Islamic University of Technology

Department of Electrical and Electronics Engineering

PROTOTYPE SMART GRID ARDUINO BASED HYBRID MAXIMUM POWER POINT TRACKER

A Thesis by

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Submitted in Partial Fulfillment
of the Requirements
for the Degree of

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CERTIFICATE OF RESEARCH

The thesis titled "PROTOTYPE SMART GRID ARDUINO BASED HYBRID MAXIMUM POWER POINT TRACKER" submitted by Fanding Darboe (190032201), Abubacarr Salele (190032205), Binta Sanyang (190032206); Nabil Ayshan (190032207) *has been accepted as satisfactory in partial fulfillment of the requirement for the Degree of Bachelor of Science in Technical Education with Specialization in Mechanical Engineering.*

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DECLARATION

We hereby declare that this thesis titled "Prototype Smart Grid Arduino Based Hybrid Maximum Power Point Tracker" is an authentic report of our study carried out as requirement for the award of degree Bachelor of Science in Technical Education with Specialization in Electrical Engineering at Islamic University of Technology, Gazipur, Dhaka, under the supervision of Prof. Dr. Md. Rezaul Hoque Khan, EEE, IUT in the year 2022.

The matter embodied in this thesis has not been submitted in part or full to any other institute for award of any degree.

12-05-2022

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ABSTRACT

Prototype wind and solar smart grid controller Arduino is the brains behind this project. There are 48 pages in this book, with two tables, 17 figures, and 37 numbered references. April 2022 for a Bachelor of Science in Technical Education with specialization in (Electrical Engineering). Renewable energy technology is increasing with less expenditure; they provide superior alternatives to traditional generation in terms of both environmental stewardship and economic savings. Optimizing battery charging with renewable energy sources is a critical issue regarding microgrids systems, as well as off-grid system, thereby posing huge difficulties when it comes to extreme and adequate storages. There might be life span issues or total failure in the case when usually less or extremely charged, the controller Arduino sufficiently enhances the efficiency of both the solar and wind simultaneously. In the case of power generation, expenditure and management, using a single controller to handle two systems is more efficient, but at the sacrifice of efficiency. The hybrid maximum power point tracker regulates both wind and solar energy using two synchronous buck DC-DC converters. The hybrid maximum power point tracker had a normal efficiency in the bench test, whereas the individual controller had a normal efficiency. Due to the Arduino's frequency. A different microcontroller produces a significantly quicker frequency, allowing for a smaller inductor and higher current before oversaturation.

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Introduction

1.1 Background

Due to the rapid increment of outdated conventional power generation, unsustainability of fuel based growing concern about the huge implication that these power sources pose to our atmosphere; there has been an immense on the introduction of renewable energy sources into power systems. In addressing these aforementioned difficulties, current research has concentrated on reducing losses on electric power networks and as a result, more efficiently utilizing energy sources. The next-generation electrical system is what a smart grid concept is. Which optimizes energy supply, distribution, and consumption by utilizing advanced control and communication technology. Smart grids can increase system efficiency by utilizing multiple technologies with sophisticated meters, smart devices and dual communication chain. Furthermore, reduction of greenhouse gas emission so cased due to the very crucial benefits highlighted with smart grids [1].

Power generation and consumption values are monitored at home, in real time in utilizing wind turbines and solar panels thereby reserving exported or excess energy at this stage of the project. As a result, instant, daily and weekly consumption of data needed by families that can be virtually delivered by using interface that is user-friendly. Consumers are aware of and in control of their energy consumption. According to the information provided, the system can reduce energy consumption by managing appliances while maintaining a high level of comfort in the home [2].

1.2 The Motivation

Mini energy collecting system are becoming more adequate among houses and rural locations, which require electricity when it is unavailable. The solar and wind energy are collected by the power collecting system. Instead of regularly refueling the engine, the renewable source will produce energy giving the availability of the sunlight or wind at remote locations. Our prototype project serves as a test bed for determining how to manage the energy generated by a wind turbine as well as solar panel.

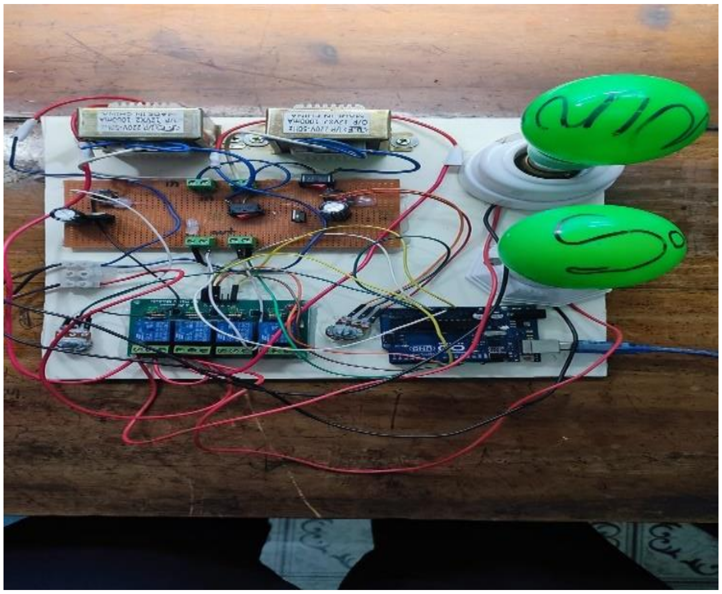

Figure 1.1 discovery prototype

It is desirable to design an economical and efficient renewable energy generation a prototype embedded with several micro controller with to enable the communication between the two grids as to determine which of the sources is needed and at what time of the day or hour, which would increase the usage of available resources while keeping the sources more consistently filled using two harvesting methods: wind and sun. Although weather can be unpredictable, having two types of harvest can boost the load factor that has a percentage of possible production based on available load at hand [3].

The implementation of this smart prototype will help the electricity consumption to be better managed and reliable. The home automated system which is been used as test bed here controls the two sources to establish from which sources power should be derived from through a built mobile application that controls and will monitor the availability of each source in real time and will send the command to controller disseminates signal to relay for triggering the amount of current needed for the operation.

1.3 Objectives

Here are some of the few objectives of our thesis:

- Examine the present state of various standard procedure for solar and wind separately.
- Create a system regulator that maintains a constant load as well as observing the power at the output.

- Check for usability and efficiency in the design.

Further to the objectives of our thesis is to evolve a smart grid prototype in light of renewable usages of electrical energy to study various performance parameters to enhance the efficient use of energy. We want to use home automation system as a test bed for the smart grid prototype by means of possible communication structure embedded with hardware/software base as well as enable smart communication and interface it with and Arduino Uno, relay together with a Bluetooth module to send instructions to the relays of the two power sources and base on the availability of these sources. Induction generators operated by wind turbines use asynchronous generators, whereas induction generators use static-speed generators that rotate at a specific spin speed. Asynchronous generators are powered by a spinning electromagnetic field produced by external links. A continuous development of magnetic fields produces alternating current (AC).

Before it can be transmitted to the battery, the load should automatically be changed to direct current (DC). To achieve that through putting alternating current AC via a bridge rectifier diode, which changes it to DC. The design of a wind turbine, as well as the wind speed, determine its performance. The ranged incise wind speed is attained through rotor's aerodynamic power surpasses maximum equipment loads while mechanical and electrical inefficacious. When the wind speed outperforms the ranges within which the turbine and generator can operate thereby not exhausting available controls, the cutout wind speed occurs. The stipulated wind speed is the wind speed at which turbine is functioning close to full efficiency. PV panels are made up of a swarm of silicon-based solar cells, which is capable of changing the energy available in photons of light into electrical power and flow. A photon that has an adequate wavelength and high enough energy can cause an electron to break free from an atom in a photovoltaic material. In a case where wind speed exceeds its normal range within when the turbine and generator may operate without exhausting structural controls, the cutout wind speed occurs. The rated wind speed is the wind speed at which a turbine is functioning very close to efficiency [4]. PV panels are made up of a swarm of silicon-based solar cells that are able to change the energy withheld in photons of light into electrical power and current. A photon with a short enough wavelength and high enough energy can cause an electron to break free from an atom in a photovoltaic material [5].

Despite the fact that the system is hybrid, it is only designed to utilize a single source in a row. The controller checks the wind speed first, in case it is not enough, it continues on to sun radiation. The system will use the power grid if neither renewable energy sources nor the power grid is available.

When the electrical grid is down and solar and wind are not functioning, the system will draw from the storage battery.

