Design of IoT Based Hybrid Renewable Energy Management System Model for a Domestic Consumer

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Abstract: **PV and Wind energies are the two important sustainable energy resources can meet world energy requirement when it is effectively consumed on its incidence. This work validates an establishment of a prototype model for the incident use of this renewable energy in home automation systemwith an Internet of things (IoT) environment. A cascaded vertical axis wind turbine with PMDC Generator is designed to give energy at low wind profile areas connected with a PV panel for the electricity generation in direct current mode. Suitable converter is used to supply and store energy in the batteries. Adriano boards control source to the appliances using SCR switching and the home appliances use alternatingcurrent converted through DC-AC Inverter.**

Index Terms - ***Cascaded vertical axis wind turbine, PV panel, Charge controller, Arduino, Internet of Things (IoT), Home automation system.***

I. INTRODUCTION

Electrical energy is the basic need for anydevelopment. The rapid increase in the fossil cost and its environment concern it is important to discuss the various methods and process of generation of power by renewable energy sources. Hybrid energy generation is more important[1] because of the inconsistency of wind flow and solar radiation. In India there are many states whose develop the hybrid energy to increase their economy and best environment condition. Presently, most of the electricity generated across the central part of India which uses coal, gas, oil, water or nuclear as a primary fuel. There are various dangerous impact occur on the environment by using coal and nuclear as primary fuel [2]. As these primary fuels are present abundant in nature, so it makes important to generate power by hybrid designing of solar and wind power plant to achieve the better environment condition and also reduce the use of existing fossil fuels resources, it is important for future renewable sources. Renewable resources neither the wind nor the solar can available all the time. So it would be important to generate power by the combination of these renewable resources. Hybrid energy power generation also offers of generating power in the remote areas in India among fifteen states Tamil Nadu is one of the most potential of renewableresources. The highest wind energy installed state Tamil Nadu[3], which has total installed capacity of 7,196 MW till June 2013, had added 8 percent wind capacity between years 2011 to 2012.

Solar is a renewable energy from the Sun, inexhaustibleand environmental pollution free. Solar panel is used toconvert solar energy directly into electrical energy. India is a tropical country and Because of its locationbetween tropic of cancer and equator the average annualtemperature of India is about 25-28 °C which amounts 3,000 hours of sunshine[4]. The National Institute ofSolar Energy in India has determined the country's solar Power potential at about 750 GW. Energy generation by use of speed of wind by rotating wind turbine is namely known as wind energy generation. Wind power generation capacity in India has significantly increased in the last few years and as of 2016 the installed capacity of wind power was 276 GW. Hybrid means combination of more than one energy source. In energy system the electricity can be generated by more than one source at a time like Wind, solar, biomass, etc.

There are various modules to generate hybrid energy, like wind-solar hybrid, Solar-diesel, Wind- hydro and Wind –diesel. Among the above, hybrid energy generation module, the wind- Solar hybrid module[5] is more important because it is abundant in nature and it is very much environment friendly. The hybridization in India has large prospect because over 75 % of Indian household face the problem like power cut specially in summer[6]. Hybrid energy systems could be potential solutions for the electricity problems in the rural region, yet vast research is needed in this aspect to make ittechnically feasible to be employed at these areas . Hybrid systems can be designed to achieve desired attributes at the lowest acceptable cost, which is the key to market acceptance.

II. LITERATURE REVIEW

Nowadays, Automation technology in controlling electronic devices and electrical energy[7] is one of the major applications .The concept of the Internet of Things (IoT) has a close relation with the blossoming home automation[8][9]. According to Euro monitor, by the year 2020 about 43.7% of the world's inhabitants will be using Internet. Wind Turbines are mainly classified into horizontal axis wind turbines (HAWT) and vertical axis wind turbines (VAWT).Among these two types variable speed wind turbine has high efficiency with reduced mechanical stress and less noise [10]. The vertical axis wind turbine has an assembly of rotor which revolves about its vertical axis. Compared to the more conventional horizontal axis wind turbine, VAWT offered several advantages, such as independent from wind direction[11] [12] the transmission of rotational parts can be mounted near the ground for ease of maintenance, lower acoustic noise signature and less upset of gravity induced due to non harmonic reversing stress at the root of the blade. Hybrid solar- wind power generation is cost effective solution for generation [13]. It only needs initial investment. It has also long life span. Overall, it is a good, reliable and affordable solution for electricity generation.

