SMART HOME ENERGY MANAGEMENT SYSTEM USING RENEWABLE ENERGY

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A thesis submitted to the Department of Electrical and Electronic Engineering in partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical and Electronic Engineering

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Declaration

It is hereby declared that

1. The thesis submitted is our own original work while completing degree at Brac University.
2. The thesis does not contain material previously published or written by a third party, except where this is appropriately cited through full and accurate referencing.
3. The thesis does not contain material which has been accepted, or submitted, for any other degree or diploma at a university or other institution.
4. We have acknowledged all main sources of help.

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Ethics Statement

We confirm that this project on "Smart Home Energy Management System Using Renewable Energy" has met the thesis criteria of graduation and this project is absolutely the result of our own efforts instead of any kind of plagiarism. Along with the support of our supervisor and the EEE department, we've accomplished the entire project on our own where we have collected some data from other sources which have been properly referenced.

Abstract

Considering both energy consumption and generation simultaneously to minimize the energy cost we aimed to develop this smart home energy management system project as home energy use is increasing day by day and renewable energy systems are also deployed. We will use Wi-Fi based energy measurement modules to monitor home appliances to know detailed energy consumption information. We are going to attach solar panel and windmill through separate inverter as the renewable energy sources for home and we will monitor the generation of renewable energy through a power line communication based renewable energy gateway. In this project a home server controls everything through a communication block. The home server accumulates the energy utilization data and generation data, after that analyzes them for energy estimation. It controls home energy use schedule to minimize the energy cost. Based on the energy generation, the home server modifies the domestic gadgets operation plan so that the energy cost reduces. For example, within the low renewable energy generation time, the operation of a few home devices can be moved to other suitable times. Users will also be able to access the home energy information through a smart device and which operation to be moved based on their priority and turn the appliances on and off remotely from anywhere using the internet. The remote energy management system provides the comparison and analysis of each home energy usage. By considering both energy consumption and generation data, the proposed project is expected to develop home energy management and to reduce the cost of energy.

Keywords: renewable energy; power line communication; home server; Wi-Fi; Energy Consumption; solar panel; wind turbine.

Dedication

To our parents, instead of their support it would not be possible for us to achieve our bachelor’s degree.

Acknowledgement

We would like to extend our sincere gratitude to our supervisor Dr. A. S. Nazmul Huda, Assistant Professor, Department of Electrical and Electronics Engineering, BRAC University whose guidance, supervision, excellence and perfection helped us a lot throughout the entire process. Also, we are grateful to BRAC University for giving us the opportunity and all the supportive materials required for the fruitful completion of the thesis.

Table of Contents

List of Tables

List of Figures

List of Acronyms

IOT	The Internet of Things
EMCU	Electric Motor Control Unit
IC	Integrated Circuit
MPU	Microprocessor Unit
PV	Photovoltaic
NEM	Net Energy Metering
BLE	Bluetooth Low Energy
TFSP	Thin Film Solar Panel

Chapter 1

Introduction

1.1 Introduction

Electricity is the base of today's modernization and to generate the electricity we use different conventional and non-conventional energy source [1]. Conventional or the non-renewable sources are those which are obtained from nature and stored for a long time such as coal, oil and natural gases. On the other hand, non-conventional or renewable sources are the one gained by natural repetition and constant flow of energy in the domestic environment such as solar energy, wind energy, geothermal energy etc [2]. In the midst of shortage of non-renewable energy, and the world's need to move towards carbon neutrality use of renewable energy is playing a great role for last two decade [1]. To subsist the booming energy urge researchers along the globe are continuously looking round for optimal solution. Wind, solar, hydro, nuclear etc. are the renewable energy sources which have immense prospective and the reliable solution to the current electricity upheaval [3]. Solar and wind energy, the most salient sources of energy are rapidly utilized today due to their malleable and eco-friendly nature. Solar power is converted to energy by using photovoltaic system in which photovoltaic cells converts solar radiation to electricity. To add, wind energy is converted to energy by using wind mills where the wind current propels the wind turbines. Both energy sources can work as hybrid renewable energy system and gradually operates in simultaneous and sequential mode. On the first hand, the system produces energy synchronously in simultaneous mode where as it produces electricity by preference in sequential mode [1].

Today, majority of people have impoverished understanding and command over their power consumption. They can lessen power consumption to some extent if they are able to monitor it. For monitoring and controlling the power consumption smart management systems that utilize IOT based microcontrollers can be introduced. With the introduction of autonomous equipment and consumer products, innovation has gradually come to place where automated home management systems are the new trend that allow us to monitor and manage physical items over the internet. We suggest using smart home energy management system to monitor and manage household appliances, therefore computerizing today's houses via the internet. This conceptual approach allows users to easily monitor and operate various household appliances via the internet. The project offers a useful application of the system for managing and measuring energy usage by each home appliances. It is an emerging technology in the 21st century. In Bangladesh most people waste energy without their consciousness. Renewable energy production off-grid along with smart home energy management system can optimize the energy crisis around the world.

1.2 Background

Around the globe 1.6 billion are lacking way in to electricity and 80% of them dwell in the countryside of Asia and Africa. This is due to dearth of electric supply and unavailability of resources. As energy consumption is increasing researchers had to find replacement for the traditional method of producing energy. This research leads to the support of using renewable energy in a more inexpensive way using Hybrid Renewable Energy System. Renewable Energy was introduced back in 200 B.C which started with the introduction of water wheels which almost relates to the hydropower functioning. Most commonly used and available renewable energy are solar and wind energy. For rural and hilly areas these powers can be utilized to generate electricity. In 2012 Getachew and Gelma outlined a hybrid power generation system using photovoltaic and wind energy for Ethiopian remote area where grid lines cannot reach. Here they included a software tool to inspect details regarding capability of solar and wind in the subject research area.

It also discussed about individual hybrid energy saving structure and also internalization of the structure for removing irregular interval. They used HOMER for optimizing and designing the hybrid system [4]. Again, Ammar I.I proposed an off-grid energy generation based on renewable energy technology in IRAQ including the application of HOMER. This proposal mentions about both off grid and on grid simulation process. Here, it is estimated cost of energy for the system is $0.998/kWh for off grid and $0.2/kWh for on grid system. The proposal aims to decrease effect of using fossil fuel and meet power demand in a small town named Bald Ruz in Diyala, Iraq [5].

In recent days majority of people have little idea about how much energy they are consuming beyond necessity. A study shows one of 4 person in Sweden are unaware of their power use and doesn’t have command on it. Again 4 out of 10 person is eager to know about the energy use and wants to manage the power consumption in an efficient way [6]. A home energy management system which is based on PLC (power line communication) was outlined by Young –Sung Son, Topi Pulkkinen in August 2010.In this system a smart meter is used which gives real time power consumption detail in every 15-20 minutes and processes the detail to the user. The system depends on power use record to control devices [7]. Again, on March 2014 A ZigBee based Home Energy Management System was proposed by Alphy John, I. Bildass Santhosam. Here PIR sensors are used along with Zigbee Hub. The PIR sensors detect human presence in order to decrease unwanted power use. The LCD shows the detail of power used and data of PIR sensor [8].

In May 2014, Jinsoo Han, Chang-Sic Choi, Wan-Ki Park, Ilwoo Lee, and Sang-Ha Kim proposed a Smart home energy management system including renewable energy based on ZigBee and plc. This project focuses on both production and controlling energy consumption. Here PLC is used to monitor the energy production whereas ZigBee helps in measuring consumed energy. EMCU is used for measuring energy and power use of the appliances. The domestic server analyzes and controls the energy use time to lessen the cost [8].

1.3 Objective:

The objective of the project is to ensure economic power generation for the people residing in deep hilly areas and rural area where grid lines are not available and the smart management system will ensure the load operation of the power used. It aims to acquire economic development, improving way in to energy, environment friendly power generation, gaining real time data of power used and also letting the users control and lessen power consumption remotely.

1.4-Motivation:

Current energy upheaval caused in significant energy use degradation in all range. Due to mass installation of home appliances energy use has been increased. To solve the home energy problem energy retaining and renewable energy sources are the possible methods taken under consideration. Energy use as well as energy production have to be equally considered in order to minimize home energy price. Numerous analyses suggest smart home energy management system [8]. People can decrease at least 20% of energy use if they get access to this system [6].

1.5 Outline:

The work is arranged orderly to have a better insight. The rest of the paper includes:

- **Chapter 2** gives a brief description about the proposed system
- **Chapter 3** includes the methodology which includes methods, implementation, data collection
- **Chapter 4** demonstrates the prototype implementation
- **Chapter 5** states result analysis and discussion
- **Chapter 6** highlights the conclusion and possible future works.

Chapter 2

Proposed System Description

2.1 Proposed System Design:

In our proposed project we intend to design a smart home energy management system along with using renewable energy based on WIFI. To begin, we will use two sustainable energy sources: solar energy and wind energy. We will employ solar panels and wind turbines based on their efficiency to transform this energy into electricity. We will use an inverter to convert the DC current produced by the panel and turbine to AC current. The current will be stored in a long-lasting battery. For appropriate charging and draining of the battery, a hybrid charge controller is utilized in conjunction with the battery. Furthermore, in addition to energy generation, we will concentrate on the energy management of the specific dwelling. The smart home energy management system is based on a microprocessor that enables Wi-Fi for remote control of appliances, such as esp32 or esp8266. The microcontroller will send data and receive instructions from a mobile app through a server which can be either local or cloud based. The microcontroller will also be linked to the relay, which will be utilized to operate the appliances automatically. Different current and voltage sensors or energy sensors can be used to measuring the energy produced and usage. If the battery charge becomes too low, we can cut down the power from battery and use fuel-based generators to avoid battery damage and discontinuity of power use. But the generator will only power the low energy essentials appliances to reduce fuel cost and carbon emission. The system will tell the user about current power consumption of each appliance, battery charge level, power factor etc. and give notifications when the battery is running out using an app in the phone like Blynk. This way the user will also be able to control the loads in the house by using the app. We will try to get required power generation by using HOMER simulation. Voltage and current sensors will be used for each load for giving reading of their individual load. The control unit retrieves data from the server and again directs it to the load. Overall process will take the least time possible. The loads will turn off at a certain battery level percentage, giving the user to monitor the homes power production and consumptions and adjust accordingly using the app remotely. Below are the some of the devices and modules that can be used in this project.

2.2 Systematic Block Diagram:

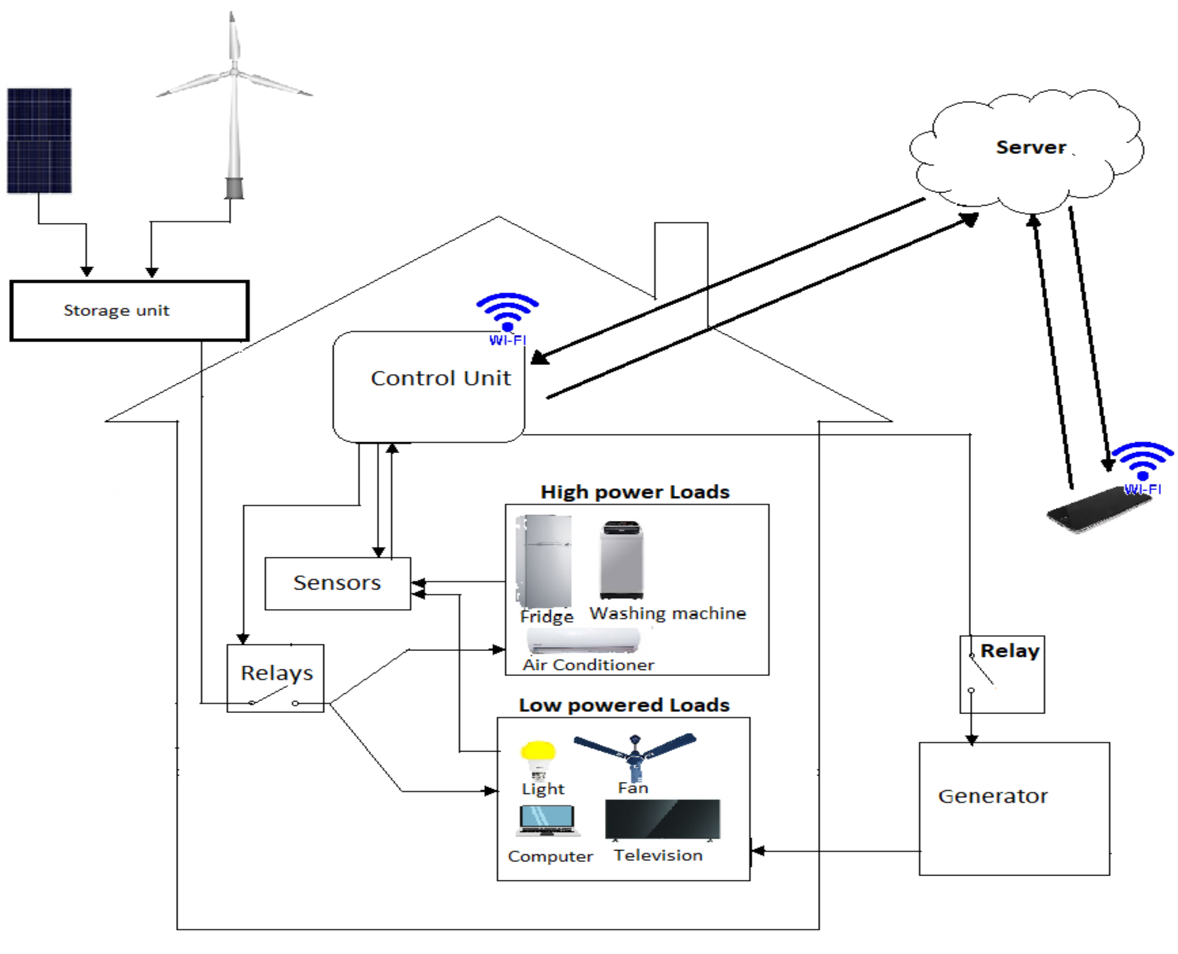


Figure 2.1: System Block Diagram

2.3 Solar panel

A solar panel's components are solar cells. On the top surface of the solar panel, solar cells, also known as photovoltaic cells, are placed in a grid. Electrons are removed from the silicon atoms of a cell when light touches it. Direct current (DC) electricity is generated by the passage of electrons into the cell. The DC power output is then sent via an inverter, which converts it to AC electricity. AC stands for alternating current. AC electricity is the form of electricity utilized in computers, homes, businesses, and other electronic devices.

2.4-Types of Solar Panel:

i) Monocrystalline Solar Panel

Monocrystalline silicon (mono-Si) is the most common kind of silicon chip used in today's electronics. The Czochralski method is used to produce silicon mono-crystals into alloys up to two meters long and weighs few 100 kilograms. For further process, the cylinders are cut into smaller wafers of a few 100 μm [9]. The high purity of silicon is due to the fact that this generation of solar cells has the greatest efficiency of more than 20%.The panel offer the advantages of producing more electricity, taking up little space, and working better [10].

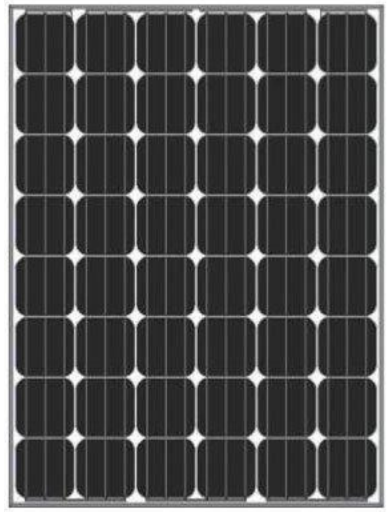


Figure 2.2: Monocrystalline solar panel [10]

ii) Polycrystalline Solar Cell

Metallurgical level silicon is used to make polysilicon. The Siemens method is a chemical purifying method. The unstable silicon gets distilled under this method and their high-temperature breakdown into silicon. A new refining method is gaining traction. A continuous flow reactor is used. In addition, the solar industry. Improved metallurgical-grade silicon is produced (UMG-Si). The production of one megawatt (MW) of conventional photovoltaic panels necessitates around 5 tons of polysilicon [9]. Because they are impacted to a larger degree by warmer temperatures, it has a poorer efficiency of approximately 15%, less area effectiveness, and a shortened life, even at reduced end cost [10].