1.4 Overview of Chapters

The chapter 2 breaks down several surveys of various manageable methods as well as variable charge resistors. In addition, several methods by obtaining tracker for maximum power points. The chapter 3 discusses in deep, crucial ideas which tracker for maximum power point can attain controller through the wind and solar, thereby outlining components of various systems. The chapter 4 elaborates on method of system topology, software of Arduino, which dictates controller. The chapter 5 outlines several bench tests and implementation of solar and wind controller system independently. The chapter 6 contains conclusion, possible recommendation to improve hybrid controller design.

Chapter 2

Review of Literature

2.1 Introduction

Ways for optimizing battery charging from renewable technologies is a hot topic when we talk about off-grid and micro-grid installations; these are rapidly increasingly significantly bigger installations. Batteries should be properly charged. The battery can be overcharged or undercharged, resulting in failure and a loss in battery life. It is critical to keep the battery charged in order for it to last as long as possible. The same is true for permitted discharge; batteries cannot discharge beyond their minimum level discharge over a long period [6] [7, 8].

Charge controllers are as good as the resources they collect. The charge controller's design is determined by the systems that harvest the resources. A photovoltaic (PV) system can be installed in any location with plenty of sunlight. Due to the fluctuation in wind speed at any given time, wind, on the other hand, can be more specific in how to harvest. The ability to capture the solar and wind energy using a single controller will make installation easier, reduce costs, and enhance power generation. Having adequate techniques for charging the solar and wind technologies separately will assist improving and designing a controller that accommodate the two.

2.2 Wind Turbine with Induction Rotation

Induction generators are used in asynchronous generators driven by wind turbines, whereas generators with synchronization are generators with fixed speed, which rotates at a specified rotational velocity. Induction generators work by creating a spinning electromagnetic field in the armature windings. Alternating current (AC) is produced by the unchangeable building and collapsing of magnetic fields. The current must be converted into direct current before it can be sent to the batteries (DC). Process is accomplished by feeding AC via a diode bridge rectifier, which changes the current to DC [9].

The design of a wind turbine, as well as the wind speed, dictate its staging. The rated cut-in wind speed is acquired when the rotor's aerodynamic power exceeds the sum of equipment loads and mechanical and electrical inefficiencies; this is achieved when the rotor's aerodynamic power surpasses the sum of equipment loads and mechanical and electrical inefficiencies. The cutout wind speed happens when the wind speed exceeds the limits within which the turbine and generator can operate without exceeding structural limitations. The rated wind speed is the speed at which the turbine is at or near maximum efficiency. A simplified power curve for a hypothetical turbine-generator system is shown in Figure 2.1.

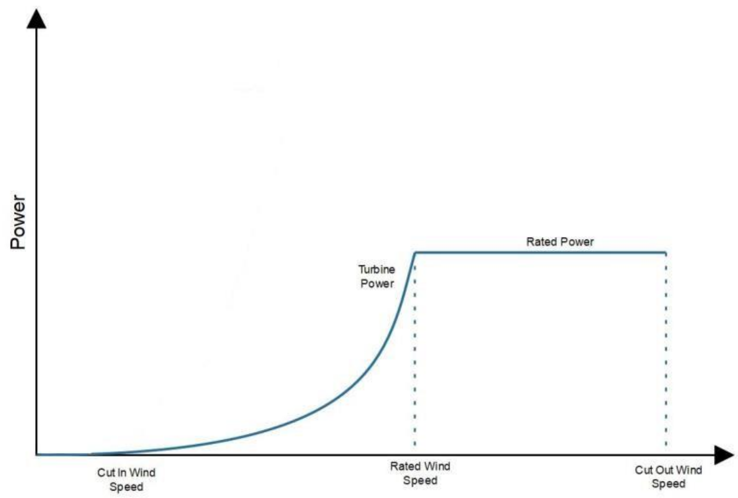

Figure 2.1 Wind turbine power curve [10].

2.3 Panel photovoltaic

The PV panels are made up of a number of silicon-based cells of solar, which are capable of changing energy contained in the photons of light into electrical power and current. A photon with a short enough wavelength and high enough energy can cause an electron to break free from an atom in a photovoltaic material. Electrons are swept toward a metallic contact when an electric field exists, where they are transformed into electric current. Figure 2.2 shows the voltage and current of a typical solar panel power curve. When the current and voltage meet at their highest, it is called the maximum power point (MPP). The capacity to track the MPP is the most effective method of energy collection [11].

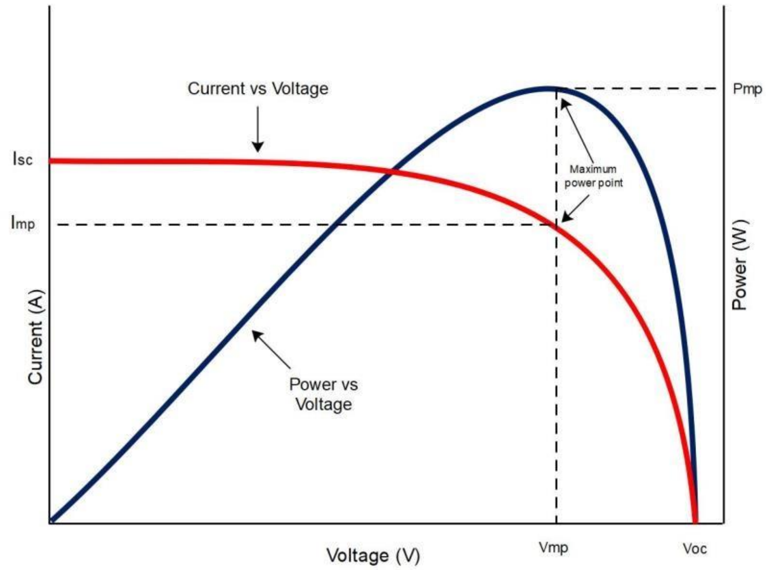

Figure 2.1 solar cell's IV curve [12].

2.4 Lead Acid Rechargeable Battery

Batteries that can be recharged provide excellent storage options for electric power. Understanding how a battery behaves when building a charge controller, how it performs during its peak states has an impact. Figure 2.3 illustrates this. , the battery has volts maximum and minimum, and exceeding the maximum or going below the minimum can shorten the battery's life. The state of charge (SOC) and the input voltages) of the battery determine the amount of current flowing [13].

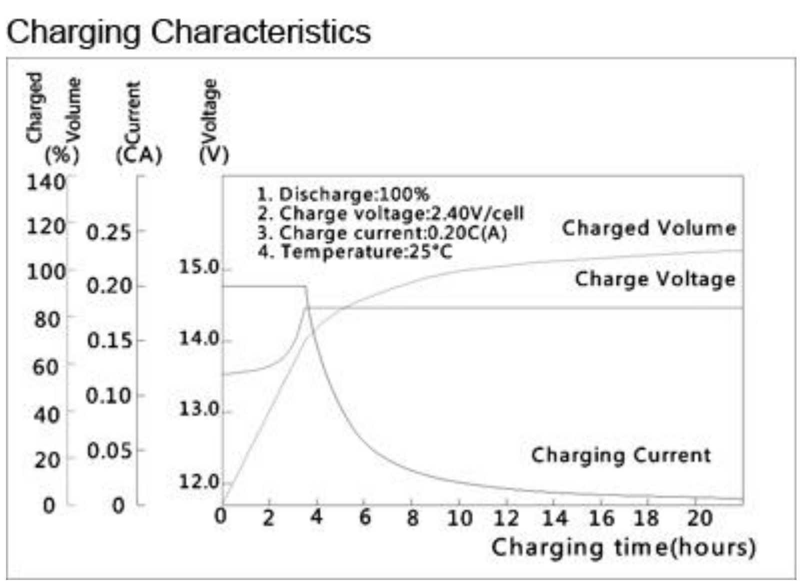

Figure 2.3 typical 12V 24 A-h lead-acid batteries characters [14].

2.5 DC to DC Power Converter Circuits

Hybrid controllers should account for energy produced and the charging capacity of the battery. Several ways are employed in proper charging of batteries with renewable energy; the most frequent, but inefficient, method is to use a controller known as pulse width modulation (PWM). Voltage is usually decreased to commensurate charge voltage of batteries in a pulse width modulation hence allowing constant input from source. There will be deflection after batteries attain maximum capacity [13].

Chapter 3

Hardware for System

3.1 System Elements

The Arduino-based controller's system architecture is described in detail in this chapter. It will go into how the controller's design incorporates numerous components and sensors. The Arduino UNO by setting both the wind and solar circuits, the source code in the blink app, so defining their lines of code and identifying the energy source accessible at a particular time. For each circuit, the controller using data from the inputs and outputs adjusts the duty cycle. The controller triggers a relay when the battery reaches its maximum capacity, which delivers any residual power to a dump load resistor[15].