III. DESIGN CALCULATION FOR WIND AND PV ENERGY

This article gives importance to design an innovative cascaded vehicle axis wind turbine to get optimum wind energy at the proposed location along with PV panels and suitable controllers.

3.1 Design of cascaded vertical axis wind turbine

Cascaded vertical axis wind turbines are a type of wind energy technology that consists of two or more VAWTs stacked vertically as shown in Fig 1. The primary reason for using cascaded VAWTs is to increase the power output of the wind turbine while minimizing the land area required for installation.

3.1.1 Design calculations for VAWT model

The power in wind[14] defined as, $P_W = \frac{1}{2} c_p \rho A V^3$ *Watts* (1)

Where, Air density ρ = 1.23 kg/m^3

Sweep area A = π RH m^2, Radius of the wind turbine R (m), Height of the wind turbine (m)

Wind speed V = 4 m/s (average minimum wind speed in the area)

Power coefficient C_p = 0.2 to 0.3 for a VAWT model

The power available from the wind is given by the equation (1). The equation describes the effect of wind speed on wind power generation because it is cubed, unlike other values. The cascaded vertical axis turbine shown in figure includes 3 VAWT models connected in parallel with individual gear mechanism on a common shaft connected to PMDC generator. Each VAWT model consists of 3 blades with 1 m height 0.25 m Chord length. VAWT models are arranged in a increasing height to avoid wind wake effect on other VAWT models.

