficiency**, and **reliability**:

1. **Solar Tracking**: LDR sensors and servo motors enhanced solar panel output by maintaining optimal sunlight exposure.
2. **Wind Contribution**: The wind turbine provided supplementary power during low-light conditions.
3. **Energy Distribution**: The Arduino microcontroller ensured smooth operation, managing energy from solar, wind, and battery sources.
4. **Remote Monitoring**: Real-time data tracking and remote control through the **Blynk app** optimized energy management and system performance. The system demonstrated high efficiency and reliability in energy generation, storage, and load management, making it suitable for remote areas.

C. Performance Analysis

1. **Energy Generation**: Solar tracking significantly improved energy output, while wind turbines ensured continuous supply during variable conditions.
2. **Efficiency**: The hybrid system reduced grid reliance, with efficient energy storage and load balancing.
3. **Reliability**: Real-time monitoring via sensors (LDR, ACS712) and the Arduino ensured reliable operation with minimal downtime.
4. **Load Management**: Automatic power switching prioritized renewable sources, preventing energy wastage.
5. **Remote Monitoring**: The Blynk app provided real-time data visualization and system control for off-grid applications.

D. Challenges and Solutions

1. **Solar Tracking Issues**:
   a) *Challenge*: Environmental factors affect panel orientation.
   b) *Solution*: Improved LDR calibration and tracking algorithms.
2. **Wind Turbine Fluctuations**:
   a) *Challenge*: Inconsistent energy generation.
   b) *Solution*: Store excess energy in batteries during peak wind conditions.
3. **Battery Storage Limitations**:
   a) *Challenge*: Overcharging and limited capacity.
   b) *Solution*: Use smart charge controllers and expand battery capacity.
4. **Power Distribution**:
   a) *Challenge*: Managing energy flow from multiple sources.
   b) *Solution*: Integrate a smart relay-based power switching system.
5. **Wi-Fi Connectivity**:
   a) *Challenge*: Weak connectivity in remote areas.
   b) *Solution*: Use long-range Wi-Fi modules or LoRa communication.
6. **Blynk App Interface**:
   a) *Challenge*: Complex user interface.
   b) *Solution*: Simplify UI with intuitive controls and visual data representation.
7. **Power Consumption**:
   a) *Challenge*: High consumption by system components.
   b) *Solution*: Use low-power components and enable sleep mode.
8. **Data Accuracy**:
   a) *Challenge*: Real-time reporting inconsistencies.
   b) *Solution*: Calibrate sensors periodically and buffer data for smoother reporting.

By addressing these challenges, the system achieves **optimal performance**, providing an efficient, reliable, and remotely controlled renewable energy solution for off-grid applications.

CONCLUSION AND FUTURE SCOPE

A. Conclusion

The **Smart Hybrid Renewable Energy (SHRE) Management System for Remote Villages** successfully integrates solar and wind power to provide a sustainable and reliable energy solution for remote and off-grid areas. The system combines solar panels, wind turbines, and battery storage to ensure continuous power supply while minimizing dependency on external grid power. The use of the **ATMega328P microcontroller**, **LDR sensors**, and **ACS712 current sensors** enables real-time monitoring, solar tracking, and optimized energy management, enhancing the system's efficiency and reliability. Additionally, the integration of the **Blynk app** provides remote monitoring and control, allowing users to analyze energy performance and make adjustments conveniently. The project achieves its objective of delivering a cost-effective, scalable, and environmentally sustainable energy solution, offering a viable model for rural electrification and energy independence, particularly in areas with unreliable grid access.

B. Future scope

The future of hybrid energy systems lies in their ability to combine renewable energy sources like solar and wind with advanced energy storage technologies to create reliable, efficient, and sustainable power solutions. Increasing adoption of hybrid systems will be driven by growing environmental concerns, government incentives, and the need for energy reliability in regions with fluctuating renewable energy availability. Technological advancements, including improved energy storage, smart grid integration, and optimized energy management systems, will enhance efficiency and cost-effectiveness. Hybrid systems are particularly suited for **microgrid applications**, enabling localized power generation and resilience in remote areas or during grid disruptions. Potential applications include residential and commercial buildings for energy self-sufficiency, industrial facilities for reducing carbon emissions, and remote communities for providing reliable electricity access. Key challenges include seamless **grid integration** to manage energy fluctuations, reducing upfront system costs, and establishing supportive regulatory frameworks to promote hybrid system deployment. With ongoing advancements, hybrid energy systems are set to play a critical role in sustainable energy generation, addressing environmental challenges while improving energy accessibility and independence.

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