3.2 System Design

The first step is to choose which technique will be used to ensure that this project is carried out. We used the strategy of first creating a system block diagram so that we can visualize the entire project situation

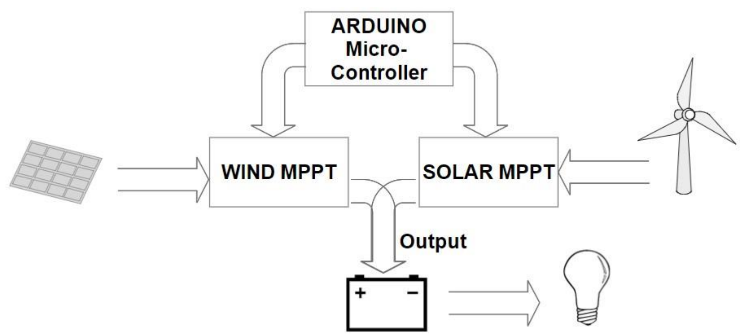

Figure 3.1 Arduino hybrid controller block diagram [16].

The block diagram depicts how the peripherals are connected, as well as how the system communicates. The following steps explains the block diagram:

- AC Source: the AC source gives 220 volts power, it acts as the two renewable sources.
- Arduino Uno: they serve as the microcontroller designed and programmed to administer certain functions. It is the main controller of the system, where all connections is being done to transmit and receive signals to show final display of the loads through the relay. Simply connects to a computer with USB cable.

- Bluetooth Module: the serial module works as a master Connectifier, thus acting as a medium of connection between the Arduino and the other software used in this project. Moreover, based on the structured block diagram, the Bluetooth is considered as the internet of things and software development network medium.
- Relay: the 5-v channel relay connects or disconnects the load whenever desired. The actuation of the relay signal is sent from the Arduino. It has an LED that shows the state of the relay.
- Battery Bank: The battery bank for this project is made up of two 12V ultra-lead acid batteries connected in series to achieve a voltage of 24 v. The batteries are designed to drain load while being charged by a solar panel or wind turbine [13].
- Blynk Mobile App: programmed application (interface) shows all the (2) renewable energy sources and is capable of identifying which of the sources is on peak as well as sends command for load supply or withdrawal at any time necessary.

3.3 Selection of Components

The smart Grid prototype should be built to handle the wind turbine and solar panels employed at the project site in Islamic university of technology for future design considerations.

3.3.1 Arduino UNO

The Arduino UNO is a multi-purpose microcontroller, as shown in Figure 3.2. For this project, the use of stored programs and commands are conducted to create the interactions possible between the peripherals. The Arduino IDE platform was used to write the command in the code [17]. An integrated 6-channel A/D (analog-to-digital) converter is included in the Arduino UNO microcontroller. The converter returns integers ranging from zero to 1023 with a 10-bit resolution. In this project, the analog pins are mostly used to read ASC712 sensors and voltage divider the pins are digital GPIO (general-purpose pins (input/output) that are utilized to power the LCD display [18].

Figure 3.2 Arduino UNO

3.3.2 Voltage Divider

Inputs are analog. On the Arduino UNO can be used to determine the difference in DC voltage between 0 and 5 volts. The Arduino's voltage measurement range has been extended. Creating a voltage divider with two resistors. The voltage to be measured is denoted by VIN. Monitored, and Vout is the divider's voltage output, which will be attached to the input pin. The voltage divider lowers the applied voltage. Within the Arduino's analog input range using the voltage divider calculation given above, divide Vout by 1023 and multiply by 5v. In Equation 3.1 to get, the real voltage Arduino will measure the voltage $R2$.

$$Vout = Vin \times \underline{\hspace{2cm}} R1 + R2$$

Voltage divider formula*[19]*……………..(Eq 3.1)

3.3.3 Relay 4 channel 5 v

The Interface board for a 5-v 4-channel relay in "context" for controlling high voltage, high current load. The relay takes four different load at the same time. If there is command sent from the source code to either give 5-v current at a particular time it will sense and trigger. It may also be that command can be sent for relay to offload five v and it accurately does exactly what the program entails. The relay module has an in built opt coupler and an LED.

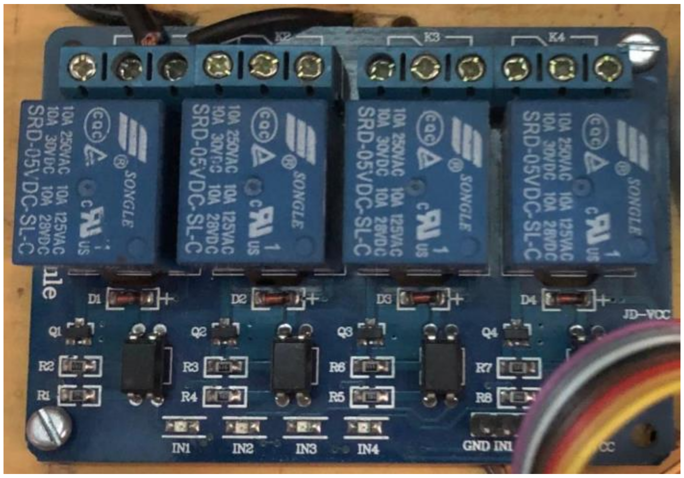

Figure 3.3 Relay

3.3.4 Main components and tools used

i. Arduino Uno
ii. Bluetooth Module
iii. Relay
iv. Resistors
v. Connecting wires
vi. Bulbs and holders (load)
vii. Supply

3.4 Smart Home- A test Bed for Smart Grid

The smart home project began on April 21, 2021 with a budget of more than $200 at Islamic university of technology and it lasted around one year. The suggested smart home concept's main scheme is presented, along with renewable energy sources and other critical components.

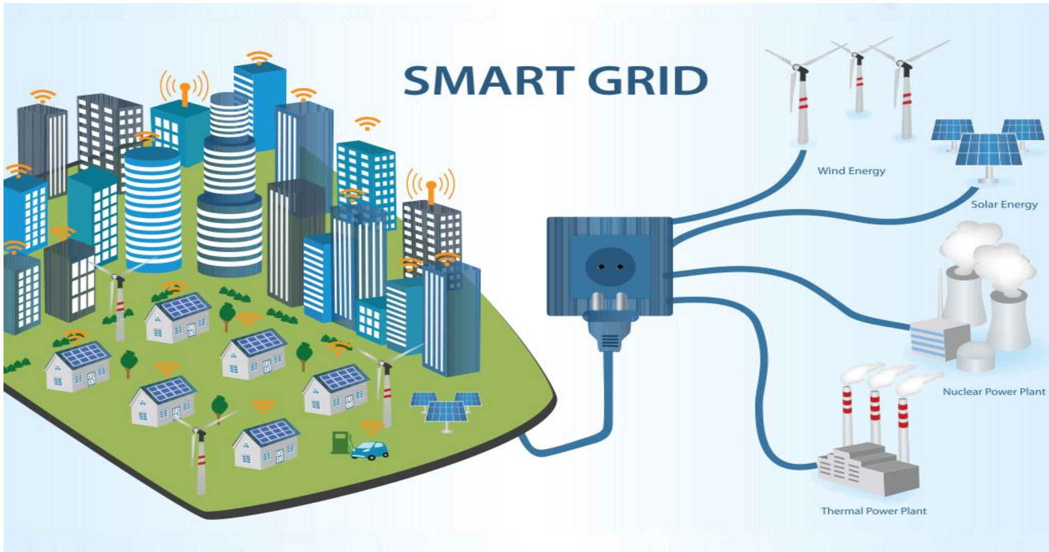

Figure 3.4 General scheme of smart home system[3]

Because the project is so large, there are three key sub-processes in this process. (I) creation of a residential energy demand management algorithm, (ii) integration of renewable energy sources into the system and grid, (iii) creation of a communication network smart home is key integral part of smart grid and this is why we used the smart home as a test bench for it will lead us towards the implementation of smart grid as a prototype [18, 20, 21]. The next diagram below here elaborates the specific components that our project is aimed at improving and implementing.