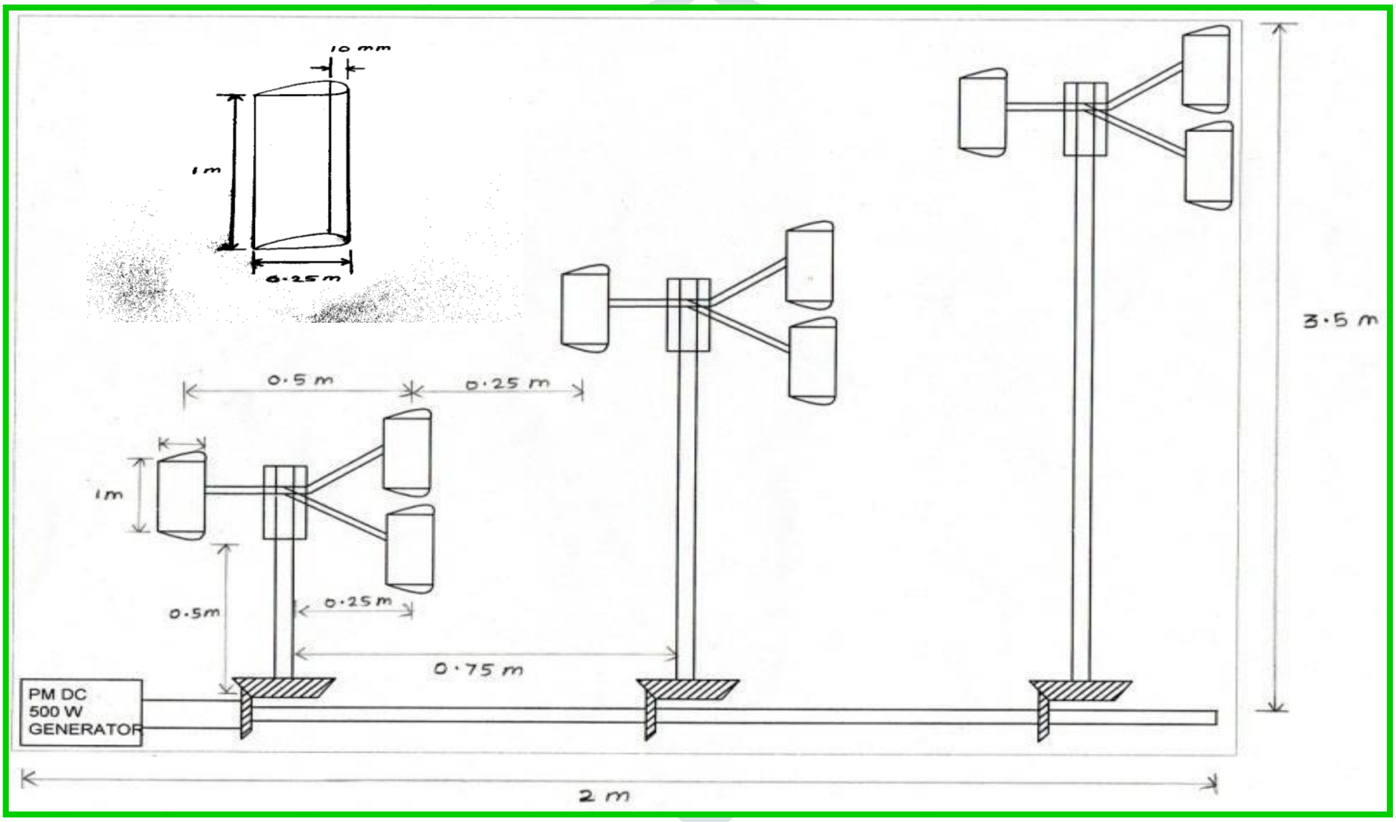

Fig 1. Cascaded vertical axis wind turbine with an airfoil dimensions

This combination exhibits similar characteristics, like three alternators connected in parallel to meet more electrical load. The practical demonstration of this cascaded vertical axis wind turbine is shown Figure 2. This combination capable of generating 500W, 24V at rated wind speed conditions. The output energy available from this cascaded wind turbine is connected to suitable 24V charge controller and then it is connected to the battery for the backup purposes. This proposed location known for its low wind speed, but the PMDC generator used for this wind energy conservation gives rated output only at 1500 RPM. In order to give the right speed for a conversion from the wind turbine, suitable gear ratio in the range of 1:7 is used as shown in Fig.2.

Fig 2. Practical model of cascaded vertical axis wind turbine with a 1:7 gear and PMDC generator

3.1.2 Design calculations for PV model

Solar panels (PV) generate electrical power from sunlight, which can be harnessed to provide renewable energy. However, the output from solar panels can fluctuate depending on factors like the intensity of sunlight, temperature, and shading. As the solar panel is placed in the path of light direction, we get efficient output from the panel like 19.7V to 20V for a panel with 24V rated voltage as shown in Fig 3. and the total power of the solar panel is 180W.

Fig 3. 24V, 0.8 kWp Solar panel

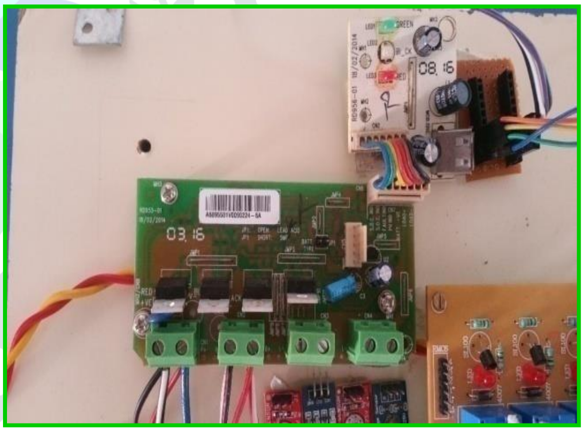

Fig 4. PWM Charge controllers

A charge controller or charge regulator as shown in Fig. 4 is basically a voltage and/or current regulator to keep batteries from overcharging. It regulates the voltage and current coming from the solar panels going to the battery. The use of a charge controller in conjunction with solar panels can significantly improve the reliability and efficiency of solar power systems, making them more practical for off-grid or remote applications[15]. PWM charge controller [16] with high efficiency we aregoing to use in work. This design is connecting a solar panel (180W, 24V) in parallel 500W, 24V wind turbine and 4 batteries (12V, 7.5Ah) with series & parallel combinations to suit 24V and 15Ah. These combination renewable sources with lead-acid batteries allowed taking domestic load with suitable inverter.

