Published by :
https://www.ijert.org/
An International Peer-Reviewed Journal

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 04 , April - 2026

IoT Based Multi Source Renewable Power Generation with Inverter Control

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ABSTRACT: - A virtual power plant (VPP) is a cloud based distributed power plant that aggregates the capacities of diverse distributed energy resources (DERs) for the purpose of enhancing power generation as well as trading or selling power on the electricity market. The main issue faced while working on VPPs is energy management. Smart energy management of a VPP is a complex problem due to the coordinated operation of diverse energy resources and their associated uncertainties. This research paper proposes a real time (RT) smart energy management model for a VPP using a multiobjective, multi-level optimization based approach. The VPP consists of a solar, wind and thermal power unit, along with an energy storage. The phrase "multi-level" describes three distinct energy levels represented as three houses with varying loads. A VPP's bidirectional communication infrastructure is used to enable RT operation. Three different methods are used to perform multi-objective RT smart energy management on a community-based dwelling system: advanced multi-objective grey wolf optimization (AMO-GWO), hybrid optimal stopping rule (H-OSR), and hybrid particle swarm optimization (H-PSO). The suggested method focuses on accomplishing the goals of real-time pricing, efficient energy use, pollution reduction, cost minimization, appropriate load scheduling, and overall customer comfort. The three methods are compared with one another through a comparative examination of the computed real-time pricing. On average, H-PSO outperforms H-OSR by 7.86%, whereas AMO-GWO outperforms both H-OSR and H-P-SO by 10.49% and 5.7%, respectively. This study finds that the fastest, most cost-effective, and most efficient optimization algorithm for RT smart energy management of a VPP is AMO- GWO.

INTRODUCTION:

Sustainable energy and economic growth are essential for the industry's survival due to the world's rising energy demands. However, a significant energy crisis has been brought on in many nations by ineffective government policies, a sharp rise in demand, and a lack of electricity. The situation has gotten worse due to emissions from traditional sources, transmission losses, and power theft. Virtual power plants (VPPs) have been brought to the sector to enhance the current situation. To improve power generation and trade or sell power on the electrical market, a VPP is a cloud-based distributed power plant that combines the capacities of several distributed energy resources (DERs) [1]. It is a network of interconnected storage systems, flexible power consumers, and decentralized and medium- sized power generating units that are distributed via a central control centre [2]. They continue to operate and own themselves independently, nevertheless. By intelligently allocating the power produced by individual units, a VPP seeks to reduce grid load during peak hours. As shown in Figure 1, every member of a VPP is linked to the central control system through a remote-control unit. This makes it possible for the hub to effectively oversee, manage, and oversee every asset. [3] Create a model for assessing a VPP's physical attributes. A VPP designs its framework and coordination mode using wavelet packet decomposition and particle swarm optimization (PSO) techniques.

[4]. It uses electric vehicle (EV) integration to balance the production of wind power. To maximize benefits for a VPP, a two-level market gaming system [5] uses Monte Carlo simulations to schedule an energy storage system (ESS), demand response (DR), and DERs. Probability distribution, interval, and possibilistic description models [6] thoroughly examine three key factors of uncertainty: renewable power, market price, and load demand. Delay in communication, random the goal of the stochastic programming model, stochastic robust model, and robust model is to use bidirectional communication infrastructure to enable RT operation of a VPP.[7] investigate how power system transients are affected by coordinated and uncoordinated frequency regulation of VPPs. Photovoltaic (PV) power output and demand are treated as unknown parameters in a two-stage robust optimization model.
[8] that examines a VPP's bidding strategy and applies it on a test system. The best economic dispatch strategies are fully examined in the earlier literature. To function effectively in the event of a cyberattack, it suggests a reliable distributed economic dispatch method [9]. The IEEE 14-bus test system is used using a novel binary backtracking-search method [10], and the optimization

procedure is finished in 100 iterations. Strong duality theory, Karush-Kuhn-Tucker optimality requirements, and Mixed Integer Linear Programming (MILP) are used in this bi-level optimization framework.[11] to combine the DR potential of commercial buildings and other DERs in a technical VPP; [12] to create a service-oriented approach, Demand Side Management (DSM) of smart consumers applies MILP. It seeks to restrict single distribution network users to the supervised physical domain. A risk-averse stochastic framework technique is employed.

[13] to reduce risk. It considers the possibility of activating EVs and smart buildings in DR programs, with the goal of short-term scheduling of VPPs in a competitive context. For a multi-operator plant, the default penalty mechanism [14] suggests a bidding-based bi-level multi-time scale scheduling technique to address issues with interest distribution among operators.[15] is developed to simulate the profit maximization, operation, market clearing, and price formation of virtual storage plants (VSPs). By classifying customers based on their distinct attitudes, a data-mining-driven incentive-based DR method [16] simulates the exchange of electricity between a VPP and its members. A new VPP based on power to gas (P2G).

[17] The market's perspective in the context of VPP is the focus of a significant amount of study. The multi-stage stochastic programming approach[18]makes use of Mark decision procedure ,out-of-sample comparison, and the stochastic dual dynamic programming technique. It enhances a VPP's bidding strategy in the Spanish spot market. Profit maximization and day-ahead (DA) self-scheduling of a VPP under uncertainty are the focus of stochastic adaptive robust optimization [19]. It makes use of intervals, confidence boundaries, and scenarios. The goal of the two-stage robust optimization approach [20] is to develop effective bidding strategies in the face of uncertainty. It verifies the ensuing pricing systems based on real-time (RT) and DA marketplaces during an actual case study. As shown as figure(1) schematic diagram of elements of VPP.