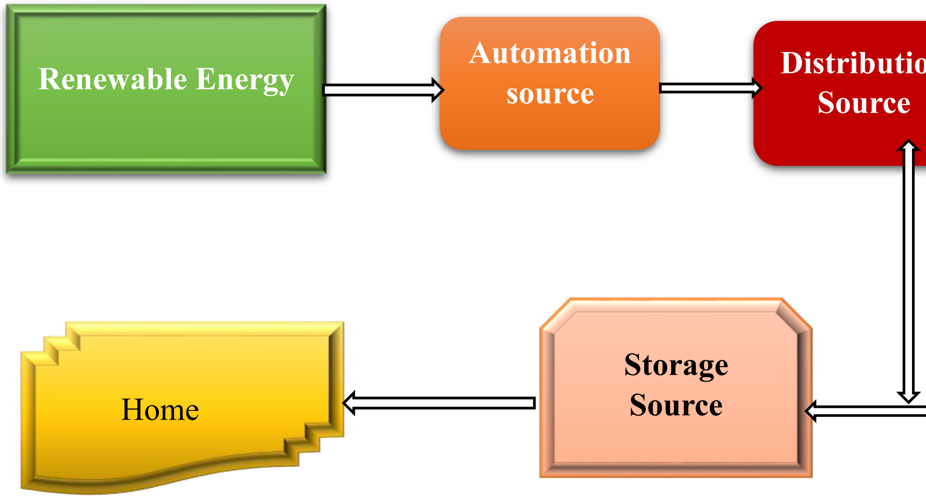

Figure 3.5 Block diagram of smart home

3.4.1 Circuit simulation and Outcome Analysis

The simulation of the smart home system is achieved through the proteus software simulation system, following various approaches to improve traditional power system in tender with increased energy used and the emergence of environmental concern. To that purpose, the 'Smart Home Automation System' idea was developed to address the aforementioned issues. The experimental smart home automation is designed in the software to incorporate two renewable energy sources and a smart communication system that can encompass internet of things, software development network base and a storage facility in the framework of a prototype.

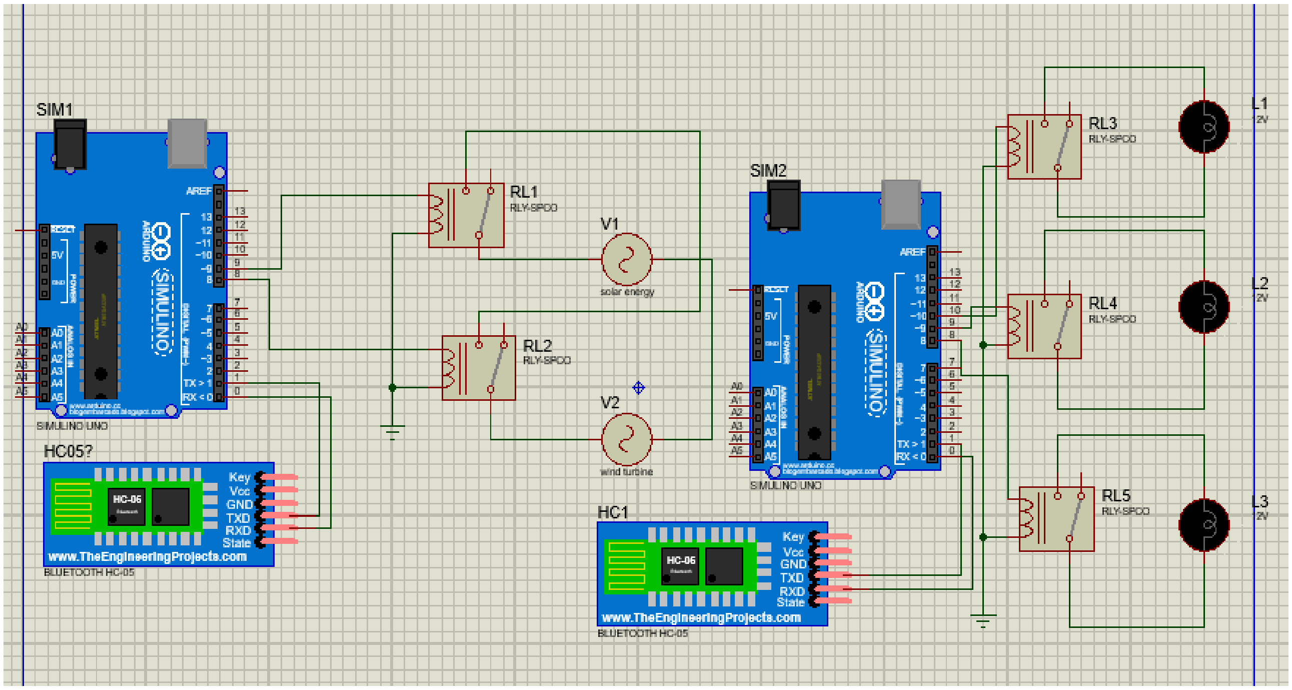

Figure 3.6 Circuit simulation diagram

3.4.2 Outcome Analysis

The implementation of the project is successful as wished. The integration of the smart grid components, together with the Arduino Uno, the Blynk app, relay and the Bluetooth module all worked as expected. The blink app the source made it possible for an uninterrupted communication to be established between the components and the mobile app. The Arduino Uno process the information based on what it has been commanded to execute and it did exactly that. The energy sources send power to the Arduino with the help of a laptop 5volt is energized, the Bluetooth module sends instruction through the app to send a trigger message to the relay. It is considered as the powerhouse or the main brain of the project.

The Blynk app provides the interfacing and shows us the two renewable energy sources as in wind and solar. Giving their availability the source code that has been programmed has the independent ability to ascertain which of the source to bring on/off or to supply the amount of load that we need at any given time, for example in a situation when the solar is unable to produce enough amount of energy to be supplied due to the unavailability of enough sun then the wind turbine can be used to supply the current needed vice versa.

The battery bank operates on two instances: (1) when there is excess energy, the battery opens and stores (bulb) turns on battery indicator. (2) When the two sources are totally out of power due to unavailability of enough sun light or wind, the battery opens and send the energy needed during that period and the load turns on by the help of the Arduino [3, 17, 22]. The Bluetooth module gives us the opportunity to remotely access the information the Blink app. When the Bluetooth is connected with both the Arduino and the mobile app, the energy is released from our mobile phone and when needed load can be turned on off. This was tested and fulfilled.

3.4.3 Integrating the Blynk App Source Code with Arduino Module

The connecting of mobile application with Arduino is very reliable for both the two renewable energy sources. Normally, this is the concept of power been realized by application and is capable of deciding on which one to turn on / off at a given time. Here we would interface the Arduino module with the Bluetooth I order to send command to the relay to release 5-v by using the mobile app. This interfacing, the system would be made with the help of Arduino Uno. The Bluetooth module is connected to the relay through Arduino, which executes the commands as programmed, in the microcontroller / source code[23].

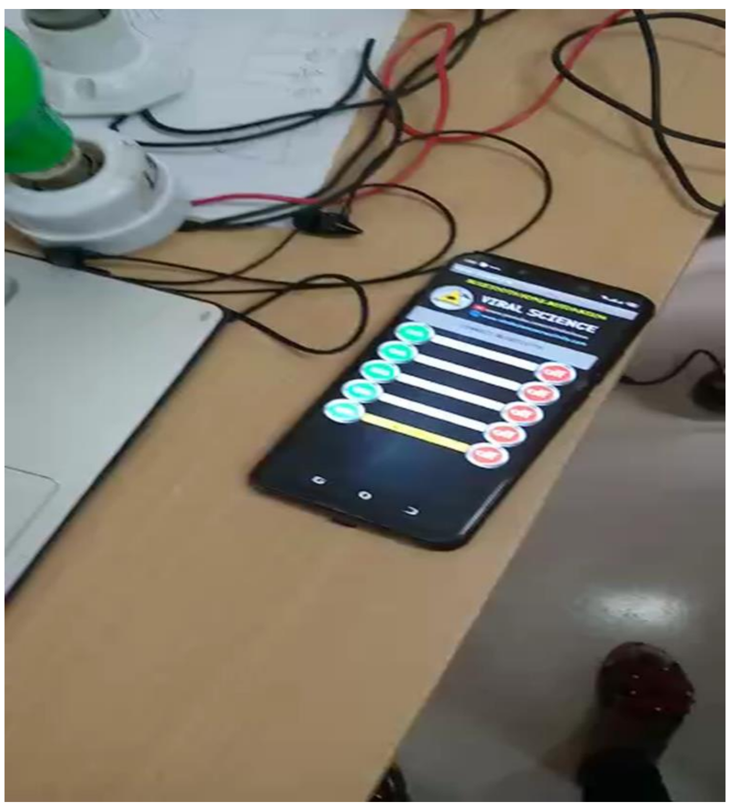

Figure 3.7 Blynk Iota App

3.4.4 Automotive Relay

The wind turbine's load would eventually be controlled by the 896H Relay. A low-cost, high-power 24-v relay can handle up to 50-A. To avoid damage to a wind turbine, it must have a consistent load. When the battery is full, the relay switches the load from the battery to the Dispose of load resistors.