IV. IoT BASED HOME AUTOMATION SYSTEM

Fig .5 shows the block diagram of the hybrid power based IoT home automation system[17]. This block diagram includes blocks such as wind and PV renewable sources at 24V with suitable voltage controllers and voltage, current sensors connected to 24V, 15Ah batteries. The wooden board collects the voltage and current information from the renewable sources and voltage information from the battery. According to the program given into the Arduino board, the activating signals are given to the relay driver. From the relay driver, the loads are switched on to the inverter supply. In between the load and the inverter, the Internet of Things (IoT) is set to control the supply of the load.

Arduino ESP module for the wireless connection to the Wi-Fi router and connect to the internet where we can load a web page. Hence, the entire switching will be designed on a web page where the required user can only access it and switch ON/OFF the load where ever wants to control to use internet control.

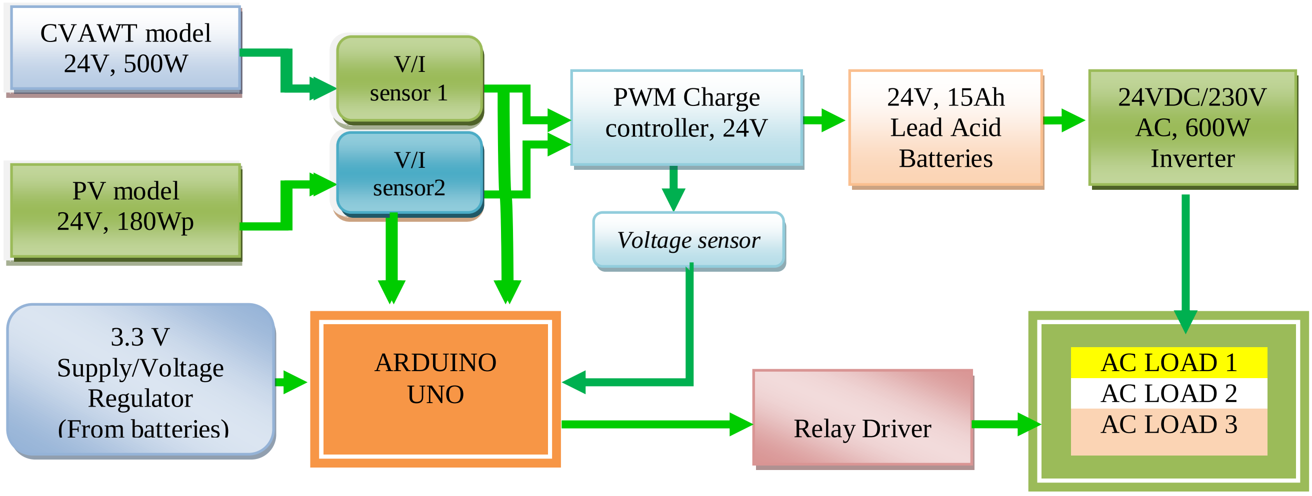

Fig.5 Hardware model block diagram

4.1 ESP Arduino Shield

ESP8266 Arduino shown [18][19] in Fig.6 is an impressive, low cost Wi-Fi module suitable for adding Wi-Fi functionality to an existing microcontroller project via a UART serial connection. This module can even be reprogrammed to act as a standalone Wi-Fi connected device. It requires 3.3V power and does not power it with 5 volts. This ESP8266 needs to communicate via serial port at 3.3V and does not have 5V tolerant inputs, so you need level conversion to communicate witha 5V microcontroller like most Arduino uses.