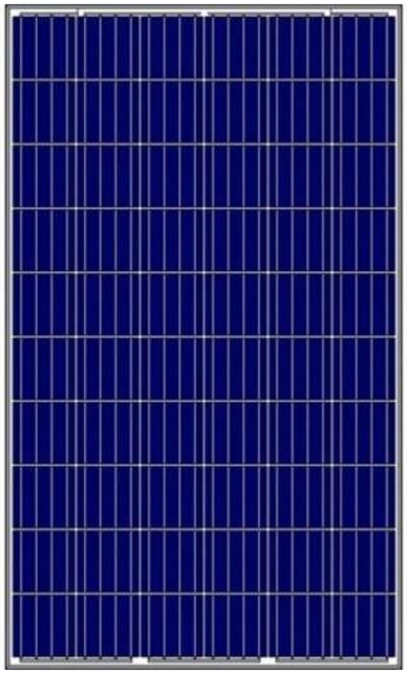


Figure 2.3: Polycrystalline Solar Panel [10]

iii) Thin Film Solar Panel (TFSP)

Thin film solar panel is produced by depositing one or more thin layers of crystalline silicon on a base like glasses, plastics, or metals. Thin film cells can be more pliable, lighter, and get less friction as a result of all this. TFSP is utilized in solar systems and as a moderately PV varnishing substance that may be bonded onto windows [9].

Figure 2.4: Thin Film Solar Panel [9]

2.5 Wind Turbine:

Wind energy is generated using a special form of turbine known as a wind turbine, which collects kinetic energy and converts it to electricity. When there is a variation in air pressure, air travels from larger pressure locations to reduced pressure regions. Three spinning wings on a steel frame tower make up a wind turbine. Less frequent variants include those with two wings or lattice towers made of concrete or steel. The tower allows the turbine to move since it is 100 feet or more above the ground. At higher elevations, benefit from faster wind speeds. The propeller blades of turbines, which behave like airplane wings, collect energy from the wind. On one side of the blade, as the wind blows, a low-pressure airbag forms. The rotor turns as the low-pressure airbag pushes the blade towards itself. A lift is the term used to describe this action. Lift is significantly more powerful than drag, which would be the pressure of wind against by the blade's face [11].

2.6-Types of Wind Turbine:

Depending mostly on axis around which the turbine spins, there are different sorts of wind turbines. Turbines that revolve round the horizontal axis (HAWT) are more prevalent than turbines that revolve round the vertical axis (VAWT) [11].

i)The Vertical-Axis Wind Turbine

There are two types of VAWT

- Savonius
- Darrieus

The Darrieus utilizes blades identical to all those seen on HAWTS, but the Savonius uses drag coefficient to function like it's a pelton wheel [11].

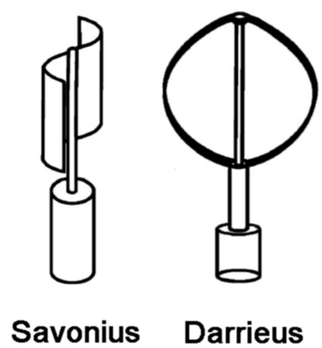


Figure 2.5: Vertical Axis wind turbine [11]

ii) Horizontal Axis Wind Turbine

For the HAWT, the power generator with primary rotational shaft is usually located just at top of the structure. The HAWT has a design that requires it to face towards the wind in order to maximize power; this procedure is termed yawing. In most cases, the turbine is linked to the generator shaft through a gear, which converts the turbine's slower revolution into a quicker rotation appropriate for driving a generator [11].

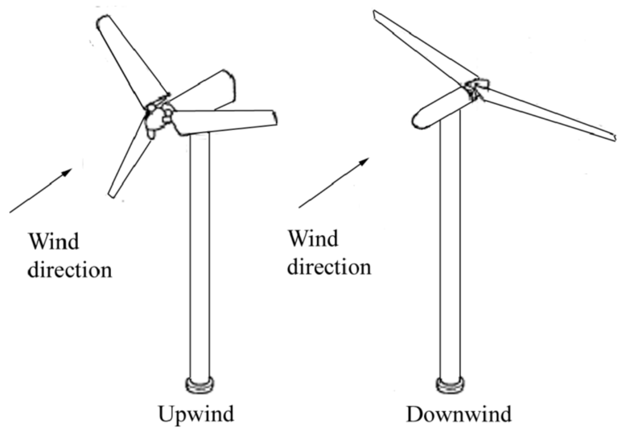


Figure 2.6: Horizontal Axis Wind Turbine [11]

2.7 Microcontroller

Microcontrollers are compressed microcomputers used to operate modules like office equipment, robotics, household appliances, automobiles, as well as a variety of other devices. Storage, ports, and, especially a CPU are all included in a microcontroller. Microcontrollers are primarily used in gadgets that require the operator to exercise some measure of control.

2.8 Types of microcontrollers:

There are many microcontrollers that can be used for smart energy management systems.

Such as (i) ESP8266 (ii)ESP32

i) ESP32:

The combination of Wi-Fi, Bluetooth, and Bluetooth LE in the ESP32 means that all of our modules may be utilized for a variety of applications, making them truly versatile. Wi-Fi allows for communication over a large region, whilst Bluetooth allows a user to rapidly locate and connect a module to their phone.

The ESP32 microcontroller has two unique cores, Bluetooth and Bluetooth Low Energy (BLE) connectivity, four different timers, and a hall effect detector [12].

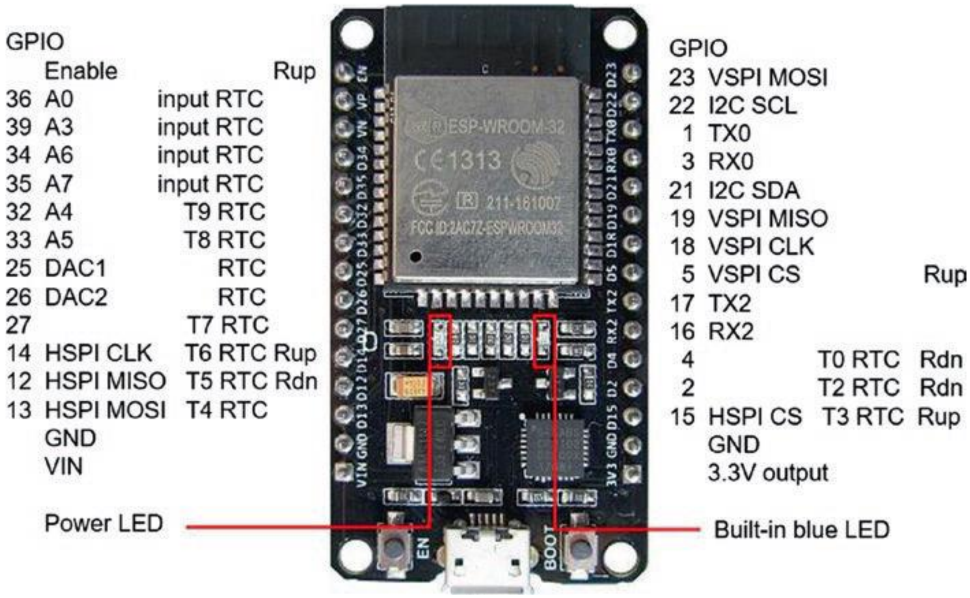


Figure 2.7: ESP32 Microcontroller [12]

ii-ESP8266:

The ESP8266EX's Tensilica L106 32-bit processor uses very little power and has a peak clock rate of over 160 MHz. The board runs on 3.3 V and can be powered by a 5 V micro-USB link, the 3.3 V voltage controller, or the 3.3 V pin directly, but the latter is recommended. The pins are not 5V tolerant, and the maximum current stock for each pin is 12 mA [12].

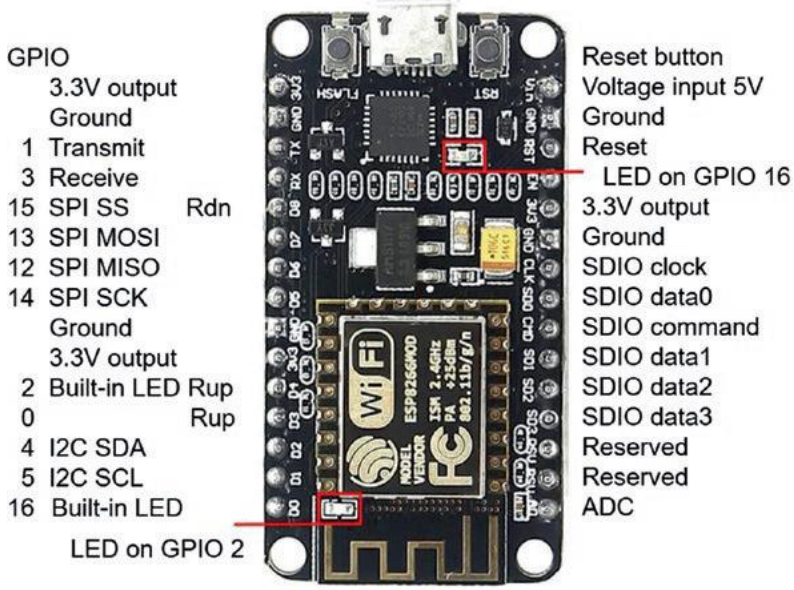


Fig 2.8: ESP8266 microcontroller [12]

2.9 HOMER:

Homer is a simulation software used to do the required energy stability calculation round the year.

It also compares the load each hour and gives a detailed calculation of the power consumption.

Chapter 3

Methodology

3.1 Project Simulation Using Homer

We simulated this project using homer and estimated the required energy generation and an optimized number of solar and wind modules for best performance and cost

Appliances used in a Typical House hold:

Appliances	**Amount**	**Watt(each)**
Light-outdoor, dim light, large energy bulb	**1,2,8**	**35,0.5,20**
Fan	**5**	**60**
Computer	**1**	**150**
Refrigerator	**1**	**220**
Television	**1**	**65**
Wi-Fi Router	**1**	**10**
Air Condition	**1**	**1500**
Washing machine	**1**	**500**
Water Pump	**1**	**250**
Oven	**1**	**2000**
Blender	**1**	**300**
Charger, Printer etc.	**1**	**20**
Exhaust fan	**1**	**30**

Table 3.1: Load estimation of Appliances.

Time Duration for each appliance to be used in the house:

12am – 6 am: (3 dim light, 1 LED outdoor light, 3 fans, 1 refrigerator, Wi-Fi router)

6am – 8am: (3 fans, 1 energy light, 1 refrigerator, Wi-Fi router)

8am-10am: (4 fan, 1 refrigerator, Wi-Fi router, 2 energy bulb, exhaust fan)

10am-11am: (1 computer, Wi-Fi router, 1 refrigerator, 3 fans)

11am-12pm: (1 computer, Wi-Fi router, 1 refrigerator, 3 fans, 1 exhaust fan, 1 blender, water pump)

12pm-1pm: (Air condition, Wi-Fi router, refrigerator, 2 fans, 1 washing machine, 1 exhaust fan)

1pm-3pm: (Air condition, Wi-Fi router, refrigerator, 2 fans, 1 exhaust fan)

3pm-5pm: (3 fans, Wi-Fi router, refrigerator, 1 computer, television)

5pm-6pm: (3 fans, Wi-Fi router, refrigerator, 1 computer, television, Oven)

6pm-8pm: (refrigerator, Wi-Fi router, 1 LED outdoor bulb, 5 fans, television, 6 energy bulb)

8pm-9pm: (refrigerator, Wi-Fi router, 1 LED outdoor bulb, 5 fans, television, 6 energy bulb, Air Conditioner, (Charger, printer etc.), exhaust fan)

9pm-11pm: (1 LED outdoor bulb, 4 energy bulb, Wi-Fi router ,1 refrigerator,1 television, 3 fans, Air Conditioner, Computer)

11pm-12am: (1 LED outdoor bulb, 3 dim light, Wi-Fi router ,1 refrigerator,1 television, 3 fans)

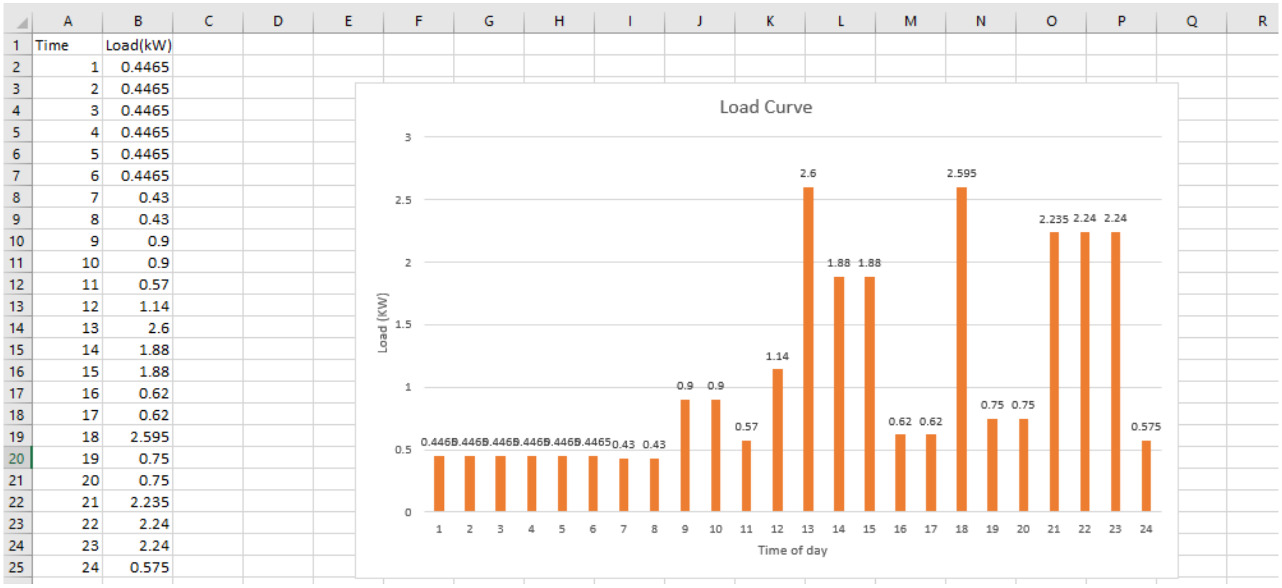
Total Energy Consumption at different hours of the day.