3.4.5 125W ALEKO Monocrystalline Solar PV Module

The ALEKO monocrystalline solar PV module with a voltage of 24 v and a power of 125W would be employed in the field test. It has a 36.6-v. working output voltage and produces 3.47-A [24].

3.4.6 500W 24V Wind Turbine

The Wind turbine with five blades, 24-v, and 500W, employed is a 24-volt, 500-watt, 5-blade wind turbine. It generates A bridge rectifier is used to convert three-phase alternating current (AC) to direct current (DC). The usage of lesser wind speeds, a tail fin to help change position and capture breezes from all directions is perfect [25].

3.4.7 Battery with Lead Acid

Two 12-v Duracell Ultra lead acid batteries are linked in series to elevate the voltage of the bank to 24-v for this project's investigation. The batteries are designed to handle load while being charged by solar panels or wind turbines.

3.4.8 Constant Current Electrical Load

This device simulates a battery while also allowing the user to manage the amount of electricity drawn. The device's power rating is 60W, with a maximum draw of 10A and a 30-v maximum output voltage. It has a large heat sink and a fan to dissipate the heat. Change the amount of current necessary to imitate with the dial. My hybrid controller will not run the system if there is no current draw. This is because the battery is at full capacity if it is not using any current.

Chapter 4

Design of Software and Systems

4.1 Introduction

The smart house is being designed as a test bed for the smart grid. Needs to be improved by adding other setup for its improvement for the final implementation of the prototype. Based on the already developed information on the previous test bench, a 3phase change over switch is found to be a consisting body of an active and passive electronic components coupled with a micro controller system and few sensors, which are further systematize to provide a real time data on the current/voltage relative power drawn on the two renewable energy sources [26].

4.2 Parameter Summary

The sensitivity of the power source is a key component to consider in our design because the device's efficiency is based on its sensitivity to differences in power usage, which is why we used two distinct sensors to measure voltage and current.

4.2.1 Data processing for values generated

The sensor's data is further processed and transformed to a digital value that the computer can comprehend. This process is carried out with the help of a microcontroller, and the necessary calculations were carried out during the conversion process in order for the microcontroller to be used throughout the process [27].

4.2.2 High level data interface

At this point, the system requires a mechanism to interface all of the processed data to the user, and the best way to do so is to employ internet of things topology communication, which will link both the values of the power consumed and the relative cost of using that power.

4.3 Controller Design

The controller's circuit schematic is shown in Figure 4.1. Building block or working principles of the system is evidently presented using a simple block below.

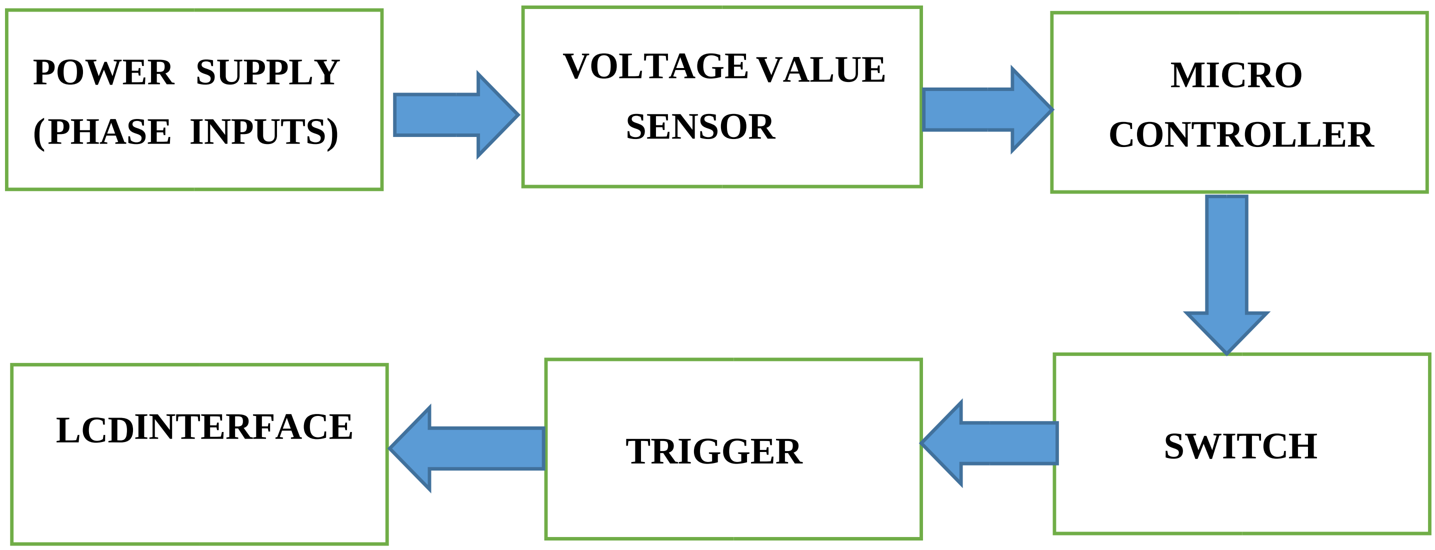

Figure 4.1 Block schematic of changeover controller

The Arduino starts by reading the defined variables and pins to build up the load controller. It assigns outputs to digital 0, 6, 7, 8, and 11 pins these pins send out either a High or a Low signal. Pins 0, 7, and 8 are set to Low (off) to prohibit flow from the output because they are used as High/Low pins.

The DC-DC converter will be if the solar panel and/or wind turbine input voltage is less than the disable voltage or the current is less than the minimum. If the system is turned off, the Arduino will keep checking to see if it can be turned back on. When the input voltages exceed the enabling voltage, the DC-DC converters are turned on. The Arduino-based 3phase automatic changeover circuit's circuit diagram may be seen here [1]. Figure four shows

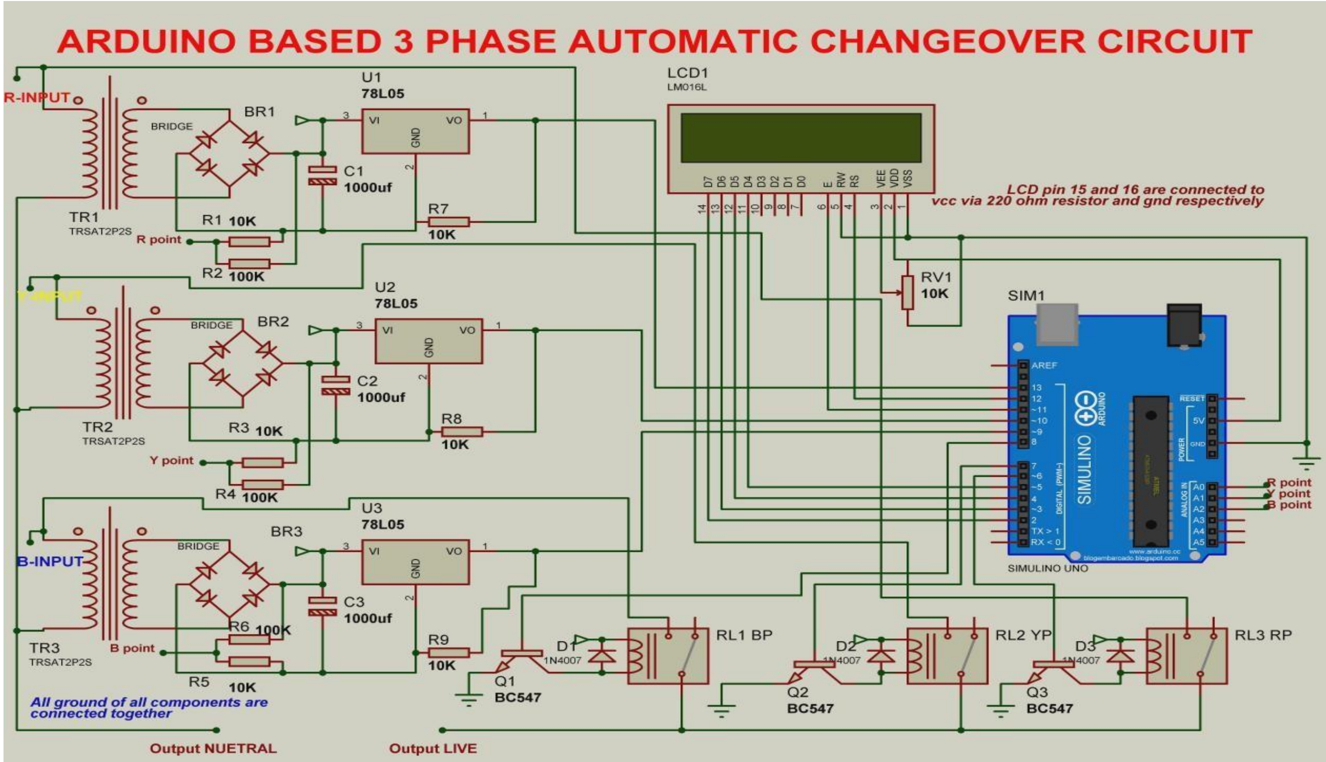

Figure 4.2 Diagram of changeover

4.3.1 Microcontroller power supply

The power supply for the microcontroller in our design is completely separate from the phase inputs, and the power source in assembly consists of an active 9 v cell BAT1, an electrolytic capacitor 470uf/16c C1, and an indication LED D1 that is linked in series with R1 560ohms.