1. Power is produced by a thermal unit and fed straight into the electrical grid.
2. Renewable energy produced by solar panels and wind turbines is delivered to the Central Control (which has a computer and monitor)for processing
3. The Electricity Market is supplied by the Electricity Grid, which is controlled by the Central control.

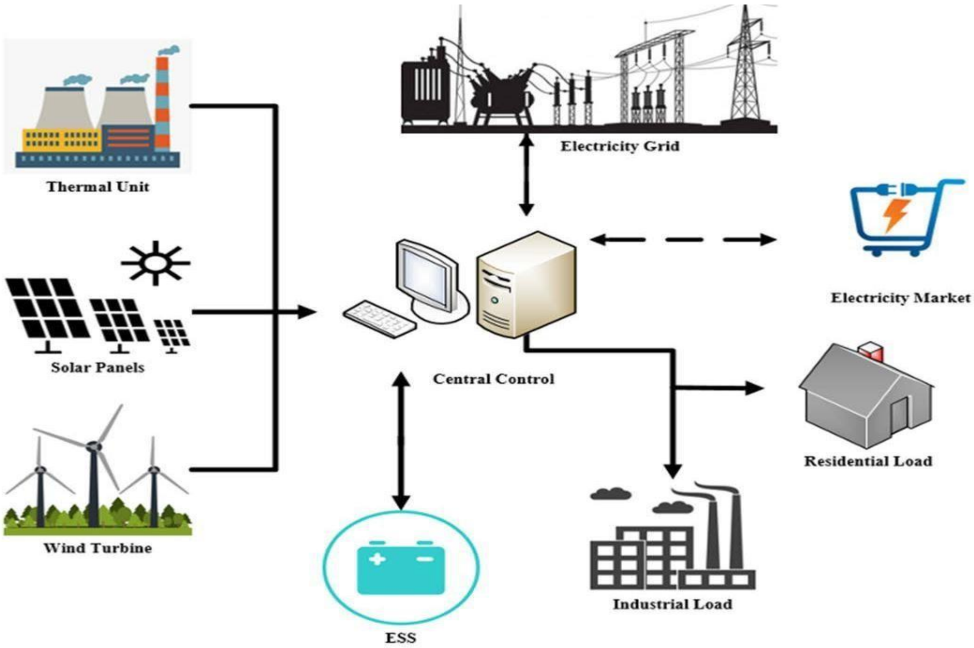

Figure 1

BLOCK DIAGRAM:

1.Several Power Sources (Wind, Thermal, and Solar) The system collects energy from different renewable sources like solar panels, thermal energy, and wind turbines. Every source generates electricity on its own.

2.SEPIC Converter Power Conversion a Single-Ended Primary Inductor Converter (SEPIC), which controls and transforms the voltage to a steady level appropriate for charging and use, is attached to each energy source

.3.MonitoringVoltage(Sensors)Both the battery and each source use voltage sensors. These sensors deliver data to the controller for monitoring and control after continuously measuring voltage levels. As shown as figure(2) block diagram.

4. Energy sources: A single-ended primary-inductor converter (SEPIC) that feeds a 12-volt battery is charged by solar, thermal, and wind generators.

5. Voltage sensing: Each source has a voltage sensor that transmits data to an Arduino microcontroller for monitoring.

6. Power management: The battery directly supplies DC load and drives an inverter for AC load, while a separate voltage sensor monitors battery voltage.

7. Control & display: The Arduino processes sensor inputs, shows information on an LCD, and communicates with an IoT server (ESP8266) to manage power distribution and supply to every component of the system.