Time duration	Load run this time	Total load energy
12 am – 6 am	3 dim lights, 1 LED outdoor light, 3 fans, 1 refrigerator, Wi-Fi router	(0.5*3+ 35+60*3+220*1+10) *6 = 2679 =2.679 kwh
6am- 8am	3 fans, 1 energy light, 1 refrigerator, Wi-Fi router	(3*60+ 20+220+10) *2 = 0.86 kwh
8am - 10am	4 fan, 1 refrigerator, Wi-Fi router ,2 energy bulb, exhaust fan	(4*60+220+10+20*2+30)*2=1080=1.8 kwh
10am- 11am	1 computer, Wi-Fi router, 1 refrigerator, 3 fans	160+10+220+3*60=570=0.57 kwh
11am - 12pm	1 computer, Wi-Fi router, 1 refrigerator, 3 fans,1 exhaust fan, 1 blender, water pump	150+10+220+3*60+30+300+250=1140= 1.14kwh
12 pm – 1 pm	Air condition, Wi-Fi router, refrigerator, 2 fans,1 washing machine, 1 exhaust fan	1500*1+10+220+2*60+500+10 =2360=2.6 kwh
1pm- 3pm	Air condition, Wi-Fi router, refrigerator, 2 fans, 1 exhaust fan	(1500+10+220+2*60+30)*2=3760=3.76kwh
3pm – 5 pm	3 fans, Wi-Fi router, refrigerator, 1 computer, television	(55*3+10+220+160+65)*2=1240=1.24 kwh
5pm- 6pm	3 fans, Wi-Fi router, refrigerator, 1 computer, television, Oven	3*50+10+220+150+65+2000 =2595=2.595 kwh
6pm – 8pm	refrigerator, Wi-Fi router, 1 LED outdoor bulb, 5 fans, television, 6 energy bulb	(220+10+35+5*60+65+6*20)*2=1500= 1.5kwh

8pm-9pm	refrigerator, Wi-Fi router, 1 LED outdoor bulb, 5 fans, television, 6 energy bulb, Air Conditioner,(Charger , printer etc),exhaust fan)	220+10+35+5*60+6*20+1500+20+30=2235=2.235kwh
9pm-11pm	1 LED outdoor bulb, 4 energy bulb, Wi-Fi router ,1 refrigerator,1 television, 3 fans, Air Conditioner, computer	(35+4*20+10+220+65+3*60+1500+150)*2=4480=4.480kwh
11pm-12am	1 LED outdoor bulb, 3 dim light, Wi-Fi router ,1 refrigerator,1 television, 4 fans	35+3*0.5+10+220+65+4*60=575=0.575kwh
		Total load =26.034kwh

Table 3.2: Total Energy Consumption Chart

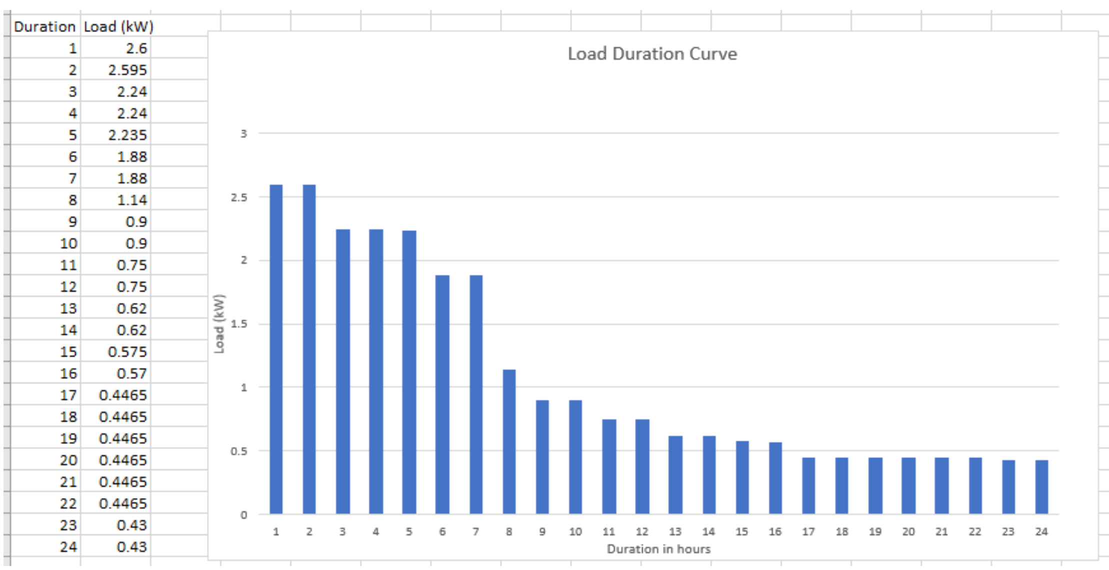
Load Curve: From the load curve we can see the **see** that the peak hours are 12am to 3pm, and during 9pm to 11pm.



Time	Load(kW)
1	0.4465
2	0.4465
3	0.4465
4	0.4465
5	0.4465
6	0.4465
7	0.43
8	0.43
9	0.9
10	0.9
11	0.57
12	1.14
13	2.6
14	1.88
15	1.88
16	0.62
17	0.62
18	2.595
19	0.75
20	0.75
21	2.235
22	2.24
23	2.24
24	0.575

Figure 3.1: Load Curve by Homer

Load Duration curve: We can see that the highest power consumption was 2.6kwh and lowest power needed in 0.43kw which is always required 24/7.



Duration	Load (kW)
1	2.6
2	2.595
3	2.24
4	2.24
5	2.235
6	1.88
7	1.88
8	1.14
9	0.9
10	0.9
11	0.75
12	0.75
13	0.62
14	0.62
15	0.575
16	0.57
17	0.4465
18	0.4465
19	0.4465
20	0.4465
21	0.4465
22	0.4465
23	0.43
24	0.43

Figure 3.2: Load Duration curve by Homer

Location: We chose a location in Bangladesh where there is development going on but less amount of grid power available.

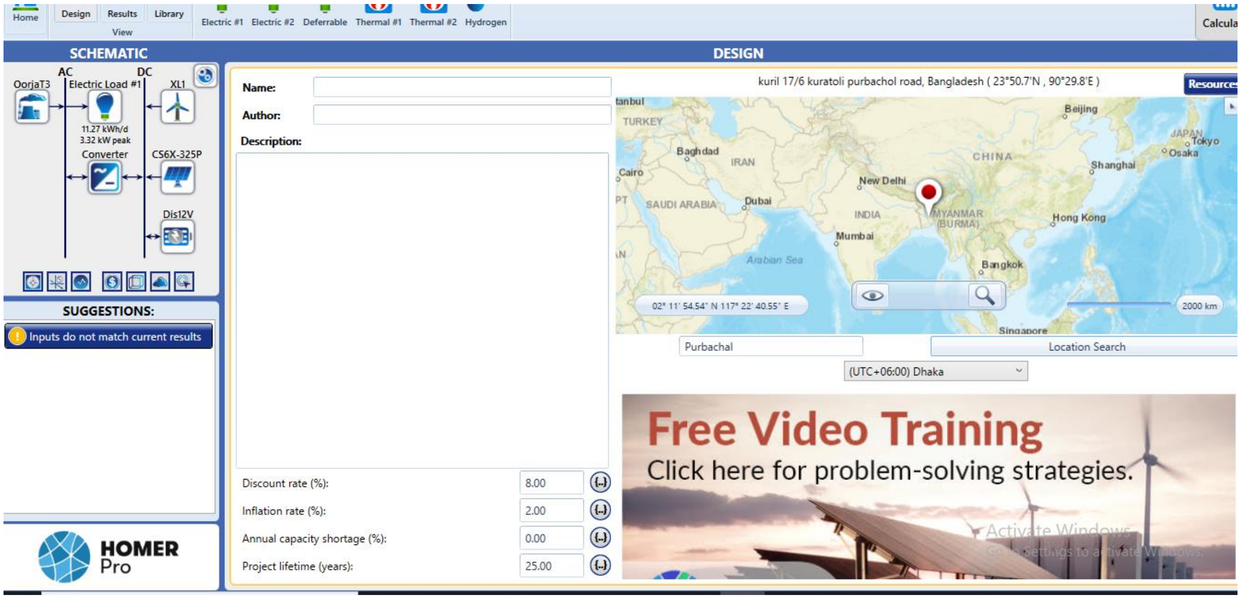


Figure 3.3: Selected Location of Homer

Schematic:

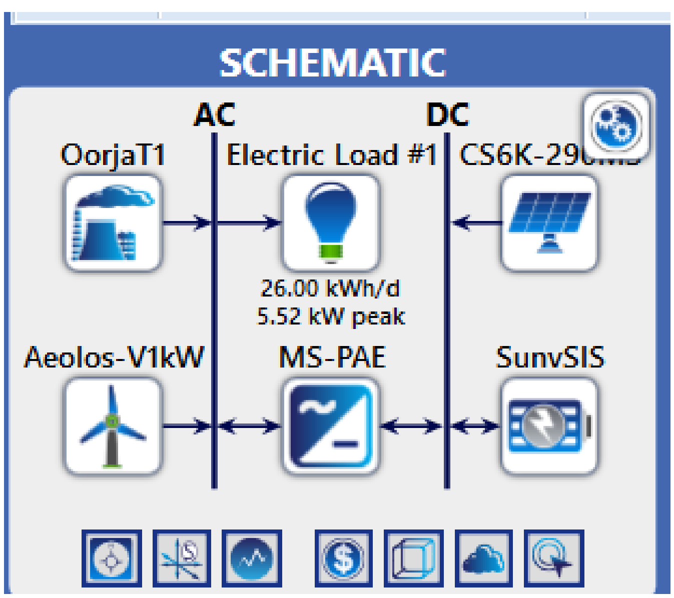


Figure 3.4: Homer Schematic

Solar GHI Recourses extracted from NASA worldwide solar data from 1983-2005, found in homer grid pro.

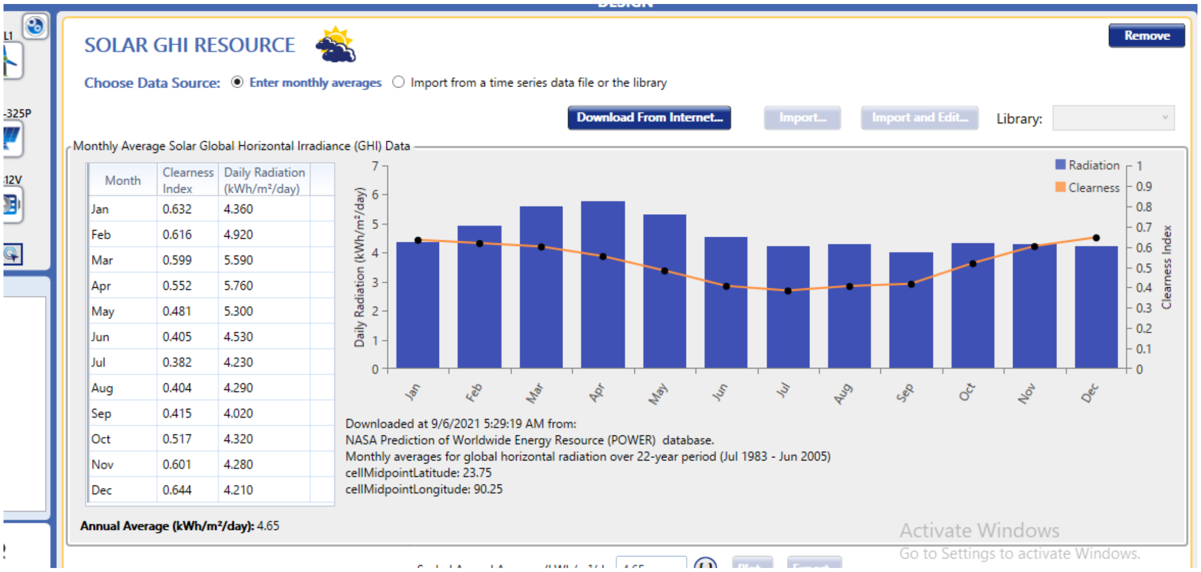


Figure 3.5: Solar GHI Resource

Wind resource:

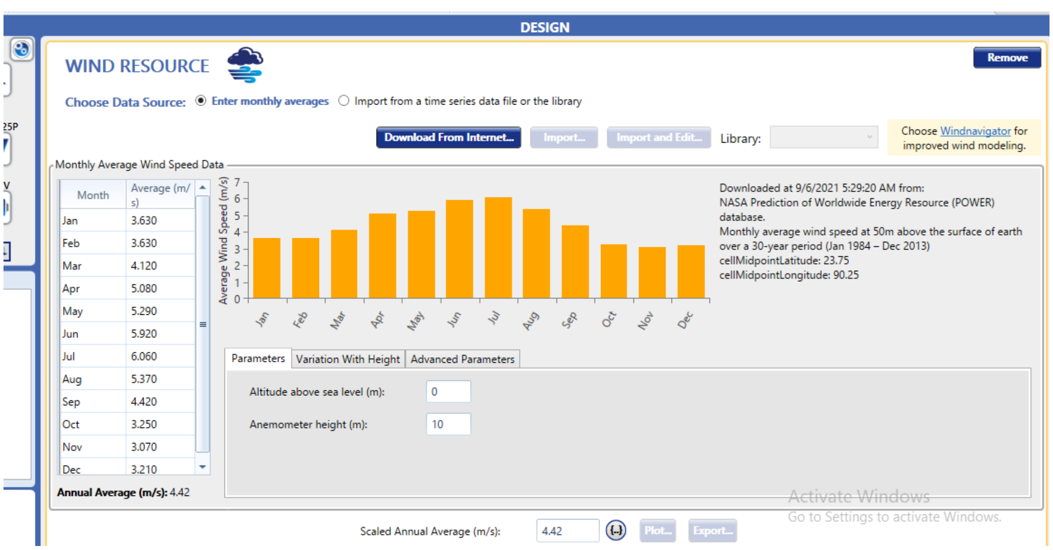
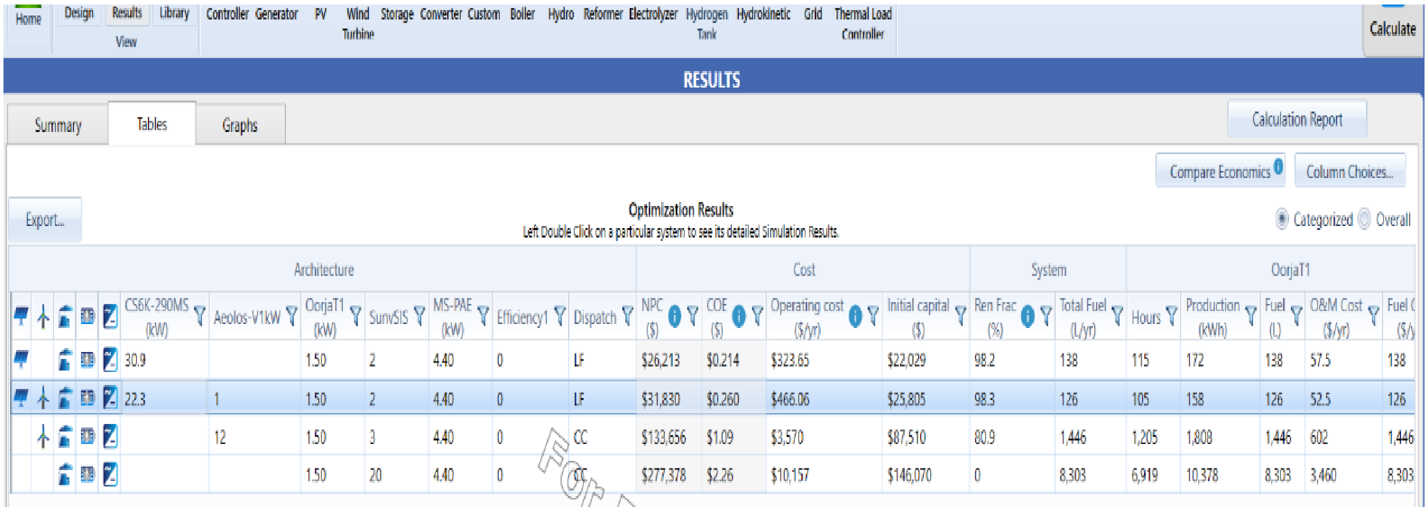


Figure 3.6: Wind resource

Optimization Results: Amount of solar and wind turbine sets needed for the project are given here, along with cost calculations. Although the most optimized set up has no wind turbine, we will be choosing the second one in order to keep a diff energy backup, renewable energies are not constant.