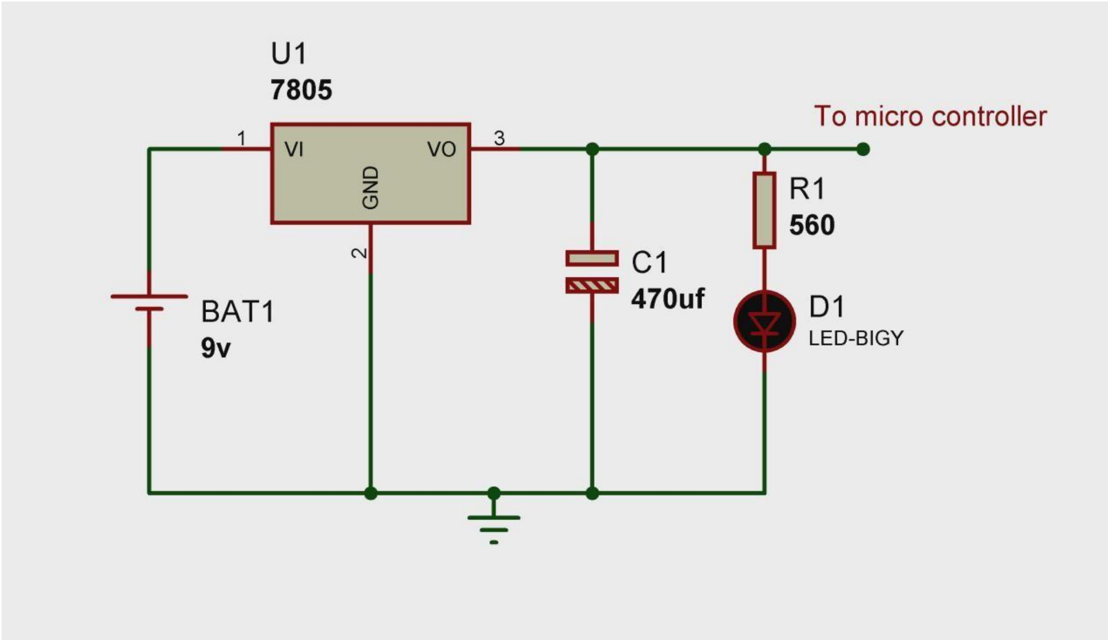

Figure 4.3 Microcontroller power supply

The 9-volt cell is a simple DC battery that gradually loses voltage as it is used. If the cell does not maintain a constant voltage, the drain will have an impact on the system. A temporal charge storage device is utilized to supply an almost continuous voltage at any instant due to this effect.

Since we have,

Battery voltage = 9 v

Required capacitor charger to do almost similar work = 7000 c

Finding capacitor/charge relationship,

Capacitor = charge

voltage

Finding charge,

Charge = capacitor × voltage …... (Eq. 4.1)

Therefore,

7000 = capacitor × 16 v…... (Eq. 4.2)

Capacitor = $\frac{7000}{16}$ …... (Eq. 4.3)

= 437.5 uf

Therefore, 470 uf / 16 v becomes the fit to do the function.

The indicator of the source is designed not to draw much power, since voltage x current = power

Therefore, $P = V \times I$

Finding I in the LED, we calculate,

9/560 = 0.01607A by using OHMs law.

= 16 mA

Power dissipated by the LED =

$P = 9 \times 0.01 = 0.144$ watt, which is quit ok for the system [28].

4.4 Software Implementation

This project utilizes a programmable IC called an ATmega328, which is often seen in Arduino Uno boards. The chip is the system's main building processor, since it receives data from the sensor, stores it in its register, and then uses the information to operate the output dispenser system. The next stage is to have the circuit connect with the controller once you have a good understanding of how it works [29].

4.4.1 IDE for Arduino

The Arduino Integrated Development Environment (IDE) is a programming environment for software code. That is needed to create the system controller's control settings. During this project, the Arduino version is used. The first stages in setting up the IDE were selecting the "Bluetooth/Arduino UNO" board under the Tools Menu and selecting the tools menu to which the UNO is present.

The controller reads the data when it receives power from the UNO. Input and output sources' stated conditions. It starts by determining which pins will produce an output and configuring the load modes for the controller. After setting up the controller before beginning the never-ending loop, it shows a welcome screen *[30]*. The loop is divided into three sections, the first of which reads both the input and output values The Arduino then begins the solar and wind updates, correcting the output voltage and input current by altering the amount of duty sent to each load pin.

4.4.2 Controller Configurations

The system starts with an Arduino module power connection, source code has been programmed to define various lines of codes after determining the available energy source at a giving time solar enable, solar load, wind enable, wind load, wind relay, solar input voltage, solar input current, wind input voltage, wind input current output voltage and output current are all defined Then configure the controller's limits for both sun and wind: Enable Voltage, Disable Voltage, Target Voltage, Maximum Current, and Minimum Current. Finally, the Output Voltage and Current Maximum and Minimum are set. Figure 4.3 illustrates this.

```
#define Solar_Enable 8
#define Solar_PWM 11
#define Wind_Enable 7
#define Wind_PWM 6
#define Wind_Relay 0
#define SVIN A0
#define SIIN A1
#define WVIN A2
#define WIIN A3
#define VOUT A5
#define IOUT A4

//Limits for Controller
#define Solar_Enable_Voltage 36.0
#define Solar_Disable_Voltage 34.0
#define Target_SVin 35.0
#define SIin_MAX 4.0
#define Iout_MIN 0.1

#define Vout_MIN 27.6
#define Vout_MAX 27.7
#define Iout_MAX 20.0

#define Wind_Enable_Voltage 32.0
#define Wind_Disable_Voltage 28.0
#define Target_WVin 30
#define Wind_Vmax 50.0
#define WIin_MAX 10.0
```

Code 0-1 Defining the system controller's power conditions

Because the clock operates 64 times faster than typical when working on Fast load, a time delay is required. The Arduino will be able to read at a normal rate because of the delay. To protect the circuit, the controllers' duty cycle must have a maximum and lowest level. Section 4.4.6 will go through this in greater depth [31]. A voltage divider was used to provide a measurable voltage for the Arduino. Figure 4.4 shows the voltage multipliers used to reflect the voltages before they are decreased.

```
//Delay for FastPWM
#define Delay 64

//Duty cycle limits
#define Duty_MIN 140
#define Duty_MAX 240

//Multiplier for Voltages
#define SVIN_MULTIPLIER 0.04212
#define WVIN_MULTIPLIER 0.05702
#define VOUT_MULTIPLIER 0.02842
```

Code 0-2 Definitions of PWM, duty cycle, and voltage multiplier

4.4.3 LCD Library and Global Variables

The library Liquid Crystal is used to work with LCD screens by the values from the input and output are shown on an LCD display. The duty cycle, input and output voltages and currents are all set as global variables [32]. Figure 4.5 shows this.

```
//Set up the LCD library
#include <LiquidCrystal.h>
#define LCD_RS 12
#define LCD_RW 13
#define LCD_EN 9
#define LCD_D7 2
#define LCD_D6 3
#define LCD_D5 4
#define LCD_D4 5
LiquidCrystal lcd(LCD_RS, LCD_RW, LCD_EN, LCD_D4, LCD_D5, LCD_D6, LCD_D7);

//Some global variables
uint8_t solar_dutycycle;
uint8_t wind_dutycycle;
float solar_voltage;
float solar_current;
float wind_voltage;
float wind_current;
float output_voltage;
float output_current;
```