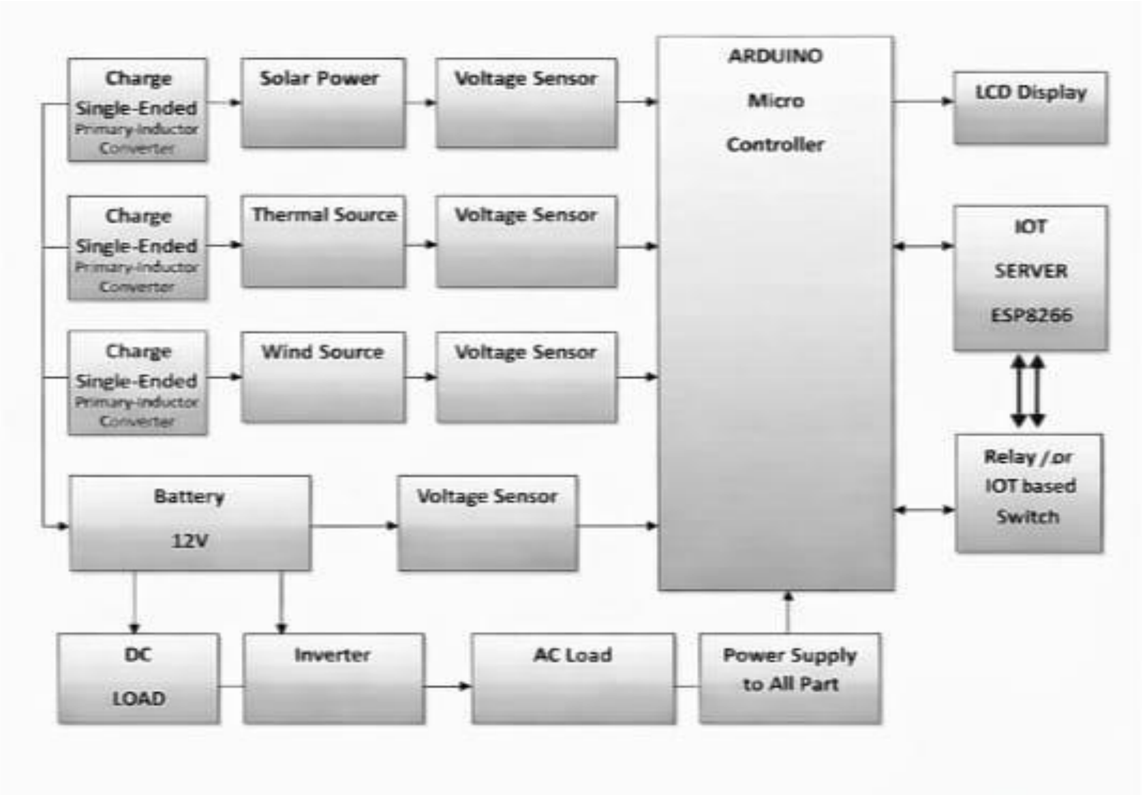

Figure 2

SYSTEM DESIGN AND METHODOLOGY:

1. VPP ARCHITECTURE

The physical and cloud-based domains make up the proposed VPP architecture. While the cloud-based domain refers to interactions between the VPP management hub and other application-programming interfaces (APIs), the physical domain includes generation and distribution. The operation of both domains and their interrelationships are depicted in Figure 2. A generation side and a distribution side make up the physical domain. A thermal unit, solar power plant, and wind farm that are connected to the grid and an energy storage system make up the generation side. Utility and a sizable community-based housing system make up the distribution side. A fuel cell (FC)-based energy storage system is another component of the VPP that stores energy during periods of strong PV generation and low electricity marketprices. Smart appliances that can be controlled and moved to a scheduled time are found in every home. The generation forecasting system in the cloud-based sector includes PV, wind, and thermal forecasting APIs. The VPP control hub, which communicates with the power market, load control and optimization system, and ESS, is the center of the cloud-based domain. Every home has a monitoring system that measures the electrical characteristics of its various circuits. They gather information and store it on the cloud. Via an API, external regulators and the VPP operator can access this data.

2.RENEWABLE ENERGY RESOURCES

The suggested architecture takes into account maximal solar and wind installation at the generation side in order to produce a carbon-negative output. These resources are in line with minimum expenses, maximum efficiency, and other benefits for each home's customers. The efficiency of the DC/DC converter at Maximum PowerPoint Tracking (MPPT), rated power at 1 kW/m2, and perpendicular radiation are all necessary for solar generating. Variations in the weather, solar radiation, and physical characteristics of the installation site, such as dust and precipitation, all affect the amount of solar electricity that is produced. The wind speed at the installation site is the primary factor driving the wind power plant's turbines. Wind turbines' mechanical and electrical capacities determine how much wind power they can produce. While electrical power is produced by multiplying mechanical power by the generator's efficiency, mechanical power is acquired directly. The cut-in wind speed m/s, current wind speed m/s, rated wind speed m/s, cut-out wind speed m/s, maximum output power (kW), and output power at cut-out speed (kW) all have a significant impact on how well turbines operate .As shown as figure(3) schematic diagram of physical domain and cloud based domain of a vpp.

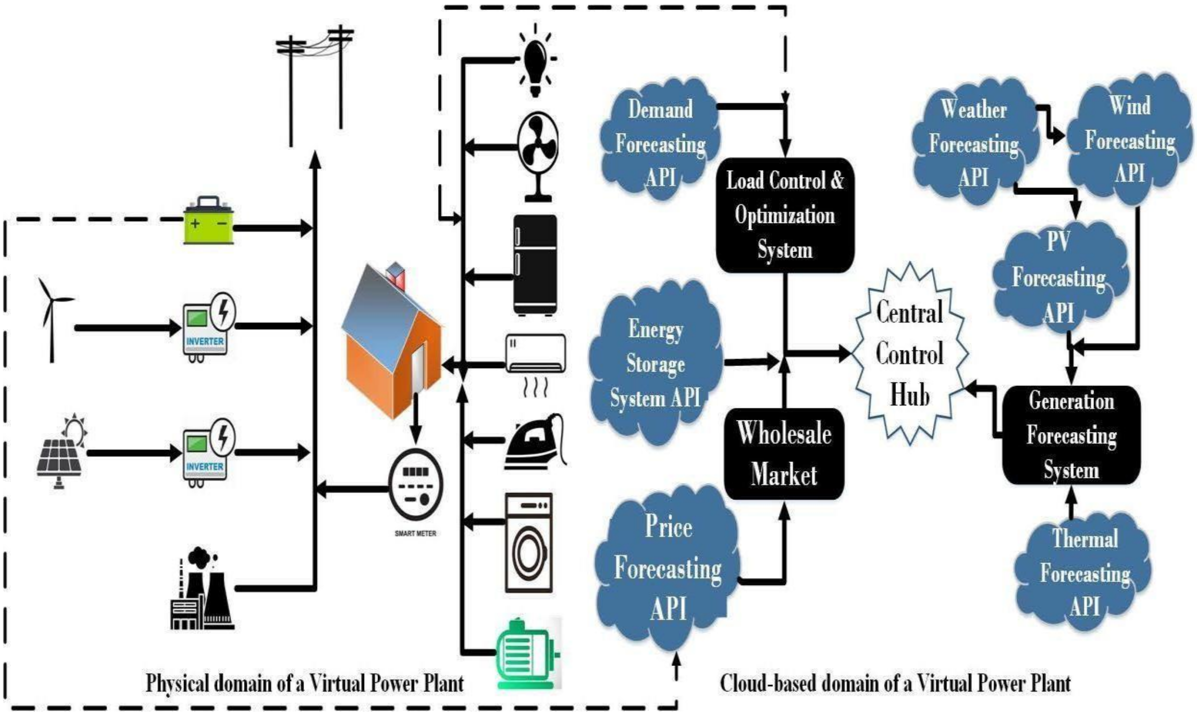

Figure 3

3.COMMUNITY BASED DWELLING SYSTEM:

A community-based living system with several residences makes up the demand side of the suggested VPP architecture. As shown in Figure 3, dwellings are categorized into three income levels: low, moderate, and high. Depending on the status it enjoys, every residence has a variety of light and heavy loads. Each home's loads are divided into light and heavy loads accordingto kWh ratings and consumption frequency. Heavy loads have a kWh value of more than one kWh, while light loads have a rating of less than one kWh. The various load types and their names are shown in Table 2. VPP uses wind and solar power at the generation side to run the entire community efficiently and fuel cells as the storage system.

STORAGE SYSTEM:

Setting up time settings and defining VPP (Virtual Power Plant) variables are the first steps in the procedure.Solar power (Pv), anticipated power, load (PL), price (Pt), and storage parameters are examples of input data that is gathered.An optimization problem with restrictions and goals is formulated by the system .As shown as figure(4) storage system

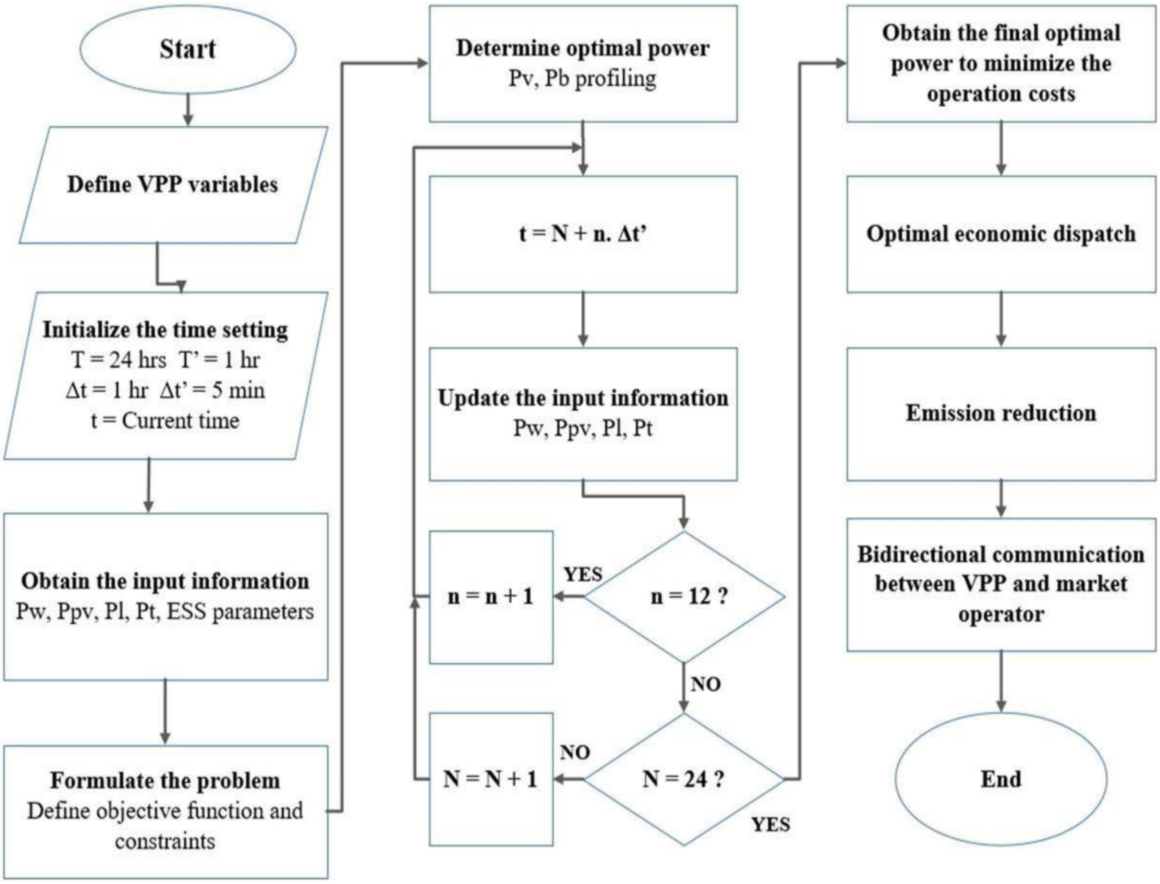

Figure 4

4.SMART ENERGY MANAGEMENT (SEM):

For house and business owners, energy and electricity consumption have always been a worry. People's awareness of their energy use is becoming increasingly crucial as resources become limited and electricity prices keep rising. This is accomplished by setting up an energy management system, which teaches the user how to conserve energy and when they use it most. One method to comprehend the idea and operation of smart energy is through smart energy management. Some smart energy systems are simple, such using smart appliances, while others are more complicated, like solar panel installation and multi-building automated utility systems.

PROBLEM FORMULATION:

1. JAVA AGENT DEVELOPMENT FRAMEWORK

The Java Agent Development Framework (JADE) is a type of Java-based software framework. JADE creates intelligent multi-agent systems using a variety of graphical tools that adhere to the Foundation for Intelligent Physical Agents (FIPA) specifications. Numerous machines with different operating systems can share a JADE-based system.This configuration is managed by a remote graphical user interface (GUI), which can modify it during runtime by moving the agents between machines. The JADE offers an efficient and safe environment for developing and implementing intelligent agents.Class libraries are used to generate and modify agent behaviors.graphical tools that are well-organized for agent management and monitoring.a solid paradigm for creating and carrying out tasks.peer-topeer agent exchange.As shown as figure(5) enabling the distributed system.