Architecture							Cost				System		OorjaT1				
CS6K-290MS (kW)	Aeolos-V1kW	OorjaT1 (kW)	SunvSIS	MS-PAE (kW)	Efficiency1	Dispatch	NPC ($)	COE ($)	Operating cost ($/yr)	Initial capital ($)	Ren Frac (%)	Total Fuel (L/yr)	Hours	Production (kWh)	Fuel (L)	O&M Cost ($/yr)	Fuel C ($/y
30.9		1.50	2	4.40	0	LF	$26,213	$0.214	$323.65	$22,029	98.2	138	115	172	138	57.5	138
22.3	1	1.50	2	4.40	0	LF	$31,830	$0.260	$466.06	$25,805	98.3	126	105	158	126	52.5	126
	12	1.50	3	4.40	0	CC	$133,656	$1.09	$3,570	$87,510	80.9	1,446	1,205	1,808	1,446	602	1,446
		1.50	20	4.40	0	CC	$277,378	$2.26	$10,157	$146,070	0	8,303	6,919	10,378	8,303	3,460	8,303

Figure 3.7: Optimization Results

Cost Summary: As we can see most of our money is going behind storage unit, to store more energy as we don't have grid option. The wind Turbine is also quite expensive but because solar energy is not available all the time, wind turbine will give a backup and work complimentarily with the solar panel.

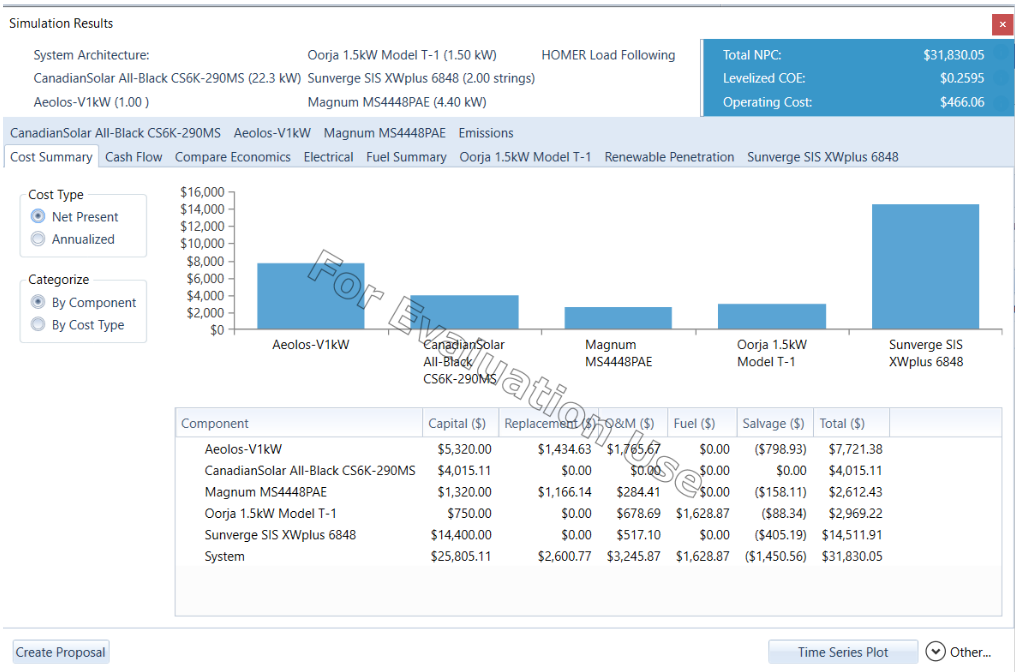


Figure 3.8 Cost Summery

Electrical Summary

It seems that with the set-up we get from the homer simulation there is way too much extra energy produced which will get wasted. This energy can be sold to other households or government or we can reduce the number of panels solar units suggested in the homer simulation. A good option wd be to use 20 solar panels which gives a total output of 5.8kW.

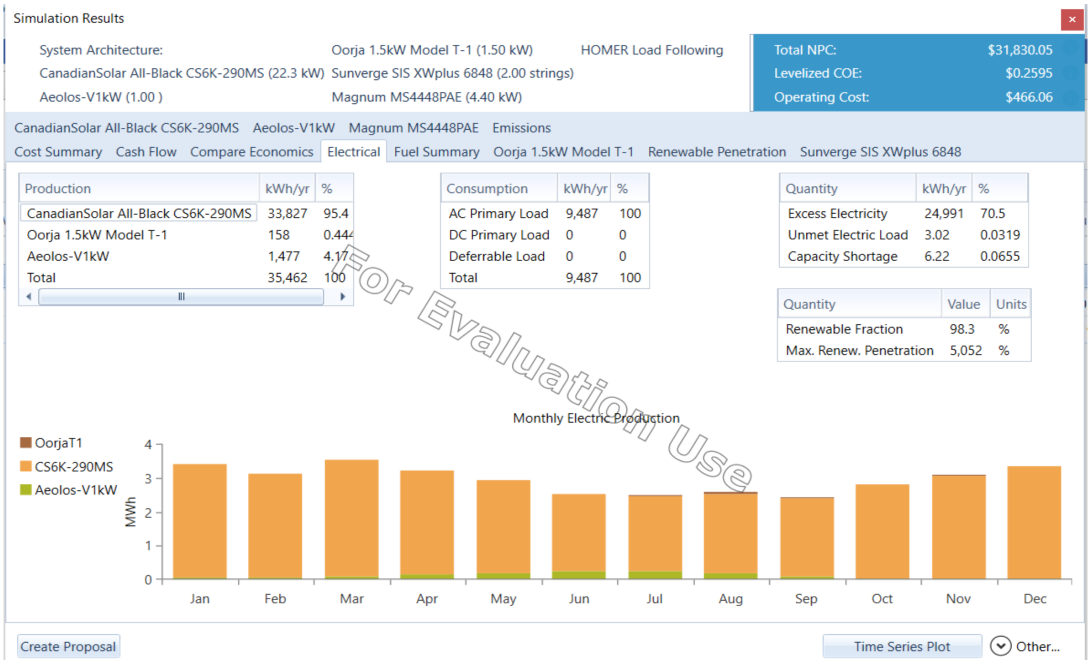


Figure 3.9: Electrical Summery

3.2 Required Components:

This section offers a detailed estimate of the project's components. To complete this project effectively, we initially planned to create a hardware module. We created a circuit module that uses a microcontroller chip to operate a variety of gadgets. The components that w used to construct our smart home energy management system using renewable energy system are listed below.

Required Components For the project:

Name of the Components	Ratings	No. of Components
Solar panel	Maximum power 290W 12V rated Voltage Type: Flat plate.	**20**
Wind Turbine	1kW	1
Charge Controller	12V hybrid Solar-Wind Charge controller.	1
Inverter	4500W, 12V DC to 220V AC	1
Energy Meter-Pzem-004t	Maximum 100 amp	3
Current Sensor	Current Transformer, 100A AC Current Sensor	Dependent on number of appliances
Voltage Sensor	DC voltage sensor VCC < 36V	2
LCD Monitor	16x2 I2C LCD monitor	1
4 Channel relay	5V 4 Channel relay for microcontrollers.	Dependent on number of appliances.
1 Channel relay	5V 2 Channel relay for Microcontrollers	1

Microcontroller	Esp32 wroom, Esp32 Doit, esp32Wrover or better	1-5 depending on amount of appliance being controlled and monitored
Battery	12V 11kwh Lithium-ion battery	1
Home Server and app	Blynk	N/A
Generator	3kW Auto start AC Generator	1

Table 3.3 Required Components List

3.2.1 Hardware Modules:

I. Microcontroller:

In the technological revolution that has influenced modern life, the microcontroller has played a crucial, if not dominant role. Microcontrollers are compact, adaptable, and low-cost devices that may be effectively implemented and programmed not only by expert electrical engineers, but also by amateurs, students, and professionals from a variety of fields [13].

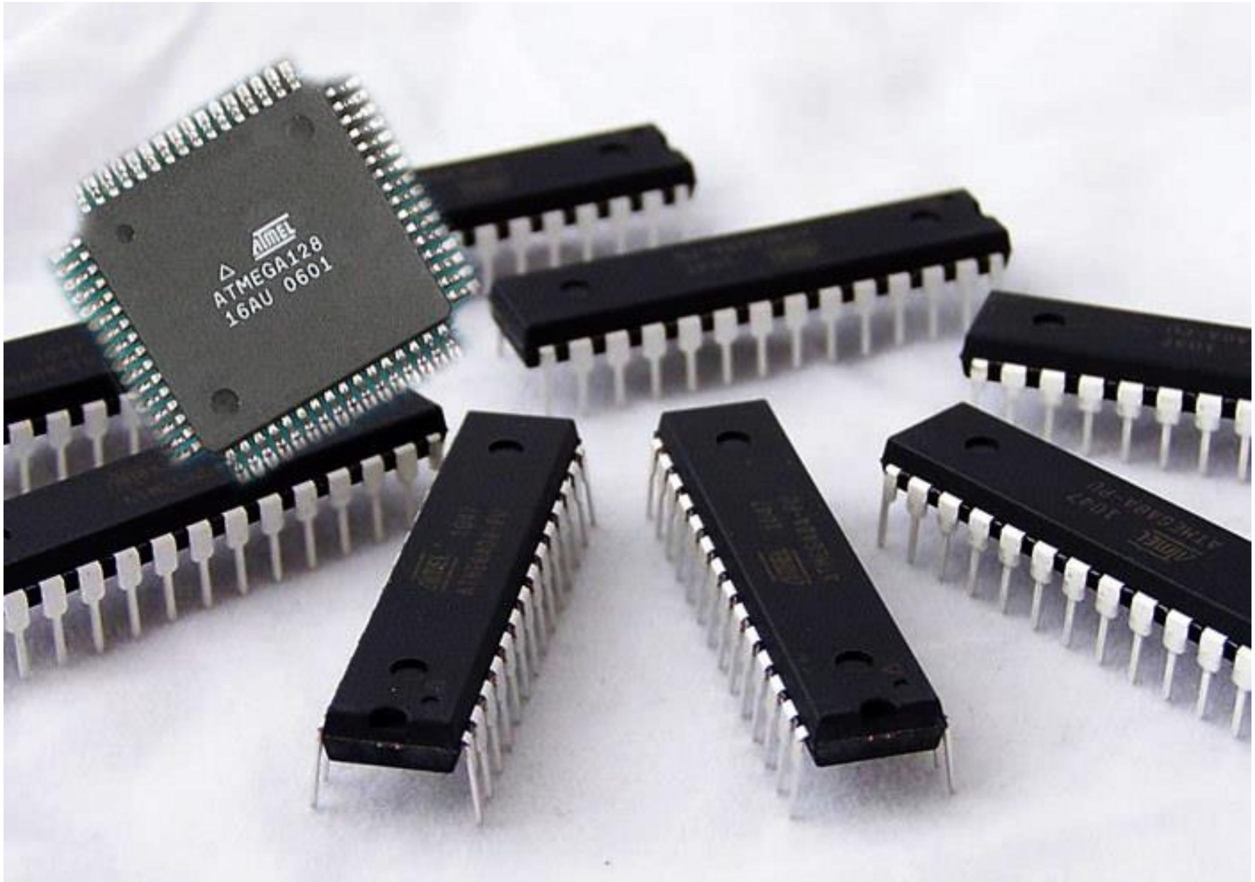


Figure 3.10: Different types of Microcontrollers [13]

A microcontroller is an integrated circuit (IC) that uses a microprocessor unit (MPU), memory and various peripherals to control other portions of an electronic system. These devices are made for embedded applications that require processing and responsive interaction with digital, analog and electromechanical components.

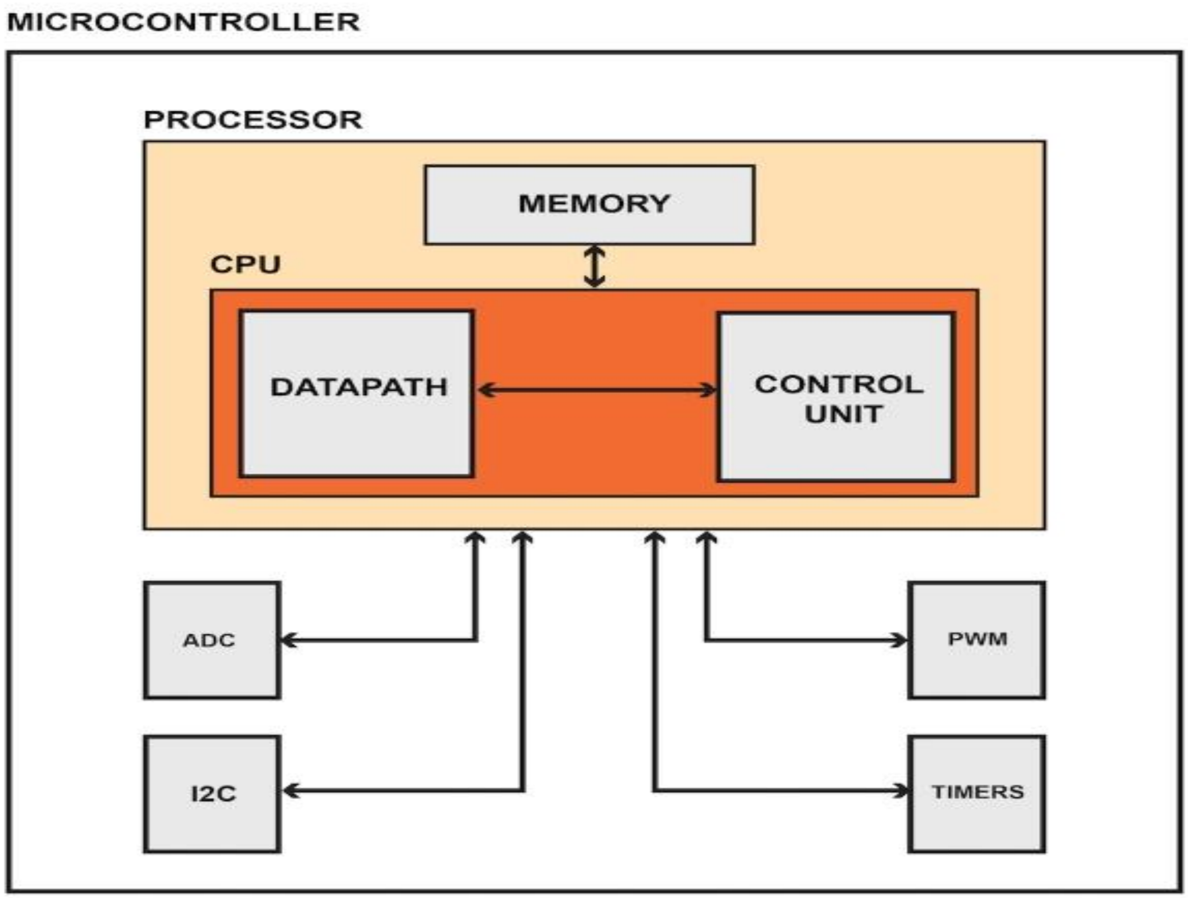


Figure 3.11: Microcontroller Working Principle

In this study, we use Espressif Systems' ESP32, which is developed for Internet of Things and embedded system projects. The ESP32 is cheap and low-power system on a chip microcontroller series that has Wi-Fi and Bluetooth features. It has a highly integrated structure driven by a dual-core Tensilica Xtensa LX6 microprocessor [13]. A smart home energy management system employing renewable energy, based on the ESP-WROOM-32 and a mobile application is discussed in detail as an example of successful practical implementation of the device.