Code 0-3 LCD library with global variables

4.4.4 Enabling and Disabling

Disabling and enabling settings are used to guarantee that electricity is given when it is needed and redirected when it is not. The only difference between the wind and solar MPPTs is the usage of a wind MPPT relay to protect the wind turbine and maintain a steady load a Channel registers control whether the clock source's prescaler is enabled or disabled. Shown in Figure 4.11.

```
//Turn on the Solar DC-DC converter
void solar_enable()
{
  // Clock source enabled with prescaler=1
  TCCR2A &= 0b10111111;
  TCCR2A |= 0b10000000;
  //Enable signal high
  digitalWrite(Solar_Enable, HIGH);
}
//Turn on the Wind DC-DC converter
void wind_enable()
{
  // Clock source enabled with prescaler=1
  TCCR0A &= 0b10111111;
  TCCR0A |= 0b10000000;
  //Enable signal high
  digitalWrite(Wind_Enable, HIGH);
  digitalWrite(Wind_Relay, HIGH);
}
//Turn off the Solar DC-DC converter
void solar_disable()
{
  //Enable signal low
  digitalWrite(Solar_Enable, LOW);
  // Clock source disabled
  TCCR2A &= 0b00111111;
  solar_dutycycle = 0;
}
//Turn off the Wind DC-DC converter
void wind_disable()
{
  //Enable signal low
  digitalWrite(Wind_Enable, LOW);
  digitalWrite(Wind_Relay, LOW);
  // Clock source disabled
  TCCR0A &= 0b00111111;
  wind_dutycycle = 0;
}
```

Code 0-4 Enabling and removing solar and wind power

4.4.5 Duty Cycle Configuration for DC-DC Converters

To keep the upper MOSFET's bootstrap capacitor charged, the duty cycle is adjusted below 100% in both buck converters. If the bootstrap capacitor is not charged, the gate will flip off, leaving the transistor half conducting.

```
void solar_duty(uint8_t sduty)
{

  if(sduty>Duty_MAX)
  {
     sduty = Duty_MAX;
  }

void wind_duty(uint8_t wduty)
{
  if(wduty>Duty_MAX)
  {
     wduty = Duty_MAX;
  }
```

Code 0-5 Setting duty cycle under maximum

By requiring a duty cycle greater than 50%,

A synchronous buck can prevent voltage from the output from flowing to the input.

```
  if(sduty<Duty_MIN)
  {
      sduty = Duty_MIN;
  }
  solar_dutycycle = sduty;
  OCR2A = sduty;
}

   if(wduty<Duty_MIN)
   {
      wduty = Duty_MIN;
   }

   wind_dutycycle = wduty;
   OCR0A = wduty;

 }
```

Code 0-6 Setting duty cycle above minimum

4.4.6 *Measuring and Displaying Input and Output Values*

The Arduino microcontroller reads the voltage and converts it to a number between 0 and 1023 using an analog to digital converter (ADC). If the voltage in the circuit exceeds 5 volts, it will overload. The ACS712 turns current into a voltage that may be read in the same way as the voltage divider. After 16 measurements, each value is averaged. After the numbers have been read and averaged, they are displayed on the LCD screen in Figure 4.14.

```
void read_values()
{
  float SVin_dac = 0;
  float SIin_dac = 0;
  float WVin_dac = 0;
  float WIin_dac = 0;
  float vout_dac = 0;
  float iout_dac = 0;
  for(int j=0; j<16; ++j)
  {
    SVin_dac += analogRead(SVIN);
    SIin_dac += (.0264 * analogRead(SIIN) - 13.32);

    WVin_dac += analogRead(WVIN);
    WIin_dac += (.0742 * analogRead(WIIN) - 37.62);

    vout_dac += analogRead(VOUT);
    iout_dac += (.0742 * analogRead(IOUT) - 37.81);
  }
  solar_voltage = SVin_dac * SVIN_MULTIPLIER / 16;
  wind_voltage = WVin_dac * WVIN_MULTIPLIER / 16;
  output_voltage = vout_dac * VOUT_MULTIPLIER / 16;
  solar_current = SIin_dac / 16;
  wind_current = WIin_dac / 16;
  output_current = iout_dac / 16;
}
```

```
void write_display()
{
  lcd.setCursor(1, 0);
  lcd.print("    V  ");
  lcd.setCursor(2, 0);
  lcd.print(solar_voltage);

  lcd.setCursor(9, 0);
  lcd.print("    V  ");
  lcd.setCursor(10, 0);
  lcd.print(wind_voltage);

  lcd.setCursor(1, 1);
  lcd.print("     A  ");
  lcd.setCursor(2, 1);
  lcd.print(solar_current);

  lcd.setCursor(9, 1);
  lcd.print("    A  ");
  lcd.setCursor(10, 1);
  lcd.print(wind_current);

  lcd.setCursor(2, 2);
  lcd.print(" Output Values: ");

  lcd.setCursor(1, 3);
  lcd.print("    V  ");
  lcd.setCursor(2, 3);
  lcd.print(output_voltage);

  lcd.setCursor(9, 3);
  lcd.print("     A  ");
  lcd.setCursor(10, 3);
  lcd.print(output_current);
}
```

Code 0-7 Measuring and displaying measured values

4.4.7 DC-DC Converter Upgrades for Solar and Wind

After reading the input and output data, the Arduino begins the loop. Using those values to update the DC-DC converter controller for wind and sun. According to the status of the controller and the input/output data read, the Arduino chooses whether to activate, the duty cycle can be disabled or updated. The program design for disabling, enabling, and updating the duty cycle is virtually identical in wind and solar.

If the turbine produces more than 50 volts, the wind DC-DC converter contains an additional condition to protect components that are sensitive to voltages greater than 50 volts; the controller will stop the circuit and send it to the dump load resistors.

The Arduino starts by checking the operation of the DC-DC converters. If the solar and wind voltages are less than their respective disable voltages, or if the current is less than the output's minimum, the DC-DC converters will be disabled. . The controller determines whether the input voltages are less than the target voltages, the output exceeds the output limit, the input current exceeds the input maximum, and the output current exceeds the output maximum if the operational circumstances are met. If one or more of these criteria are met, the duty cycle will be reduced until the desired output is achieved. If the voltages exceed the target voltages but the output voltage falls below the minimum limit, the duty cycle will be increased by one until the desired output is achieved. If the input voltage is higher than the enabling voltage, the Arduino will enable the DC-DC converters. It will measure and update the duty cycle when in enable mode by multiplying 255 by the output voltages over the input voltages [33]. This is shown in Figure 4.15 and 4.16.

```
void solar_update()
{
  if(solar_dutycycle) //DC-DC converter is currently running
  {
    //Disable
    if((solar_voltage<Solar_Disable_Voltage) || (solar_current<Iout_MIN))
    {
      solar_disable();
    }
    //Update
    else
    {
      //Reduce duty cycle
      if((solar_voltage<Target_SVin) || (output_voltage>Vout_MAX) || (solar_current>SIin_MAX) || (output_current>Iout_MAX))
      {
        solar_duty(solar_dutycycle-1);
      }
      //Increase duty cycle
      if((solar_voltage>Target_SVin) && (output_voltage<Vout_MIN))
      {
        solar_duty(solar_dutycycle+1);
      }
    }
  }
  else //DC-DC converter is turned off
  {
    //Enable
    if(solar_voltage>Solar_Enable_Voltage)
    {
       solar_duty((uint8_t) (255*output_voltage/solar_voltage));
       solar_enable();
    }
  }
}
```

Code 0-8 Solar DC-DC converter update

```
void wind_update()
{
  if(wind_dutycycle)
  {
    //Disable
    if((wind_voltage<Wind_Disable_Voltage) || (wind_current<Iout_MIN) || (wind_voltage>Wind_Vmax)
    {
      wind_disable();
    }
    //Update
    else
    {
      //Reduce duty cycle
      if((wind_voltage<Target_WVin) || (output_voltage>Vout_MAX) || (wind_current>WIin_MAX) || (output_current>Iout_MAX))
      {
        wind_duty(wind_dutycycle-1);
      }
      //Increase duty cycle
      if((wind_voltage>Target_WVin) && (output_voltage<Vout_MIN))
      {
        wind_duty(wind_dutycycle+1);
      }
    }
  }
  else
  {
    //Enable
    if(wind_voltage>Wind_Enable_Voltage)
    {
       wind_duty((uint8_t) (255*output_voltage/wind_voltage));
       wind_enable();
    }
  }
}
```

Code 0-9 Wind DC-DC converter update.