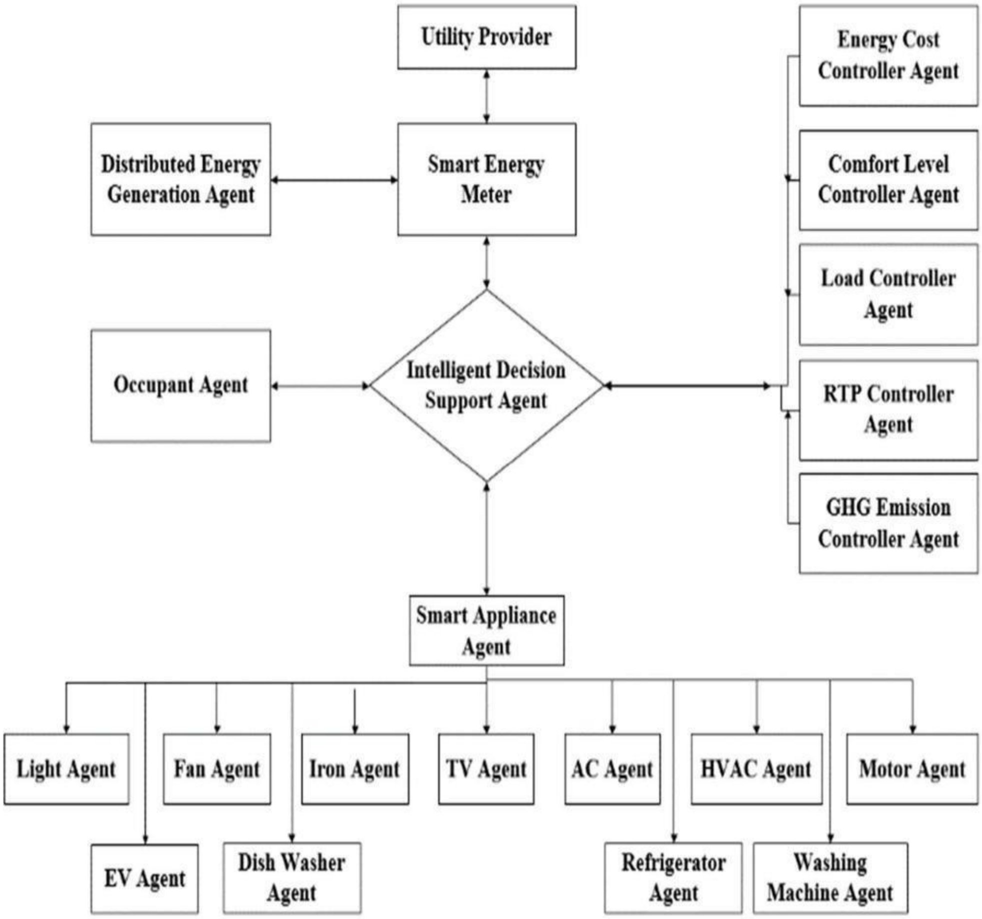

Figure 5

CALCULATION:

1. Solar Power Estimation

The formula:P = V×I $P = V \times I$
In the
P = Watts of power

V stands for voltage (volt)
Current (Ampere) = I

As an example:

18 V is the voltage of the solar panel; 2 A is the solar current; 18 × 2 = 36 W; P = 18 × 2 = 36 W

Thus, solar power produced equals 36 W.

2. Power Estimation As an example:

Wind generator voltage = 12VCurrent=1.5A$P=V\times I$ P=V×IP=12×1.5P=12 ×1.5 P= 18 W P=18W

Thus, 18 W of wind power are produced.

3. Total Power from Various Sources Ptotal = Ptotal + Ptotal = P wind + P solar For example,

   18 W of wind power and 36 W of solar electricity

   36 + 18 P = $Ptota$ = 36 + 18 P total = 54 P total = 54W The total renewable

   electricity is therefore 54 W.

4. Determining Battery Charging

   Equation:V P = I = $I = P$

   For example,

   12 V battery voltage and 54 W of power available

   = 12 54 = 54 12 I I

   = 4.5A = I = 4.5

   Therefore, the battery charging current is 4.5

CIRCUIT DIAGRAM:

To process inputs and regulate outputs, the circuit's primary control unit is an Arduino microcontroller.

Resistors and voltage regulators are used to condition the input signals from a variety of sensors and switches.A voltage regulation section guarantees a steady power supply (such as 3.3V or 5V) for components to operate safely.As shown as figure(6) circuit diagram