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II. Relays:

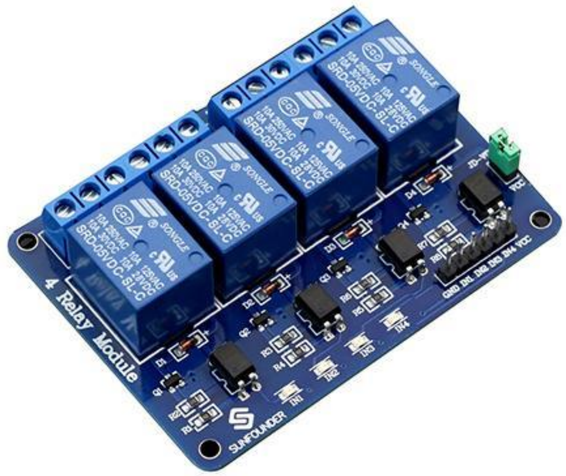

Figure 3.12: 4 Channel Relay [14]

Relays are one of the most basic components, but they are also one of the most crucial since they serve as the link between low and high-power digital circuits. In order to turn on or off, digital circuits and microcontrollers use the help of relays [14]. When current is passed via the coil of a relay, it initiates a magnetic field. When electricity is applied to the primary circuit, the electromagnet is activated, resulting in magnetic field that attracts a contact and the secondary circuit started to run. A spring pulls the contact again to the original form, turning off the secondary circuit once again at the time of the power is turned off.

III. Voltage Sensor

The Voltage Sensor is a low-cost voltage sensor that is both accurate and reliable. It is designed using the resistive voltage divider method. The Voltage Detection Sensor Module is a straightforward and useful module that uses a potential divider to lower any input voltage by a factor of 5. This allows us to use a microcontroller's Analog input pin to monitor voltages that are higher than the microcontroller can detect. For example, it can be measured a voltage up to 25V with the 0V - 5V analog input range. This module also incorporates handy screw terminals for quick and secure wire connections. It’s really simple to connect a voltage sensor to an esp32 or any other microcontroller [16].

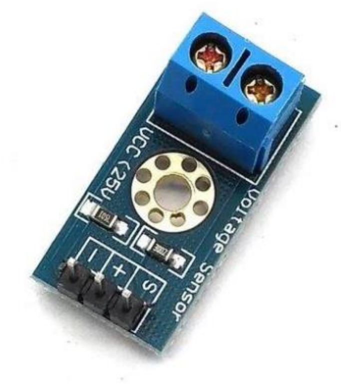

Figure 3.13: Voltage Sensor 16]

Voltage sensors can be custom made by using resistors to make voltage dividers of different dividing factors. For a VCC >36 V resistor we can use the following circuit with esp32 to divide that input by a factor of 11 and converting it to highest 3.3V output.

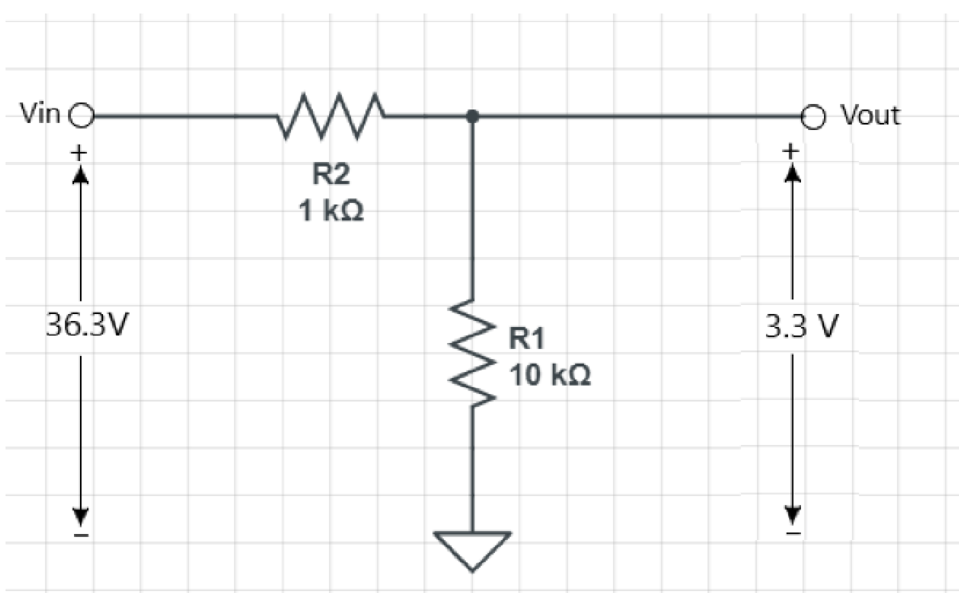

Figure: 3.14 Custom Voltage sensor VCC <36 V

IV. Inverter

One of the most important components of a solar energy system is the inverter. It's a device that converts direct current (DC) electricity generated by solar panels into alternating current (AC) electricity that the grid can use. [17] DC maintains a steady voltage in one direction, on the other hand electricity flows in both directions in an AC circuit as the voltage changes from positive to negative. Inverters are a type of power electronics device that controls the flow of electricity.

Figure 3.15: Inverter [17]

Inverters convert DC to AC by quickly flipping the direction of a DC input. As a result, a DC input transforms into an AC output. Filters and other electronics can be used to create a voltage that varies as a clean, repeating sine wave that can be delivered into the power grid. The sine wave is the shape or pattern that voltage takes over time, and it is the power pattern which the grid can use without harming electrical equipment built to operate at specified frequencies and voltages.

V. Charge Controller

A charge controller is an electronic device that regulates the electricity that flows into the battery bank from the solar array. It prevents the deep cycle batteries from being overcharged during the day and power from being returned to the solar panels overnight, draining the batteries. Although some charge controllers include some extra facilities like lighting or load management where the primary responsibility is to control the electricity.

Figure 3.16: Solar Charge Controller [17]

PWM and MPPT are two alternative technologies of solar charge controllers [17]. An MPPT charge controller is more costly and more efficient compare to a PWM charge controller and this extra cost is usually justified. In our case we will be using a 24V solar wind hybrid charge controller that can take energy inputs from both DC solar panels and AC wind turbine to charge a battery. They usually contain an AC to DC converter to change the wind Energy input to DC to charge the battery.

VI. Pzem-004t:

Pzem-004t is a module used for measuring voltages, currents, frequencies, power, power factor and energy in kWh. It is essentially an energy monitoring sensor with the complete package. It can measure up to 100A current and communicates digitally through RX TX pins [21].

VII. Current sensors:

We can use SCT-013 for measuring the AC currents flowing through the loads. These spit cores are current transformers that can measure the amount of current flowing through the wire that is placed inside its clamp. These sensors are quite accurate and can be found in 30A, 50A and 100A modules [22].

Figure 3.17: SCT-013 current transformer.[22]

VIII. **Blynk:**

We are going to use Blynk app in order to monitor and control the loads from our phones. Blynk is an IOT based smart phone app that lets users make their own projects and connect the app with the IOT based microcontrollers to receive and send data using virtual pins. The interface of the app is very user Friendly and very little knowledge is required to make your own project using Blynk app.

3.3 Explanation of Project Components Setup:

3.3.1 Planning

We planned to do a project on smart home energy management system using renewable energy such as wind and solar. Due to the current energy crisis, major energy reductions are required in all domains. As more residential appliances are installed, the energy consumption in these regions has increased [18]. Energy conservation and the use of renewable energy sources are two options for addressing the household energy problem. To reduce household energy costs, both energy consumption and generation should be evaluated at the same time. Moreover, some remote areas all over the world where grid is not available, we can implement this project in order to generate electricity and save it at the same time.

3.3.2 Project Implementation Procedures

The Internet of Things (IOT) is a term that refers to the interconnection of devices through the use of embedded systems. Home Automation is the backbone of Smart Homes, as it allows to control all of the appliances without having to get close to the switches [15]. Embedded systems have made home automation more affordable. The embedded system provides user comfort, security, and adaptability while also preserving a high level of living.

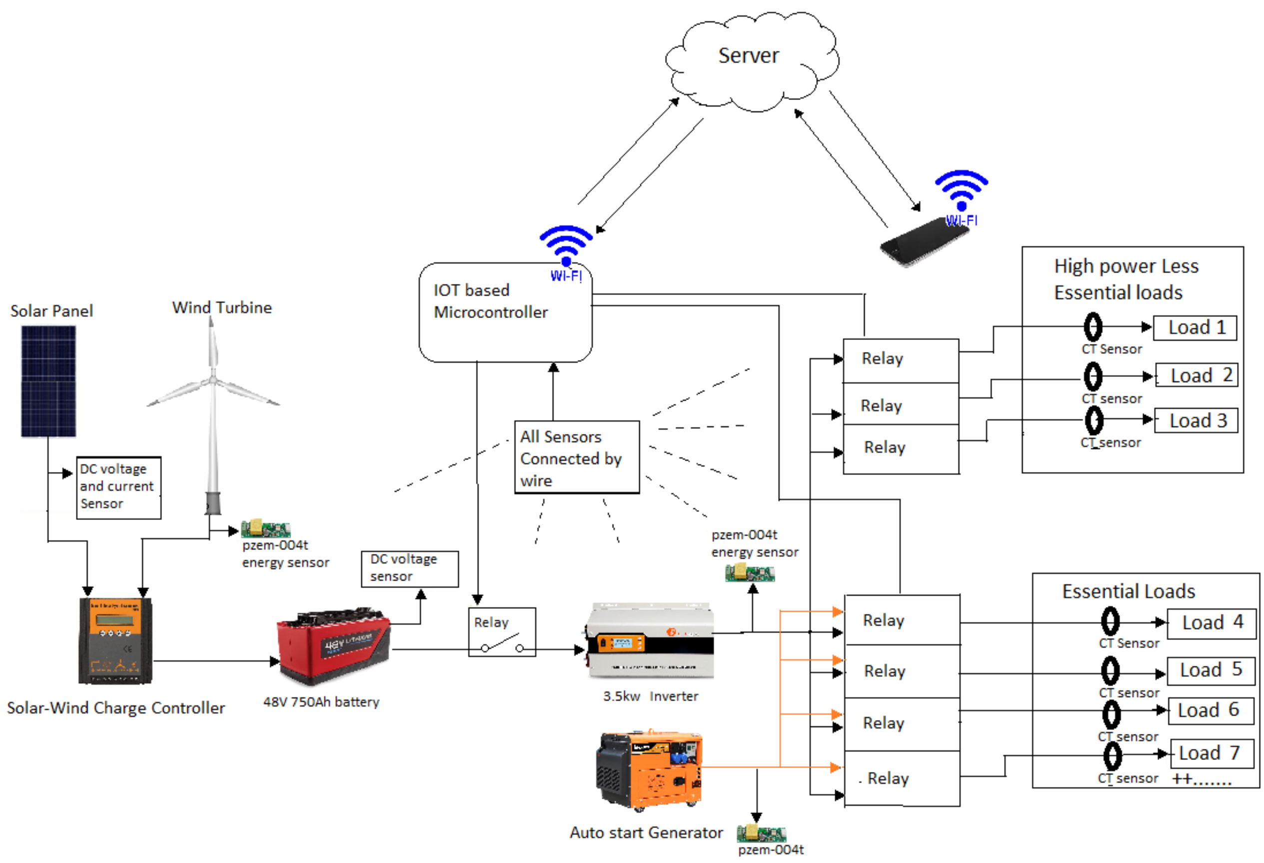

Figure 3.18: Complete Project Setup View

In this project work, we investigate a smart home scenario in which the goal is to adjust the task execution of controlled appliances in order to reduce power costs and maximize the usage of renewable energy sources. Here Energy will be produced by the solar and wind turbine modules which will then be stored in the battery using hybrid charge controller. Then the energy will be converted to sinusoidal 220V AC current so that the loads can use the energy. And the generator will be present as back up for when stored renewable energy is low.

For management and monitoring, we can start by, measuring energy output of the wind turbine using pzem-004t Module. The amount of renewable energy consumed and energy consumed from the generator can also be measure using pzem-004t module by placing pzem-004t at the place shown in the diagram. We can measure the current and voltage output of the solar cells using DC current and voltage sensors and use P=IV to find the energy output. We can find the Stat of Charge of the Li-ion battery by measuring the voltage of the battery using a voltage sensor as well. We can also measure the Current of individual loads using AC current sensors. Then we can measure the energy consumed by each appliance using the following formulas:

- Power = Voltage and power factor measured from generator or renewable energy* Current of individual appliances.
- Energy= Energy + Power x Time in Hours.

We will need more than one microcontroller as there are way too many inputs and outputs to handle for a single microcontroller. These microcontrollers can be bridged together using Blynk

App so that they can work together.

After taking all these data the microcontroller will send the data to our smart-phones using Blynk server via the internet. Now the user can see all the data and decide which loads to run and which to be shut down according to the users need and energy production capability of the renewable sensors on a particular day remotely using the app, which then send a signal to the microcontroller resulting in the appliances being turned on or off using relays. The microcontroller will also isolate the renewable energy and the loads when the battery goes down to 20 percent by using a relay to prolong battery life. It will simultaneously turn the generator on as back up, although it will power the essential loads only. Blynk will also give notifications at low battery levels for alerting the user. You can see the flow chart of the system in the next section.

3.3.3 Flow Chart:

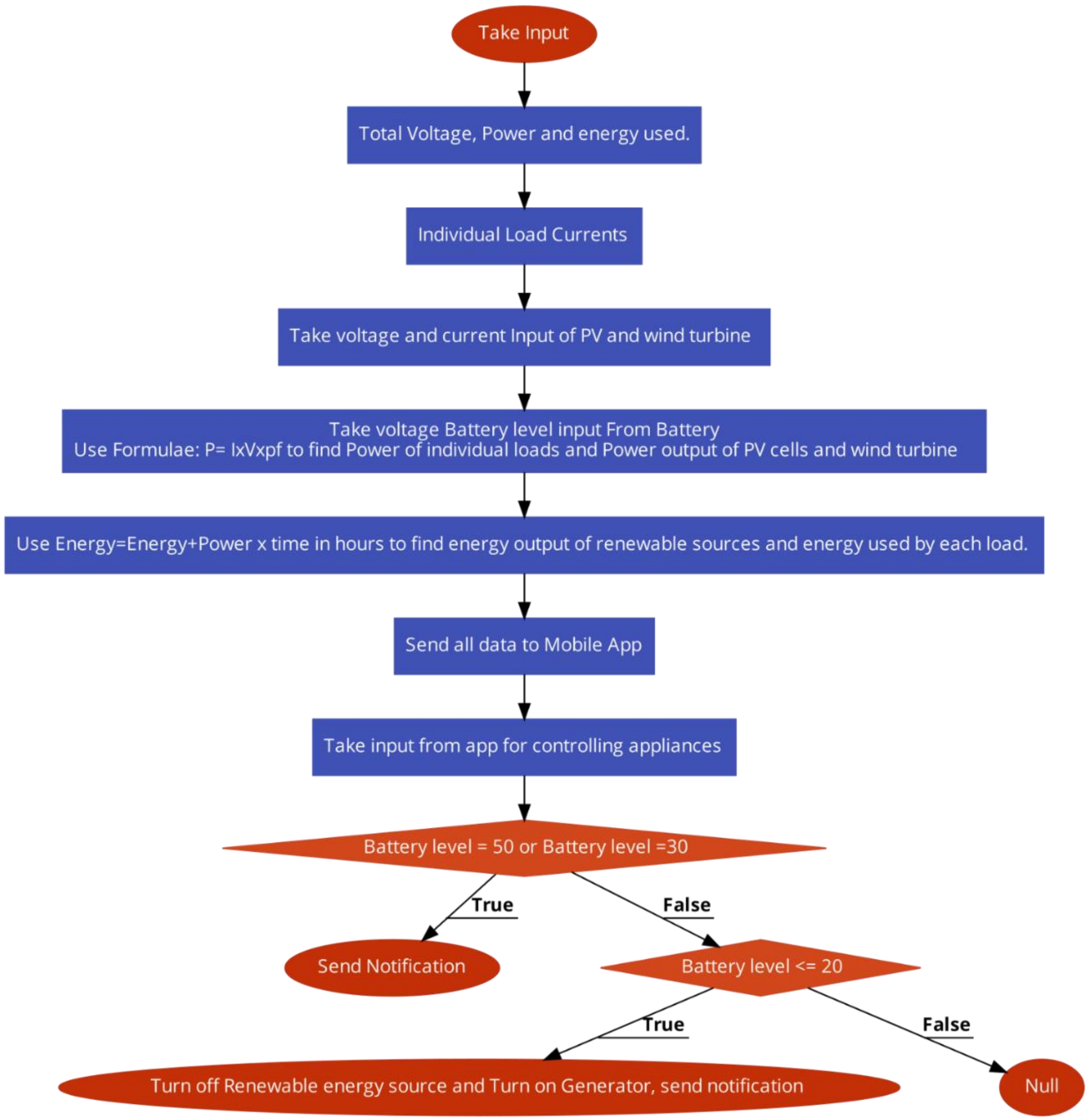

Figure 3.19: System Flow Chart

Chapter 4

Prototype Implementation and Experimental Platform

4.1 Introduction to Smart Home and Renewable Energy System

Carbon emissions on the planet have increased significantly in recent years as a result of industrialization, automation, and people's modern lifestyles. The use of nonrenewable energy sources is heavily reliant on it, which has resulted in global warming due to ozone layer depletion. As a result, using renewable energy sources is a very effective method of reducing carbon emissions [20]. Renewable energy sources, such as solar energy, are increasingly being used in home automation systems.