Chapter 5

Analysis and Testing

5.1 Introduction

This chapter will go over the testing procedures and outcomes. To guarantee that the PROTOTYPE Smart Grid design and logic work properly, a bench test was conducted. To mimic two separate power sources were employed to feed each component of the circuit, including the solar panel and wind turbine. A constant current electronic load, as described in Section 3.4.8 simulates the battery. This allows power to be driven from the current source to simulate battery charging. To determine how well the smart grid controller is operating, efficiency is calculated. The input power (W) and output power (W) are compared. (W) To determine efficiency (). Equation 5.1 shows this.

$$\eta = 100\% \times \frac{Pout}{Pin}$$

Equation of power efficiency ……………………. (Eq 5.1)

Because the test equipment could only handle 60W, a smaller circuit was employed to check the controller's architecture and logic. With the exception of inductors and capacitors for DC-DC converters, components and design are identical. For solar and wind circuits, the smallest capacitance and inductance required to build the downsized hybrid controller were calculated using the equations from Section 4.2. A 100H inductor and capacitor 680F were chosen. To accommodate the test equipment's restrictions, the input and output voltages were modified. The output voltage of 13.8 volts is the charge voltage of a 12-volt battery. The maximum current that the power supplies can deliver is 5 A, a 12V rated solar panel produces 18V when exposed to light. The same conditions were used for the wind turbine [34, 35].

```
//Limits for Controller
#define Solar_Enable_Voltage 18.0
#define Solar_Disable_Voltage 16.0
#define Target_SVin 17.0
#define SIin_MAX 5.0
#define Iin_MIN 0.1

#define Vout_MIN 13.8
#define Vout_MAX 13.9
#define Iout_MAX 20.0

#define Wind_Enable_Voltage 18.0
#define Wind_Disable_Voltage 15.0
#define Target_WVin 17.0
#define WIin_MAX 15.0
```

Code 0-1 Changed controller limitations

The signal generated by the controller was collected using a RIGOL DS1054 oscilloscope. In addition to the oscilloscope, the FLIR DM93 digital multi-meter (DMM) was utilized to calibrate the exact voltage and current data displayed on the LCD display in (Figure 5.3). The test was instrumented as shown in Figure 5.2.

Figure 5.2 shows the solar MPPT circuit to the left of the Arduino. The solar MPPT is connected to the power supply to the left of the oscilloscope. The solar circuit's output is connected in parallel to the wind circuit, and the ACS712 current sensor and voltage divider's output is read from the junction where the wind and solar circuits meet.

Below, to the right of the Arduino board, which is connected to the oscilloscope's power source on the right, is the wind MPPT circuit. The hybrid maximum power point tracker's output is connected to the constant current load device.

In Figure 5.3, the input and output values are presented on the LCD panel. The solar input voltage and current are displayed on the left side of the first two rows, while the wind input is displayed on the right side of the first two rows. On the LCD's bottom row, the output voltage and current are displayed.

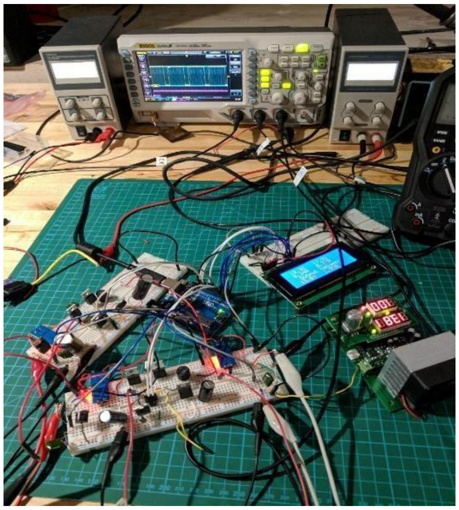

Figure 5.1 Testing Setup

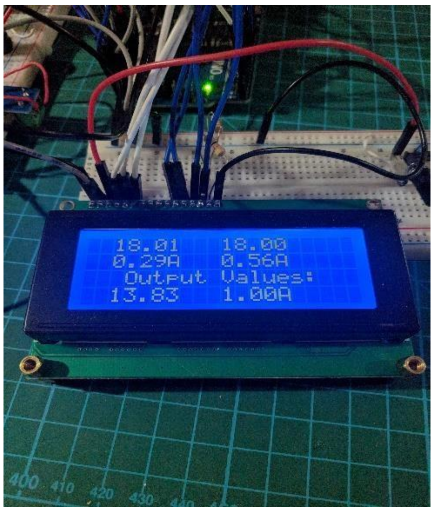

Figure 5.2 LCD display

5.2 Test of a Solar MMMP Controller

Three tests were used to assess the efficiency of solar-only, wind-only, and combination MPPTs. In this portion, only the solar maximum power point tracker was tested, with no input voltage to the wind MPPT. When there is no voltage at the wind MPPT and the solar MPPT is active, voltage is sensed at the wind MPPT has input. 5.4 Final Design of Hybrid Controller The final design of the hybrid controller is in early stages of development. The circuit is shown in Figure 5.4 the design is stepped up from the testing circuits to handle the loads of the 220-v wind turbine and 220-v solar panel.

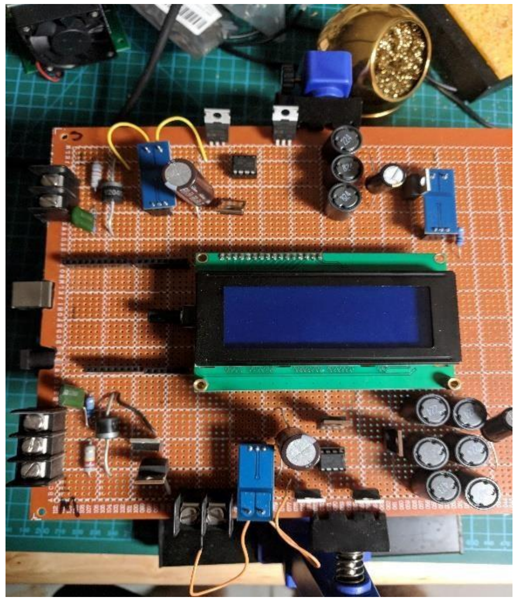

Figure 5.3 Final design concept

The adoption of this project will go a long way towards enhancing communication, energy conservation management, and eliminating developed problems of unsuitable embedded system. The automatic changeover and maximum power point tracker will continue to monitor real-time electricity consumptions and will leave small or slight differences in electricity consumption between the consumer and electricity supplier unresolved.

5.3 Cost of Prototype Components

This section is a breakdown of the cost of each individual part and amount of parts used to design the bench test hybrid MPPT controller.

Table 1 Component cost for prototype

Arduino Uno	$7.99	×1	$7.99
IRFZ44NPbF MOSFET	$.87	×4	$3.48
LCD Module for Arduino	$7.99	×1	$7.99
ACS712	$3.54	×3	$10.62
RFS1317 Inductor	$2.50	×2	$5.00
Low ESR Capacitors	$0.99	×4	$3.96

Resistors	$0.19	×6	$1.14
IR2104 MOSFET Driver	$2.40	×2	$4.80
Step-down TR	$8.20	×2	$16.40
Variable R	$3.50	×2	$7.00
Others			$131.62
		Total:	$200.00

5.4 Current Consumption Analysis

A DMM was connected in series to the Arduino UNO's input port, Vcc, LCD Display, IR2104 MOSFET driver, and ACS712 current sensors to conduct the current consumption analysis. The Arduino UNO consumes the most current, drawing 54.32mA, while the three current sensors draw a total of 36.75mA. The overall consumption is 105.94mA, which is shown in Table 5.5.

Table 2 Current consumption analysis on prototype

Arduino NO	54.32mA	54.32mA
LCD Display with Backlight	9.14mA	9.14mA
MOSFET Driver (on) ×2	2.83 mA	5.66mA
ACS712 Current Sensor ×3	12.24mA	36.75mA
	Total:	105.94mA

Chapter 6

Future Work and Conclusion

Renewable systems are becoming more affordable and have better potential than fuel generation in micro-systems, not only for the environment but also for the cost of operation. Renewable energy systems use the energy that the wind and sun provide, whereas fuel generators need to be supplied with gasoline and oil. Renewable systems are becoming more affordable with better possibilities than fuel generation in micro-systems, not only for the environment but also for the cost of operation. Renewable energy systems use energy from the wind and sun, whereas fuel generators need to be recharged with gasoline and oil. The development of a hybrid MPPT controller utilizes solar and wind energy sources. The capacity to handle two systems with a single controller improves total energy production, affordability, and manageability at the cost of efficiency. The bench test controller cost $200 in total and only used 220 volts.

The inductor size is too huge when using the controller to manage the 500W wind turbine and 125W solar panel because of the Arduino's frequency. Another microcontroller, such as the PIC16C63A, produces a significantly quicker frequency, allowing for a smaller inductor and higher current before saturation.

Wind turbines do not always provide the maximum amount of energy, as the wind speed might change at any time. The development of a buck-boost converter for the wind maximum power point tracker would allow the controller to take advantage of both lower and greater wind speed. Although the total efficiency is lower than that of a concentrated buck or boost controller, it has more power generation potentials [36, 37].

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