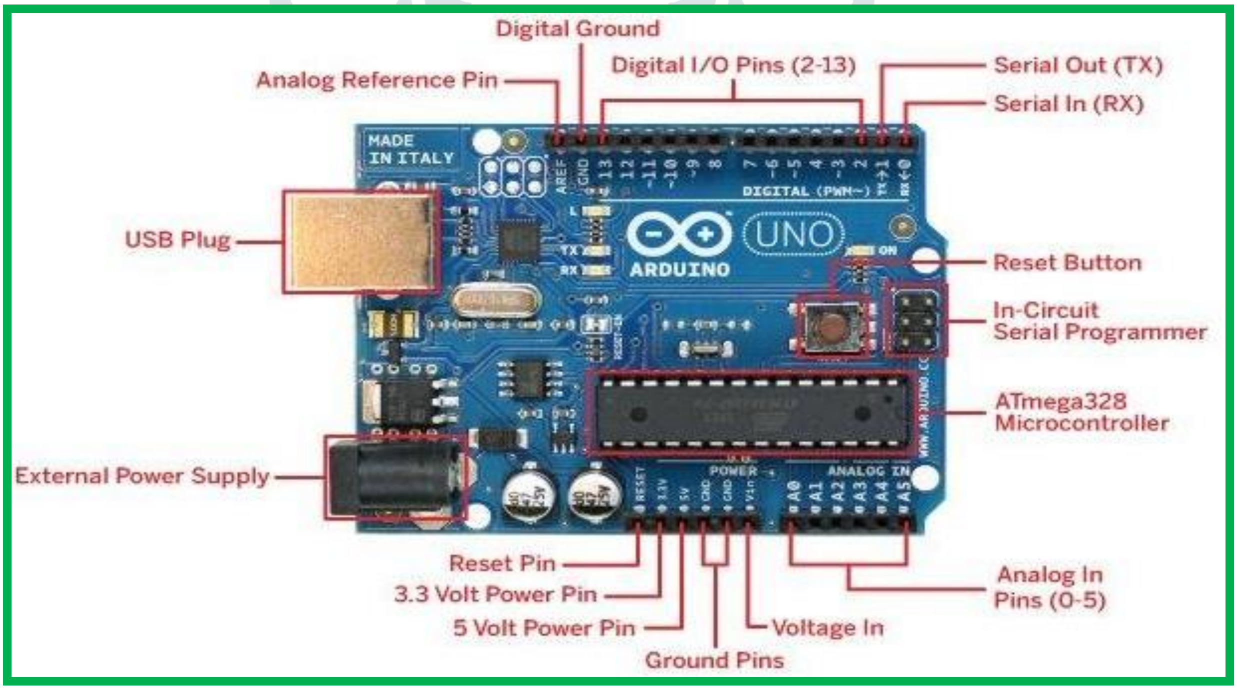

Fig.6 Hardware model block diagram

4.2 Voltage & Current Sensors

The Arduino analog input is limited to a 5V DCinput. For measuring higher voltages, need to resort to another means. One way is to use a voltage divider. It is fundamentally a 5:1 voltage divider using a 30K and a 7.5K Ohm resistor. Keep in mind; you are restricted to use voltages that are less than 25 volts. More than that and you will exceed the voltage limit of your Arduino input.

Fig.7 Voltage and Current sensors

The ACS712 Current Sensors shown in Fig are designed to be easily used with micro controllers like the Arduino. These sensors are based on the Allegro ACS712ELC chip. These current sensors are offered with full scale values of 5A, 20A and 30A.The basic functional operation of each of these devices is identical. The only difference is with the scale factor at the output. Both of these voltage and current sensors are used in this automation system with Arduino programming.

IV. IoT FRONT END & HARDWARE DEMONSTRATION WITH INVERTER MODEL

The IoT Front end, a charge controller, inverter, lamp load and Fan load are connected to consume renewable energy on its incidence with the help of Adriano programming and suitable sensors as shown in Fig 8. This output consists of the browser option that the user gives to operate for the optimum use of the home appliances. The following calculations were made for inverter and load ratings. In this calculations to switch on the load such as three LED lamps and one ceiling fan for a demonstration whenever the renewable energy sources are available with IoT.