4.1.1 In quest of a smart home energy management system

Many businesses have been forced to invent new systems for monitoring, managing, and conserving energy as the cost and demand for energy has increased [18]. A smart energy management system (EMS) can help us to save money satisfying energy needs. The Internet of Things (IoT) and Big Data are two developing technologies that can help homeowners, businesses, and industries better control their energy consumption. The goal of this project is to present a renewable energy-based Energy Management System (EMS) for smart homes.

All electronic components, subsystems, and systems of the home and business, such as heating, garage doors, entrance gates, shutters, electronic outlets, and so on, are included in home automation. Home automation has been created to provide technical solutions to address comfort needs such as energy management and lighting and heating optimization. As a result, communication networks using two twisted lines, fiber optics in a bus-based network, or an internet protocol as a standard have improved. The rapid advancement of device and communication technologies opens up possibilities for electronic system development.

Data acquisition is critical in a variety of applications, including industrial monitoring and control, home automation, water monitoring, and health monitoring, among others. In recent years, long-distance monitoring has become important. As a result, the internet of things (IOT) framework, a web-based remote monitoring framework, is a possibility [18]. Work to regulate and monitor household equipment has been created, implemented, and monitored. Where data may be monitored using a web browser and accessed via web browser devices such as a computer, laptop, or small mobile phone. In the suggested system, a minimum cost credit card sized microcontroller, such as the ESP32, can be employed.

The proposed system designed and implemented on a credit card shaped ESP32 which can control and monitor household equipment such as fan, lights, air conditioning, water pump, and so on via the internet based android apps.

4.1.2 Environmental Impact and Economic Analysis Scheme

In the near future, renewable energy will play a significant part in electricity generation. The three types of energy resources are commonly classified as follows: fossil, renewable, and nuclear. Hydropower, wind, solar, biomass, ocean energy, biofuel, geothermal, and other renewable energy sources provide for 15–20 percent of total global energy [20]. The world will soon become a global village due to the rising demand for energy as a result of the world's fast-growing population.

Solar panels, which use the sun's rays to generate power or heat, must be assessed. Solar energy cannot operate at night without a storage device, such as a battery, and overcast weather can cause daytime inconsistency. Solar energy is still valuable, but more research is needed to learn how to get the most out of it. To summarize, renewable energy installations are crucial to keeping global warming below 2°C, and their environmental and economic consequences should be researched as fully as non-renewables to attain their full potential [19].

4.2 Prototype Project Planning and Block Diagram

According to our thesis project work, we planned to do a project on smart home energy management system using renewable energy such as wind and solar. However, the situation does not favor us, we are reducing this massive project to a miniature prototype project that can be expanded to many power sectors by enlarging this miniature project. However, a wind turbine was not available for use in this miniature project, we converted mechanical energy to electrical energy, which we used as a wind turbine.

Table 4.1 Price of the Components Used

Components	Total Number of Components	Price (BDT)
I. ESP 32 WROOM	1	550
II. 5V 4 Channel Relay$ 2 Channel Relay	1	400+200 = 600
III. Solar Panel 10 W poly	1	500
IV. 775 motors as wind Turbine	1	300
V. DC Voltage Sensor	1	100
VI. Current Sensor	5	200*5=1000

VII. Inverter	1	650
VIII. 12V Acid Lead Battery	1	750
IX. Breadboard	1	200
X. PZEM-004t	1	1600
XI. Jumping Wires	50	60
XII. Charge Controller	2	200*2 = 400
XIII. Bulb	3	50*3 =150
XIV. 16x2 LCD	1	200
XV. I2C circuit for LCD	1	200
XVI. Digital logic converter	1	100
XVII. Connecting wire for loads	20 gauge	300
XVIII. Fan blades	1	100
XIX. 3.7V lithium-ion battery	4	240
XX. Potentiometers	5	5*30=150
XXI. Blynk Subscription	1	670
Total Cost		7220

4.3 Circuit Diagram of prototype:

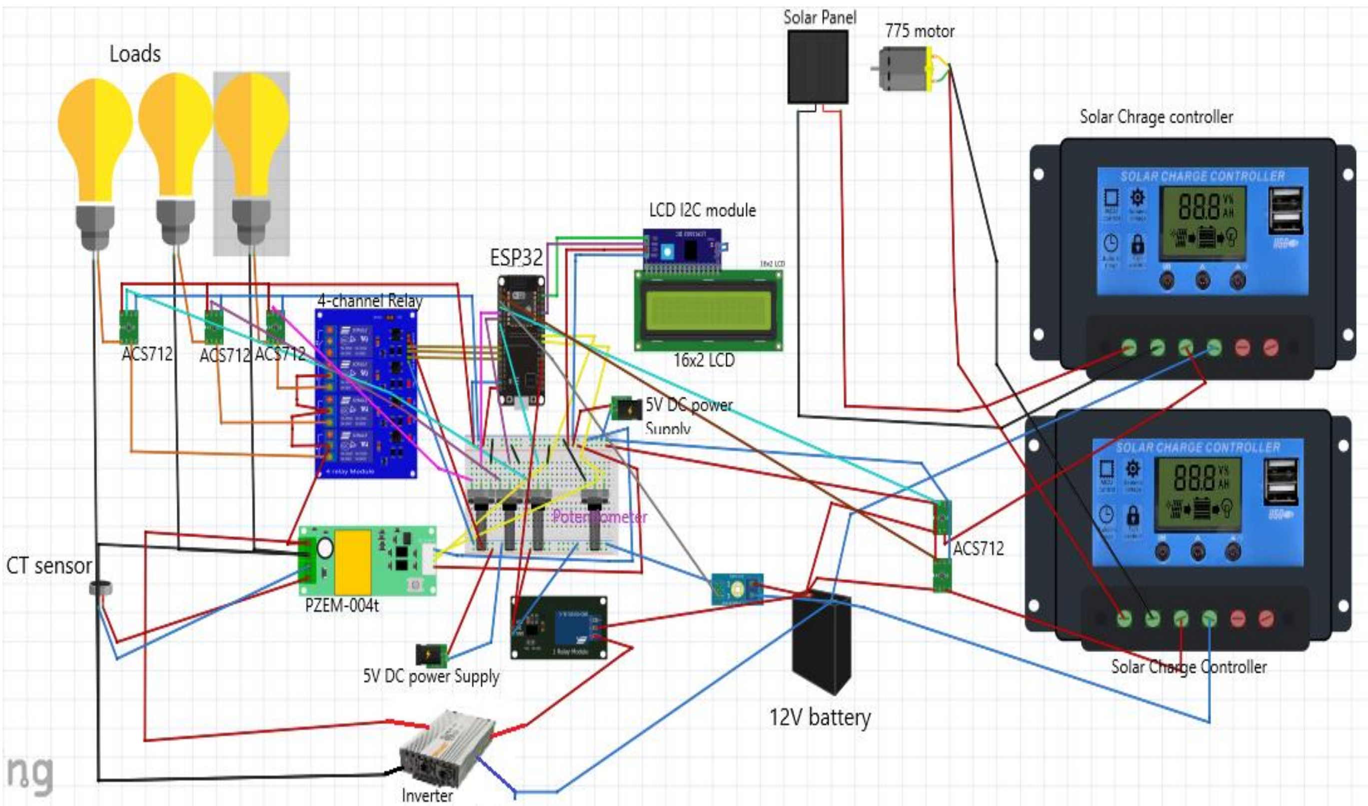

Figure 4.1: Prototype Project Block Diagram

4.4 Prototype project implementation and explanation

The prototype is very much similar to our proposed projects. Although as we cannot spend 1000s off dollars here it only used low grade experimental equipment. We are only using a 10 W solar panel for demonstration purpose and 775 DC motor to simulate a wind turbine, which are very expensive. We are also using cheap solid charge controllers rather than the hybrids ones. The battery we used here is a 12V 7.5Ah lead acid battery which incredibly small. The system however is very similar except for that we don't have a generator in our prototype. So, at low battery, the loads just turn off, as it doesn't have any backup. Here we are using ACS712 current sensors for both AC and DC current reading. This sensor uses hall effect to measure the current flowing through it. To connect in the IP+ and IP- pins internally a copper strip is used. A magnetic field is formed as current flows through this copper wire, which is detected by the Hall Effect sensor [23].

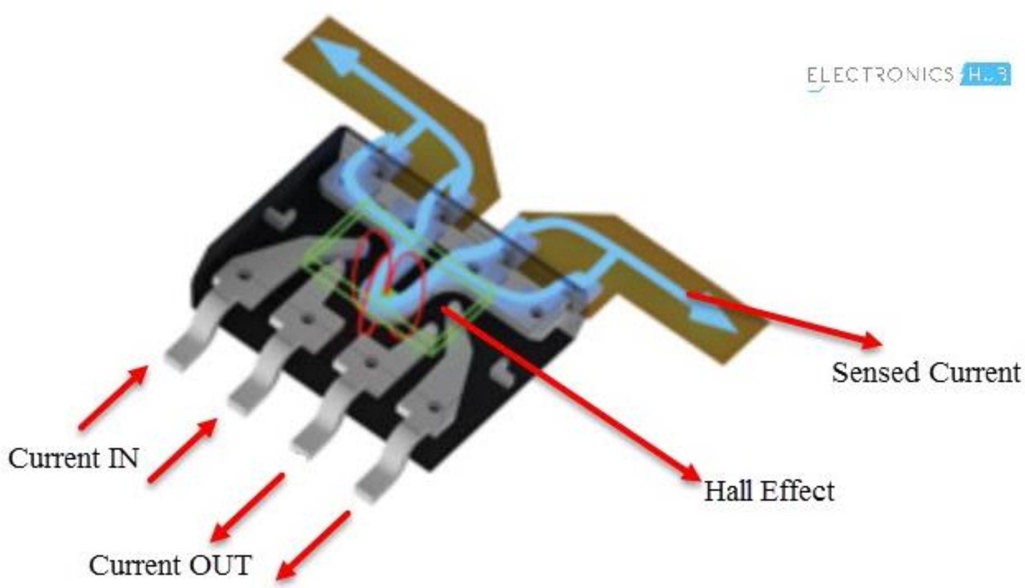

Figure 4.2: Hall effect in ACS712 [23]

Although we wanted to use current transformers but we didn't find it in the market during the project due lack of supplies. We are using 3 LED bulbs to represent our load here. Because there is no generator here and the wind turbine is DC, we do need 3 pzem-004t modules. We are using only one to measure the total load. Everything else is exactly same as the proposed system. The data we get is being displayed in the LCD module and also in the phone using Blynk app.

For measuring the Battery level, we are using SOC vs voltage table of 12V lead Acid battery, which is given below.

State of Charge	12 Volt battery
100%	12.7
90%	12.5
80%	12.42
70%	12.32
60%	12.20
50%	12.06
40%	11.9
30%	11.75
20%	11.58
10%	11.31
0	10.5

Table 4.2: 12V lead acid battery SoC Vs Voltage

Using the chart, it was coded in a way so that we can see the state of charge in the app, and also know if the battery is being charged, as we have come to know from experimentations that the battery is usually charged at 13 or more volt.

The ACS712 was quite tricky to configure as it gave nonlinear ADC values. And because ACS712 operates at 5V whereas esp32 operates at 3.3 V we had to use potentiometer as voltage divider to reduce the voltage output from the sensors and to do that we used a calibration code to see the voltage output. Even for the pzem-004t we had to use voltage divider to lower the voltage level from TX as pzem-004t also operates at 5V, and might damage the esp32.

4.5 Blynk interface and integration

For connecting the Blynk app to the microcontroller we need to add an authentication number in the programing code which is emailed by Blynk after making a project. We also need to include the SSID name and password of the Wi-Fi router in the code so the esp32 can connect with the Wi-Fi. To make a project we need to choose the microcontroller to be used.

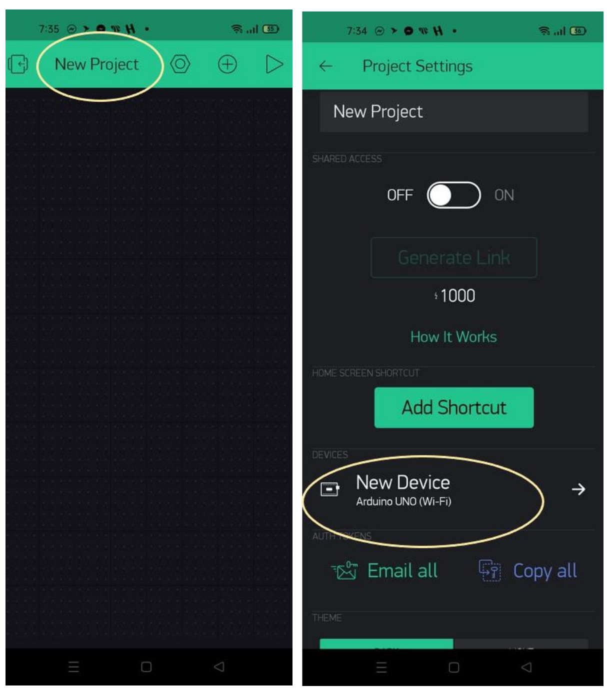

Figure 4.3: How to make new project in Blynk

Then we can add different widgets to the interface to make the project.