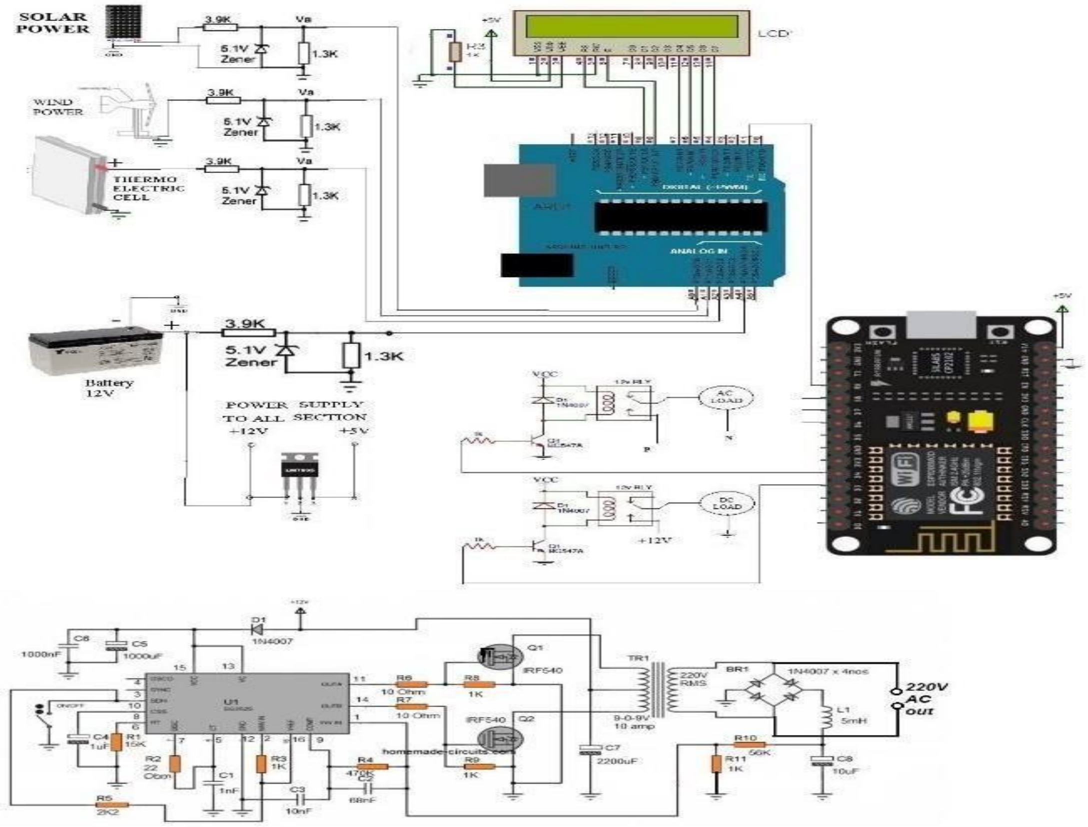

Figure 6

ALGORITHM:

Step 01:Get the system going ■˙ç

Step 02: Set the microcontroller and IoT module up. Step 03:

Check all of the sources' voltages:

Voltage of a solar panel (Vs) Vw, or wind generator

voltage Voltage

(Vb) of batteries

Step 04: Verify which green energy source is accessible.

step 05:If solar energy is available, use it as your primary source.

step 06:If wind power is not available, choose a wind source.

Step 07: Use a backup battery if both are low.

step 08:DC electricity should be sent to the inverter circuit.

step 09:DC to AC power is converted by the inverter for the load.

step 10:Forward data on voltage and current to an IoT cloud for tracking. step 11:Continue doing this repeatedly.

FLOW CHART:

1.First, the Arduino Uno and WiFi module are initialized, followed by the activation of an internet connection.2. The system determines whether there is a connection; if it is, it generates an IP address; if not, it displays an error message.3. Once a connection has been established, it measures the sensor reading and transmits the information to the WiFi module via a serial connection (protocol).As shown as figure(7) flow chart