For Load Calculation

3 LED lights = 3x9W = 27 W
1Ceiling FAN = 1x60W = 60 W
Total (power) = 87 W
87Wx3 Hours back up = 261W

For Inverter Rating

From DC to AC Conversion,
It should be 25% more than actual load
261x (25/100) = 65.25W
Approx. Total Load = 261+69.25= 326W.

However, for this demonstration a 600W inverter model is chosen to switch on AC load such as single phase induction motor based ceiling fan, knowing its surge current [20] behaviour at the time of starting. The demonstration would involve setting up the renewable energy sources and connecting them to the batteries, which would be linked to the IoT devices.

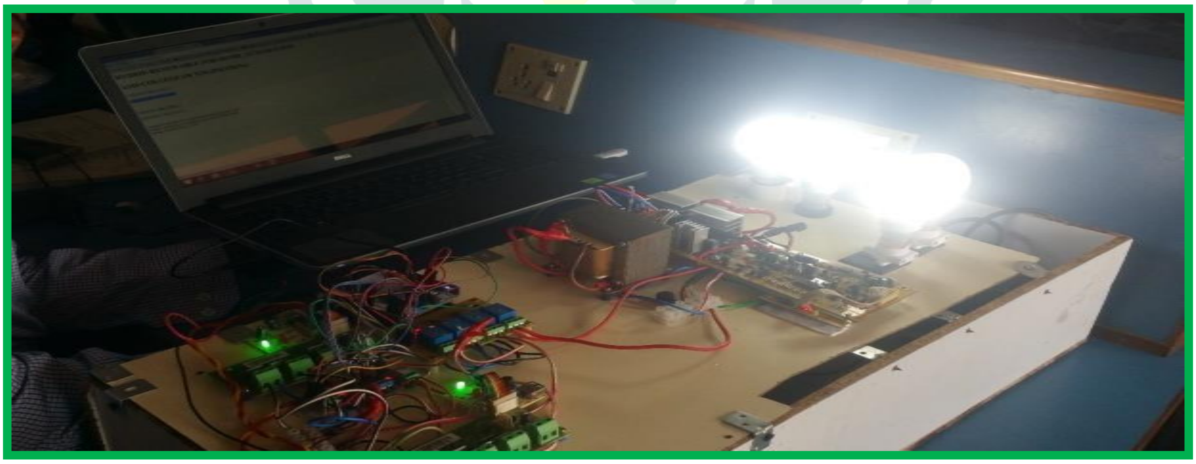

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Fig.8 IoT frontend & Hardware components connections

The devices would then transmit data on energy consumption and generation to a central hub, which could be accessed remotely via a Smartphone app or web interface. The demonstration would showcase how the system manages energy consumption by prioritizing renewable energy sources, and how it can alert users when energy usage exceeds a certain threshold. It would also demonstrate the ability of the system to automatically switch between renewable and non-renewable sources depending on energy demand and availability.

V. CONCLUSSION

The main scope of this work is to provide hardware model to make a home semi independent on grid supply and automated to use the renewable energies at its incidence.

- The 0.5kW CVAWT designed for purpose gave 90-100W even at very low wind speed 2-4 m/s through 24V, PMDCgenerator.

- Solar power of 40-60 W with wind power supplies three LED lamps and a ceiling fan load of 87 W through Arduino Processor and IoT control were effectivelydemonstrated in the electrical laboratory.
- The electrical energy of 100-120 units utilized through this model not only reduces Bimonthly Electricity bill and keeps the globe pollution free and reduces the burden on Grid supplywhich is the basic for Nation's socio- economic growth.

This proposed Internet of Things (IoT) based hybrid renewable energy management system for domestic consumers offers an efficient and sustainable solution to manage energy consumption. By integrating renewable energy sources and utilizing IoT technology, it provides a reliable and cost-effective alternative to traditional energy sources, reducing carbon footprint and promoting energy efficiency.

VI. REFERENCES

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