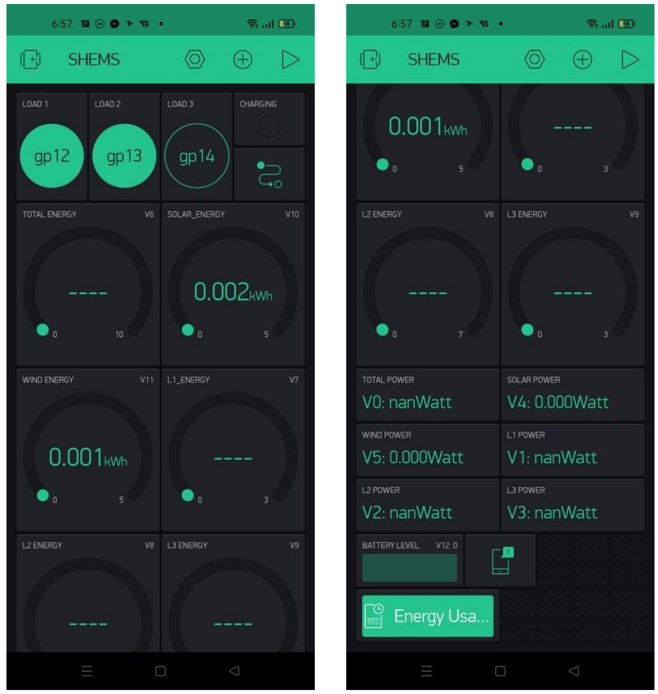

Figure 4.4: Blynk interface.

In Figure 4.4 above we can see all the date in a very graphical way. The energy consumed and produced can be seen as gauges whereas the powers can also be seen as normal values. We can see battery level and also get notifications by making events in the eventer widget The charging led also lights up when the battery is being charged.

To turn loads on and off we get the button widget and choose the gpio pin on which want the button to operate, and then connect the relay to that pin.

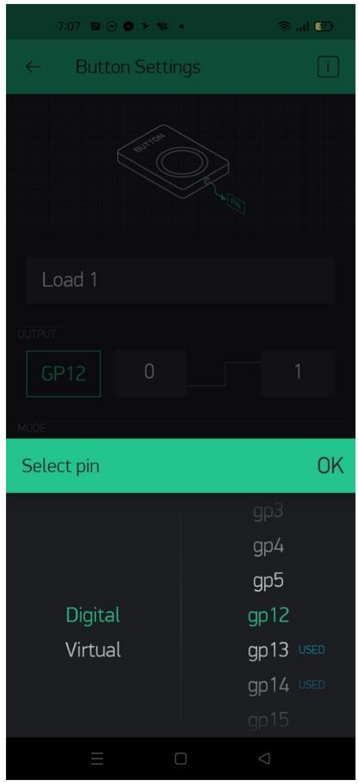

Figure 4.5: Setting buttons to GPIOs

We can get all the values from the microcontroller to the app by using the widget we want and assigning virtual pins to them, which then can be linked to the values in the program code of the microcontroller so that the values can be sent to the app to the particular widget.

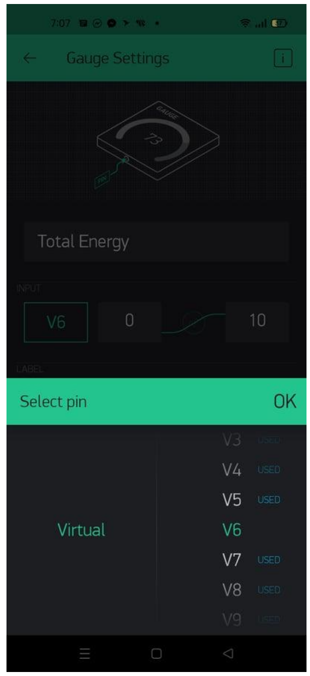

Figure 4.6: Setting virtual pins to different widgets to collect data from microcontroller.

We can give notifications by using the notification and eventer widget. For notifications to come we need to create an event on which there will be a notification. In our case its low battery levels.

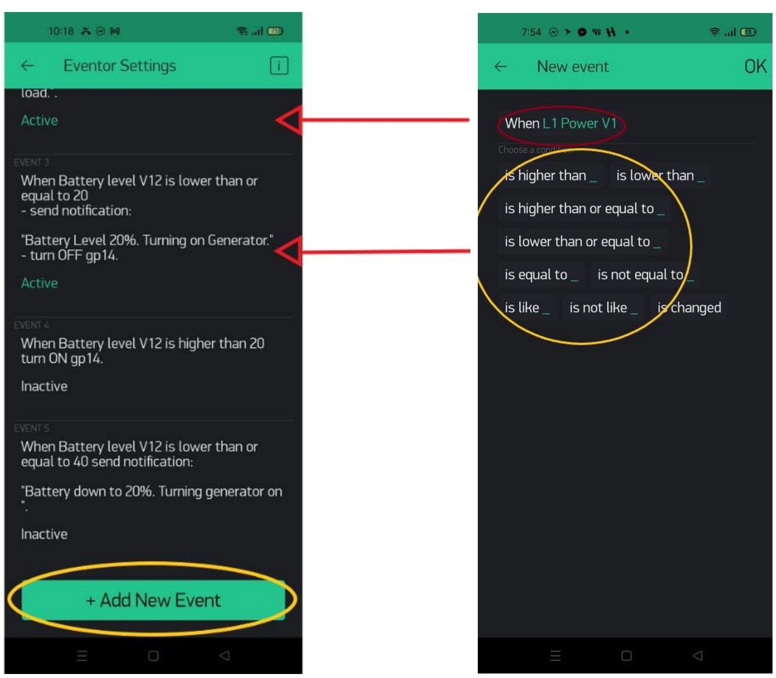

Figure 4.7: How to set notifications.

After integrating all of these things we found found the result which is included in the next chapter.

The Shot of the practical prototype set up given below:

Figure 4.8: Complete Circuit Setup View

Chapter 5

Result and Analysis

5.1 Results

Power energy and other data after 1hr. The charge of the battery is 70 percent. Some energy was produced by the renewable energy too.

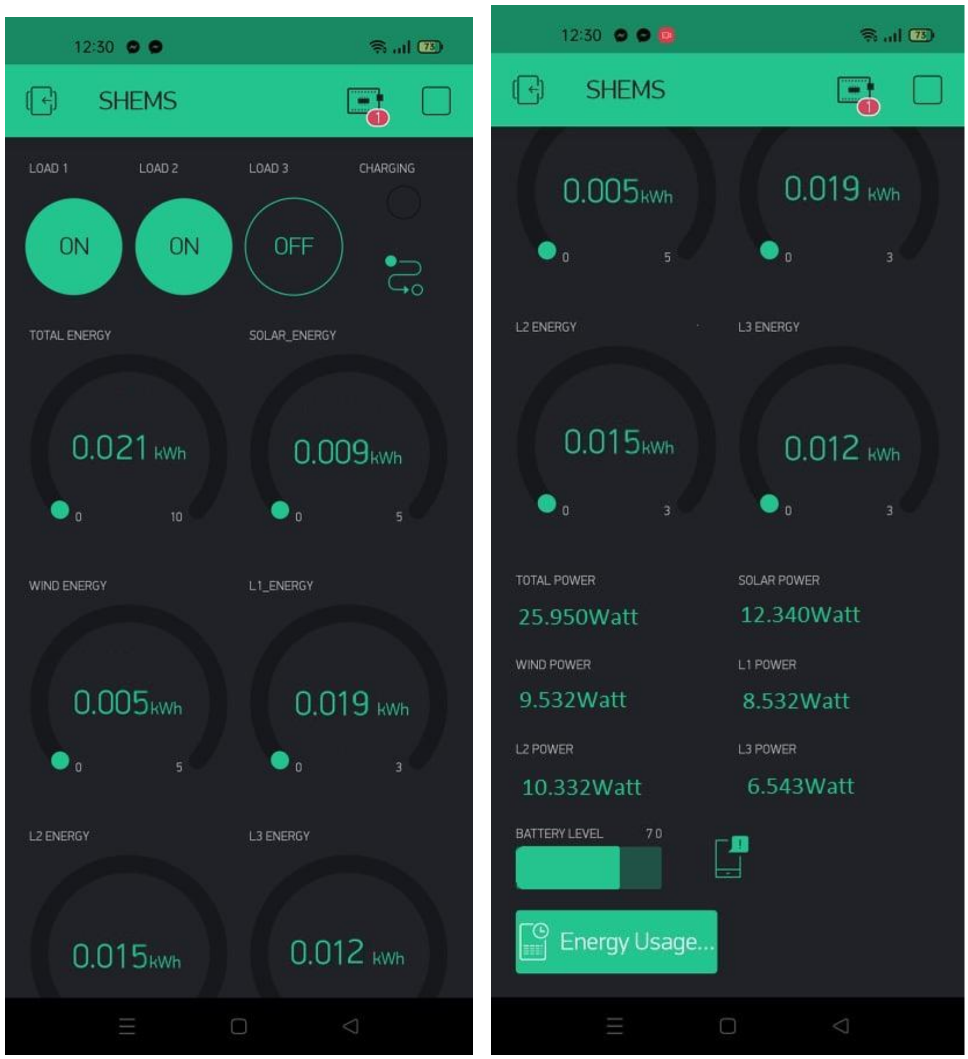

Figure 5.1: Data after 1 hour

Power energy and other data after 2hours. The charge of the battery is 30 percent. Some more energy was produced by the renewable energy too.

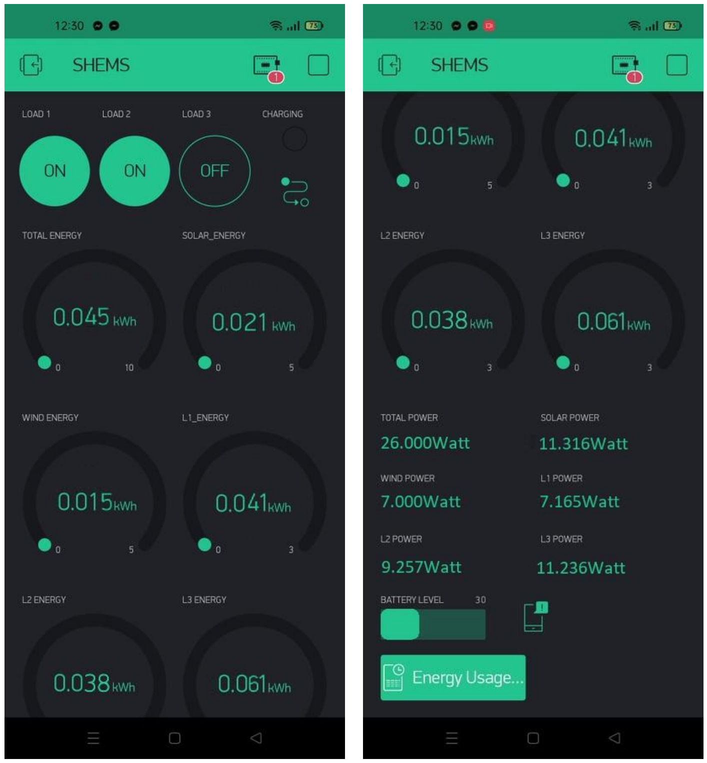

Figure 5.2: Data after 2 hours

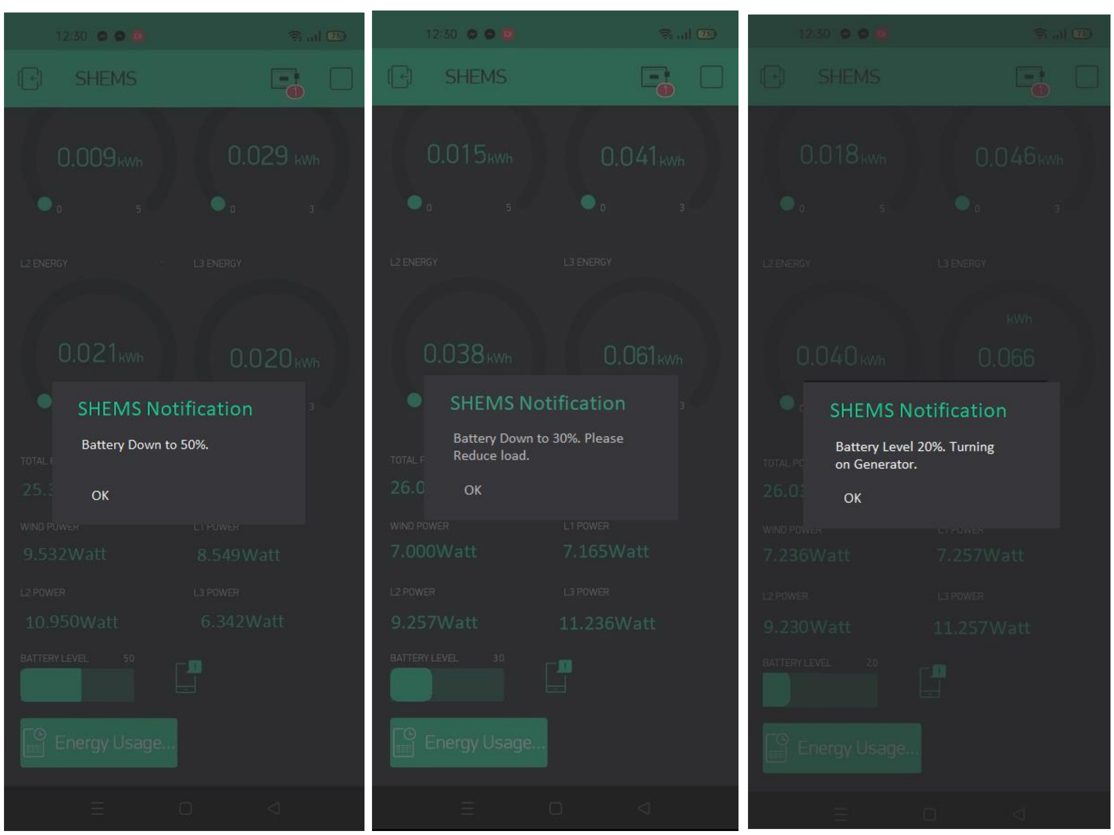

Figure 5.3: Notifications after 50%, 30% and 20% battery levels.

5.2 Analysis and Description

After looking at all the data we found that the pzem-004t give quiet accurate results, but the ACS712 were very inaccurate, as they produced a lot of noise, and the noise which contributed to higher than usual individual load energy consumption. The ACS712 module of 20A range which had lower resolution. Using a 5A modules might have given better result but we couldn't find them in the market. Same goes for the SCT-013 CT modules. They are usually a lot more accurate and stable and because it gives 1V output max, it would have been easier to configure as well. The battery ran out too fast and neither could the renewable energy sources give enough support for more than 2 hours, but it was expected as the battery and the solar modules were too small, and was only there for demonstration and not for practical work. The code worked perfectly and gave all the values to the LCD and the app. The loads could be easily turned on and off from the app and the notifications came properly in time. Even the renewable energy turned off automatically at 20% charge level.

It seems Using some better and higher end sensors and parts can improve the results drastically. It seems the project was successful, as it gave a good indication that the proposed plan can be executed without any problem by following the methodology using better equipment.

Chapter 6

Conclusion and Future Work

6.1 Conclusion

Nowadays the world is heading towards renewable energy sources as natural resources like oil, natural gas is on the wane. The usage of renewable energy sources is significantly important for the world since worldwide energy utilization is expanding day by day. While existing energy sources are not sufficient to meet the power demands, renewable energy sources come into play which have limitless supply as well as are eco-friendly. Wind energy's global potential is predicted to be more than five times that of present global energy production. Similarly, unlike nuclear power plants, which require 20 times more water, solar energy requires very little water for its whole upkeep. When compared to other energy sources, solar and wind energy have the least detrimental influence on the environment, as they do not produce greenhouse gases or pollute the water. The energy generation of Bangladesh is largely dependent on fossil fuels. The greenhouse effects of this source of power also cannot be ignored. As such, the nation is heavily advocating for the incorporation of solar power as a clean renewable source of power.