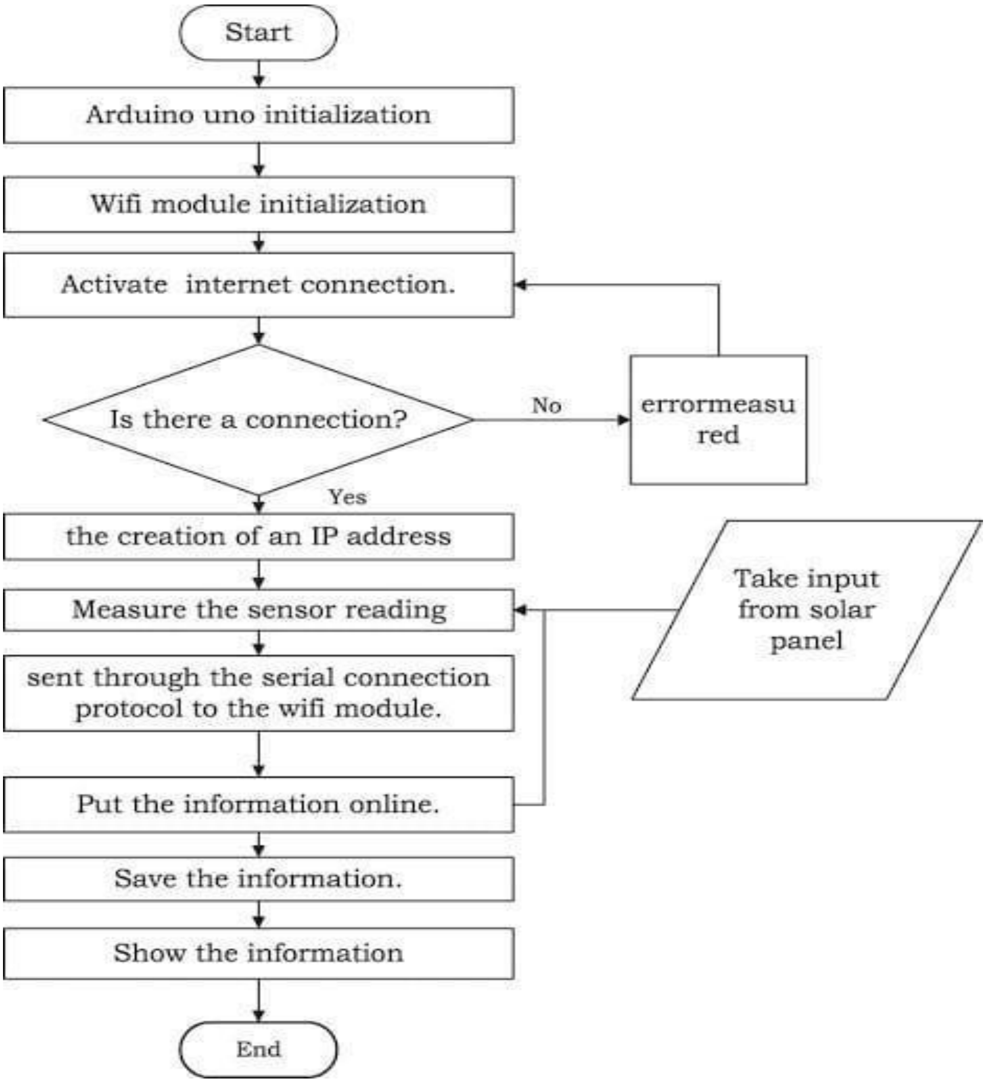

Figure 7

CODING:

```
#include <ESP8266WiFi.h>


const char* ssid = "YOUR_WIFI_NAME";

const char* password = "YOUR_WIFI_PASSWORD";


// Relay pins int solarRelay = D1; int
windRelay = D2; int
batteryRelay = D3;


// Sensor pins int solarSensor = A0; int
windSensor = D5; int batterySensor =
D6;

float solarVoltage; float windVoltage; float
```

```
batteryVoltage;

void setup()
{
  Serial.begin(9600);

  pinMode(solarRelay, OUTPUT); pinMode(windRelay, OUTPUT);
  pinMode(batteryRelay, OUTPUT);

  WiFi.begin(ssid, password);

  Serial.println("Connecting to WiFi..."); while
  (WiFi.status() != WL_CONNECTED)
  { delay(500);
    Serial.print(".");
  }

  Serial.println("WiFi Connected");
}

void loop()
{
  // Read sensor values
  solarVoltage = analogRead(solarSensor) * (5.0 / 1023.0); windVoltage
  = digitalRead(windSensor); batteryVoltage =
  digitalRead(batterySensor);

  Serial.print("Solar Voltage: ");


 Serial.println(solarVoltage);



 Serial.print("Wind Status: "); Serial.println(windVoltage);
 Serial.print("Battery Status: ");
  Serial.println(batteryVoltage);

  // Source selection logic if
  (solarVoltage > 3)
  {
```

```
    digitalWrite(solarRelay, HIGH); digitalWrite(windRelay, LOW);
    digitalWrite(batteryRelay, LOW);

    Serial.println("Solar Source Selected");
  }

  else if (windVoltage == HIGH)
  {
    digitalWrite(solarRelay, LOW); digitalWrite(windRelay, HIGH);
    digitalWrite(batteryRelay, LOW);

    Serial.println("Wind Source Selected");
  }

  else
  {
    digitalWrite(solarRelay, LOW);
    digitalWrite(windRelay, LOW);
    digitalWrite(batteryRelay, HIGH);

    Serial.println("Battery Backup Selected");
  }

  delay(3000);
}
```

OUTPUT:

Solar energy voltage is 12v

Thermal energy voltage is 12v

Wind energy voltage is 12v

Battery energy voltage is 12v

As shown as figure(8) types of voltage output

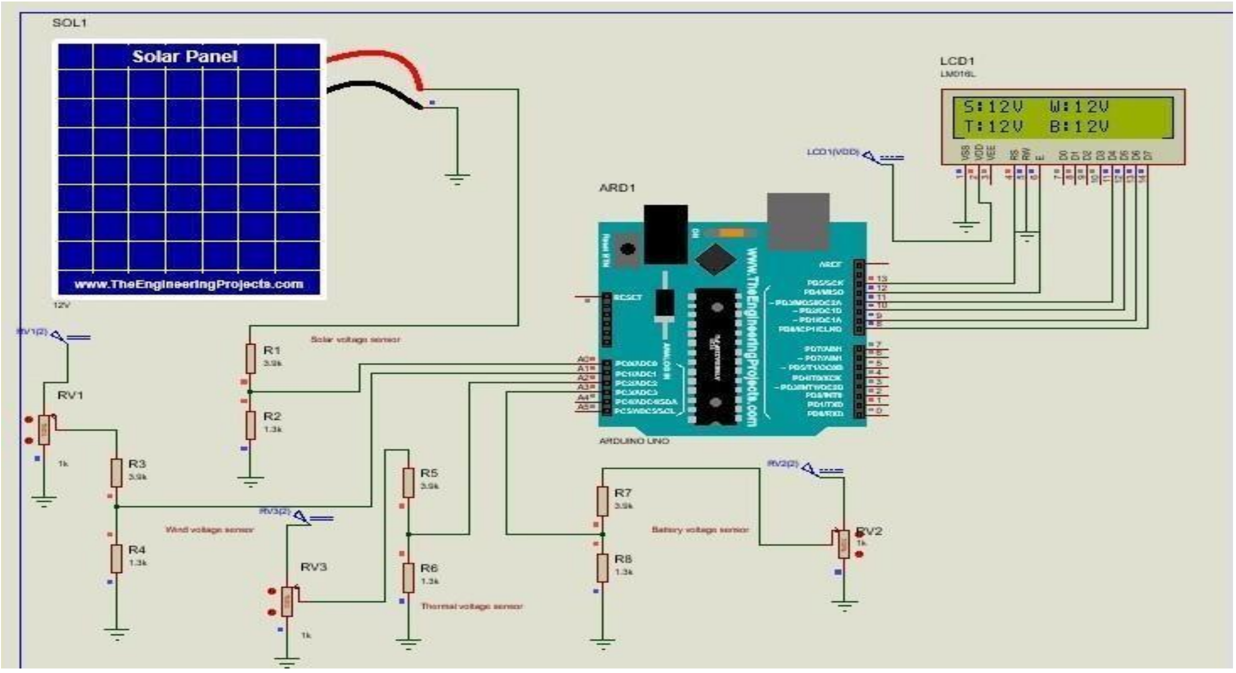

Figure 8

WAVE FORM:

1.Not using SEM (red line):Around hour six, energy use substantially increases (peak ~1.2 kWh).

Moderate intake between 10 and 18 hours.

A second peak happens between hours 20 and 21.

2. Using the blue line, SEM:Generally speaking, consumption is flatter and lower, suggesting efficiency or load shifting.

The peak at hour six is relocated and decreased.

The majority of the day is spent with minimal overall energy use.

As shown as figure(9) energy consumption

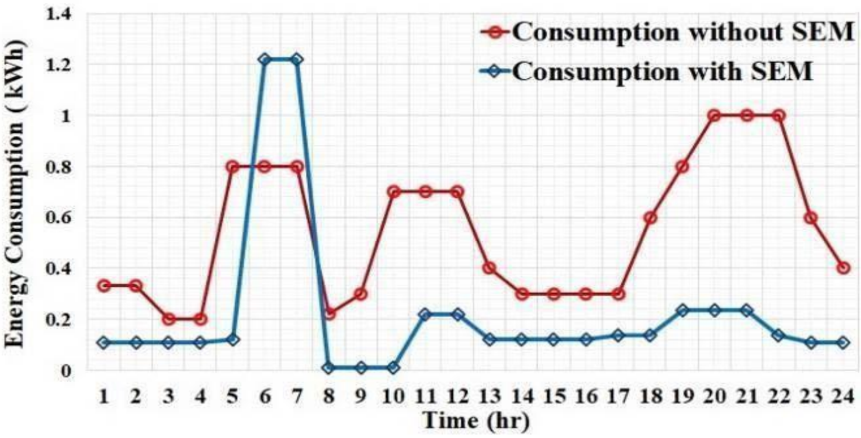

Figure 9

1. AC is the most expensive to operate, as seen by its greatest price curve.
2. The next most expensive items are iron and washing machines, which peak at noon.

3. The cost of TV series is modest, typically greater than Fan but cheaper than Iron/WM.
4. Fan's mid-range price is comparatively steady.
5. Light is the least expensive item to run because it has the lowest price curve. As shown as figure(10) real time price

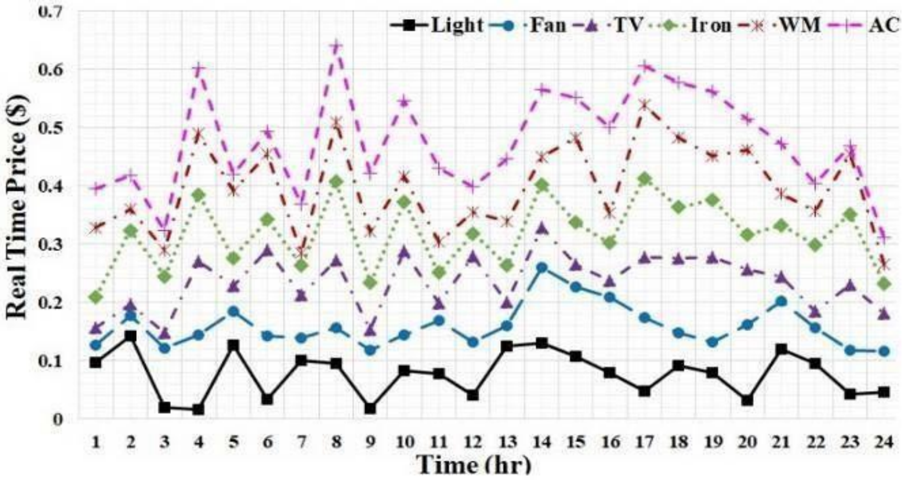

Figure 10

RESULT AND DISCUSSION:

Increased Inverter Efficiency: Smart inverters powered by the Internet of Things exhibit increased operational efficiency. Up to 80% to 92% accuracy in inverter performance and 93.33% accuracy in smart energy metering have been demonstrated by experimental setups.

Maximum Power Point Tracking (MPPT): With a reaction time of two to three seconds, IoT- based MPPT for photovoltaic (PV) systems attained 97.83% efficiency.

Lower Energy prices: An IoT-managed hybrid system that combines solar, wind, and batteries can cut energy prices by as much as 61%.

Intelligent Control & Monitoring: By integrating ESP8266 or comparable modules, voltage, current, and load may be remotely monitored. This helps to avoid overloading and overheating, extending the life of inverters and capacitors.

Managing Intermittency: The system reduces the erratic character of individual sources by mixing solar and wind power (multi-source). Wind or battery storage serves as a backup when solar output decreases (for example, during rain or at night), guaranteeing steady, uninterrupted power generation.

CONCLUSION:

Multi-source renewable systems powered by IoT offer a reliable, sustainable, and user-friendly substitute for traditional energy. When combined with intelligent optimization, the ability to remotely monitor and control inverters in real-time increases energy efficiency by more than 70% and drastically lowers operating costs.

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