In our Smart Home Energy Management System, using solar and wind generation sources we stored energy in a battery which is transferred to power loads. On the other end, a generator is also connected in case of complete power deficit from renewable sources to maintain uninterrupted supply. In the smartphone app 'Blynk', we successfully operated all power loads in several combinations via Wi-Fi with the help of dedicated components connected to the system. In the system, we also observed current power consumption, battery charge level, power factor all process within least time possible.

Our prime objective was to decrease the energy cost as much as possible in the most efficient way and desirably we have been successful to demonstrate the expected result. In the near future, this project will be more sophisticated and profitable to the consumer when we will install the Net Energy Metering (NEM) mechanism with the system to sell energy surplus generation to the distribution grid.

6.2 Future Work

6.2.1 Weather Forecast Notification:

There will arise situations like complete shutdown of both Solar and wind energy generation sources due to unannounced natural calamities like rain, cyclone, floods, hurricanes, etc. In this sort of situations, the consumers will be in huge trouble for unexpected power cuts that may discourage them to get rid of renewable power systems. To resolve this issue, we will integrate an additional feature to the control system that will fetch weather forecast data automatically and alert the consumers instantly with a notification if there is any anomaly in the weather. Thus, with this integration consumers will be in a safe position to manage how much power loads to use with existing battery energy which ensures the system to be reliable, full-fledged and uncompromising.

6.2.2 Net energy metering (NEM):

Net metering is a phenomenal billing mechanism that allows bidirectional flow of electricity between consumer and distribution grid to promote the usage of renewable energy source [24]. Many countries are encouraging net metering to reduce the need for expensive polluting power plants giving us cleaner air to breathe. Generally, Solar and wind-based power generations function in a definite period of a day also happens to be when we utilize the least extent of electricity. So, the surplus electricity generation that is way more than users need becomes discarded at that time due to lack of storage capacity. In our homer simulation run, we got to observe that a great amount of energy was generated which was being discarded due to lack of extra storage capacity. Besides, it will be additional burden of cost and space to set up more battery storage for reserve purpose. At this point, net metering becomes the most feasible management solution. When renewable sources produce more electricity than regular usage, the excess generation is sent to the distribution grid. In Net metering system, the electric meter spins backwards that functions to transfer renewable energy to the grid. Then in the off period when renewables are not producing, the electric meter spins forward again as it receives electricity from the grid. The receiving and transferring data of electricity generation will be measured and updated in both the meter and distribution grid service side. In the end of the month, the customer's bill is numbered in net value following how much electricity is sent to the grid versus how much is used complementing the name 'Net Metering'[25]. In the upcoming future we tend to extend our project by merging net metering to give customers spontaneous control to manage their own electricity cleanly and efficiently. With an adequate arrangement of renewable generation systems, we can reduce all of our monthly electricity costs as well as make a decent profit. The prime significance of net metering is to use the distribution grid as free storage to reserve power for later national usage.

6.2.3 Additional Heavy Load Override Functionality:

At present, there is no connection between the generator and high-power loads that can be refrigerator, air conditioner, oven etc. In the near future, we will set up a connection with generator and high-power loads through relays to control them automatically. When the solar panel and wind turbine generation sources will be completely off, the generator will instantly turn on the essential power loads. Simultaneously, there will be a signal passing onto the relays that the heavy power loads must be turned off. But, in some cases we may need the heavy power loads to run even with the generator powered on. Especially for that purpose, we will connect the relays to incorporate an additional override functionality to the system. In this addition, there will be complete individual control with each and every high load that will allow us to run the loads in any combination. For example, if we want to turn on one heavy load and minimize essential low power loads number, we can control it through our smartphone app. Furthermore, if we need to run more than one heavy power load it will also be possible. In these cases, the power consumption from the generator will be way higher than the default designed system.

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Appendix 1

Calibration Code:

```
#define BLYNK_PRINT Serial


#include <WiFi.h>

#include <WiFiClient.h>

#include <BlynkSimpleEsp32.h>


#include <Wire.h>

#include <LiquidCrystal_I2C.h>

LiquidCrystal_I2C lcd(0x3F, 16, 2);

char auth[] = "QRlJPxr76ce3bnmqvVTUUVKf1vE5JTA0";


char ssid[] = "TP-LINK_1CD4";

char pass[] = "12345679";


const int currentSensorPin = 33;

const int voltageSensorPin = 32;        // sensor pin

float vIn = 0.0 ;                       // measured voltage (3.3V = max. 16.5V, 5V = max 25V)

float vOut = 0.0 ;

float voltageSensorVal;                 // value on pin A3 (0 - 4095)

float raw = 0;

void setup()
```

```
{
  Serial.begin(9600);


  Blynk.begin(auth, ssid, pass);
  lcd.init();
  lcd.backlight();
}
void loop()
{
  Blynk.run();
  raw = analogRead(currentSensorPin);
  Serial.println(raw);
  voltageSensorVal = analogRead(voltageSensorPin);
  vOut = (voltageSensorVal)*(3.3/4095);
  vIn =  vOut;


   // Serial.print("Input = ");
  Serial.println(vIn);
  //Serial.println(vOut);
  Serial.println(voltageSensorVal);
  lcd.setCursor(0,0);
  lcd.print("Input =       ");
  lcd.setCursor(9,0);
```

```
  lcd.print(vIn);
  delay(500);

  // set cursor to first column, first row
  //lcd.setCursor(0, 0);
  // print message
 // lcd.print("Hello World");
 // delay(1000);
  // clears the display to print new message
 // lcd.clear();
  // set cursor to first column, second row
 // lcd.setCursor(0,1);
 // lcd.print("Hello World");
 // delay(1000);
 // lcd.clear();
}
```

Main Code:

```
#define BLYNK_PRINT Serial
#include <PZEM004Tv30.h>
```

```
#include <Wire.h>

#include <LiquidCrystal_I2C.h>

LiquidCrystal_I2C lcd(0x3F, 16, 2);

#if defined(ESP32)

PZEM004Tv30 pzem(Serial2, 16, 17);

#else

PZEM004Tv30 pzem(Serial2);

#endif

#include <WiFi.h>

#include <WiFiClient.h>

#include <BlynkSimpleEsp32.h>

BlynkTimer timer;

char auth[] = "wU2Fzr8aqdatVgej2ksMD6DBJAR9kDpH";

char ssid[] = "TP-LINK_1CD4";

char pass[] = "12345679";



#include "ACS712.h"



ACS712  ACS1(32, 5.0 , 4095, 100);
```

```
ACS712  ACS2(33, 5.0 , 4095, 100);

ACS712  ACS3(35, 5.0 , 4095, 100);

ACS712  ACS4(34, 5.0 , 4095, 100);

ACS712  ACS5(36, 5.0 , 4095, 100);


const int voltageSensorPin = 39;

const int Renewable_Relay =  15;

const int Gen_Relay =  2;

const int overidepin = 27;


float vIn = 0.0 ;                    // measured voltage (3.3V = max. 16.5V, 5V = max 25V)

float vOut = 0.0 ;

int voltageSensorVal;                // value on pin A3 (0 - 4095)


int SOC = 0;

int Charging =0;

int overide =0;


float kWh_L1 = 0;
```

```
float kWh_L2 = 0;

float kWh_L3 = 0;

float kWh_PV = 0;

float kWh_Wind = 0;


float power_L1 = 0;

float power_L2 = 0;

float power_L3 = 0;

float power_PV = 0;

float power_Wind = 0;


unsigned long lastmillis = millis();


void myTimerEvent() {


  Serial.print("Custom Address:");

  Serial.println(pzem.readAddress(), HEX);
```

```
 overide = digitalRead(overidepin);

  // Read the data from the sensor

  float voltage = pzem.voltage();

  float current = pzem.current();

  float power = pzem.power();

  float energy = pzem.energy();

  float frequency = pzem.frequency();

  float pf = pzem.pf();


int mA1 = ACS1.mA_AC();

int mA2 = ACS2.mA_AC();

int mA3 = ACS3.mA_AC();

int mA4 = ACS4.mA_DC();

int mA5 = ACS5.mA_DC();


voltageSensorVal = analogRead(voltageSensorPin);    // read the current sensor value (0 - 1023)

vOut = (voltageSensorVal)*(3.3/4095);          // convert the value to the real voltage on the analog pin

vIn =  vOut*5.128;
```

```
if (mA1 > 15 ) {
 power_L1 = (mA1/1000)*voltage*pf;
}
else {
  power_L1 = 0;
 }
 if (mA2 >15)
 {
 power_L2 = (mA2/1000)*voltage*pf;
 }
 else {
  power_L2 = 0;
 }

 if (mA3 >15)
 {
 power_L3 = (mA3/1000)*voltage*pf;
 }
 else {
```

```
 power_L3 = 0;

 }

if(mA4 > 50){

power_PV = (mA4/1000)*vIn;

 }

else

{

  power_PV = 0;

  }


if(mA5 > 50){

power_Wind = (mA5/1000)*vIn;

 }

else

{

  power_Wind = 0;

  }


kWh_L1 = kWh_L1 + power_L1 * (millis() - lastmillis) / 3600000000.0;
```

```
kWh_L2 = kWh_L2 + power_L2 * (millis() - lastmillis) / 3600000000.0;

kWh_L3 = kWh_L3 + power_L3 * (millis() - lastmillis) / 3600000000.0;

kWh_PV = kWh_PV + power_PV * (millis() - lastmillis) / 3600000000.0;

kWh_Wind = kWh_Wind + power_Wind * (millis() - lastmillis) / 3600000000.0;



if( vIn >= 13)

{

  SOC = SOC;

  Charging = 255;

  digitalWrite(Renewable_Relay, HIGH);

  digitalWrite(Gen_Relay, LOW);

  }

if( vIn >= 12.7 && vIn < 13 )

{

  SOC = 100;

  Charging = 0;

  digitalWrite(Renewable_Relay, HIGH);

  digitalWrite(Gen_Relay, LOW);
```

```
 }
else if (vIn >=12.5 && vIn < 12.7 )
{
 SOC =90;
 Charging = 0;
 digitalWrite(Renewable_Relay, HIGH);
 digitalWrite(Gen_Relay, LOW);
 }

else if (vIn >=12.42 && vIn < 12.5 )
{
 SOC =80;
 Charging = 0;
 digitalWrite(Renewable_Relay, HIGH);
 digitalWrite(Gen_Relay, LOW);
 }
else if (vIn >=12.32 && vIn < 12.42)
{
 SOC =70;
```

```
 Charging = 0;
 digitalWrite(Renewable_Relay, HIGH);
 digitalWrite(Gen_Relay, LOW);
 }
else if (vIn >=12.20 && vIn < 12.32)
{
 SOC =60;
 Charging = 0;
 digitalWrite(Renewable_Relay, HIGH);
 digitalWrite(Gen_Relay, LOW);
 }
else if (vIn >=12.06 && vIn < 12.20)
{
 SOC =50;
 Charging = 0;
 digitalWrite(Renewable_Relay, HIGH);
 digitalWrite(Gen_Relay, LOW);
 }
else if (vIn >=11.9 && vIn < 12.06)
```

```
{
 SOC =40;
 Charging = 0;
 digitalWrite(Renewable_Relay, HIGH);
 digitalWrite(Gen_Relay, LOW);
 }
else if (vIn >=11.75 && vIn < 11.9)
{
 SOC =30;
 Charging = 0;
 digitalWrite(Renewable_Relay, HIGH);
 digitalWrite(Gen_Relay, LOW);
 }
else if (vIn >=11.58 && vIn < 11.75)
{
 SOC =20;
 Charging = 0;
 digitalWrite(Renewable_Relay, LOW);
 digitalWrite(Gen_Relay, HIGH);
```

```
 }
else if (vIn >=11.31 && vIn < 11.58)
{
 SOC =10;
 Charging = 0;
 digitalWrite(Renewable_Relay, LOW);
 digitalWrite(Gen_Relay, HIGH);
 }
else
{
 SOC =0;
 Charging = 0;
 digitalWrite(Renewable_Relay, LOW);
 digitalWrite(Gen_Relay, HIGH);
 }

yield();

lcd.clear();
```

```
lcd.setCursor(0, 0);

lcd.print("Power Used:");

lcd.print( power , 2);

lcd.print("W");

lcd.setCursor(0, 1);

lcd.print("Energy used :");

lcd.print(energy, 4);

lcd.print("kWh");

delay(2000);


lcd.clear();

lcd.setCursor(0, 0);

lcd.print("Solar Power:");

lcd.print(power_PV, 2);

lcd.print("W");

lcd.setCursor(0, 1);

lcd.print("Solar energy:");

lcd.print(kWh_PV, 4);

lcd.print("kWh");
```

```
delay(2000);

lcd.clear();
lcd.setCursor(0, 0);
lcd.print("Wind Power:");
lcd.print(power_Wind, 2);
lcd.print("W");
lcd.setCursor(0, 1);
lcd.print("Wind energy:");
lcd.print(kWh_Wind, 4);
lcd.print("kWh");
delay(2000);

lastmillis = millis();

Blynk.virtualWrite(V0, power);
Blynk.virtualWrite(V1, power_L1);
Blynk.virtualWrite(V2, power_L2);
Blynk.virtualWrite(V3, power_L3);
```

```
Blynk.virtualWrite(V4, power_PV);

Blynk.virtualWrite(V5, power_Wind);

Blynk.virtualWrite(V6, energy);

Blynk.virtualWrite(V7, kWh_L1);

Blynk.virtualWrite(V8, kWh_L2);

Blynk.virtualWrite(V9, kWh_L3);

Blynk.virtualWrite(V10, kWh_PV);

Blynk.virtualWrite(V11, kWh_Wind);

Blynk.virtualWrite(V12, SOC);

Blynk.virtualWrite(V13, Charging);



/*Serial.print("mA1: ");

Serial.print(mA1);

Serial.print("mA2: ");

Serial.print(mA2);

Serial.print("mA3: ");

Serial.print(mA3);

Serial.print(". Form factor: ");

Serial.println(ACS1.getFormFactor());
```

```
Serial.println(ACS1.getNoisemV());



 // Check if the data is valid

 if(isnan(voltage)){

    Serial.println("Error reading voltage");

 } else if (isnan(current)) {

    Serial.println("Error reading current");

 } else if (isnan(power)) {

    Serial.println("Error reading power");

 } else if (isnan(energy)) {

    Serial.println("Error reading energy");

 } else if (isnan(frequency)) {

    Serial.println("Error reading frequency");

 } else if (isnan(pf)) {

    Serial.println("Error reading power factor");

 } else {

    // Print the values to the Serial console

    Serial.print("Voltage: ");      Serial.print(voltage);      Serial.println("V");
```

```
    Serial.print("Current: ");     Serial.print(current);     Serial.println("A");

    Serial.print("Power: ");       Serial.print(power);       Serial.println("W");

    Serial.print("Energy: ");      Serial.print(energy,3);    Serial.println("kWh");

    Serial.print("Frequency: ");   Serial.print(frequency, 1); Serial.println("Hz");

    Serial.print("PF: ");          Serial.println(pf);

  }


  Serial.println();

  delay(2000); */

 }


void setup()

{

 // Debug console

 Serial.begin(115200);


 ACS1.autoMidPoint();

 ACS1.setNoisemV(60);

 ACS2.autoMidPoint();
```

```
 ACS2.setNoisemV(60);

 ACS3.autoMidPoint();

 ACS3.setNoisemV(60);

 ACS4.setMidPoint(1858);

 ACS5.setMidPoint(1858);



 pinMode(Renewable_Relay, OUTPUT);

 pinMode(Gen_Relay, OUTPUT);



Blynk.begin(auth, ssid, pass);


// initialize LCD

 lcd.init();

 // turn on LCD backlight

 lcd.backlight()

timer.setInterval(6000L, myTimerEvent);

}
```

```
void loop()

{

  Blynk.run();

  timer.run();

}
```