Hybrid Power Sharing System of Grid and Solar Photovoltaic Using Microcontroller

By

Mohammad Naib Rayhan
18321002
Taifur Rahman
17121027
Habibur Rahman
18121131
Saif Sayeed
18121130

A Project 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

Department of Electrical and Electronic Engineering
Brac University
January 2022

Declaration

It is hereby declared that

1. The project submitted is my/our own original work while completing degree at Brac University.
2. The report 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 report does not contain material which has been accepted, or submitted, for any other degree or diploma at a university or other institution.
4. I/We have acknowledged all main sources of help.

Student's Full Name & Signature:

Mohammad Naib Rayhan **18321002**	**Saif Sayeed** **18121130**
Habibur Rahman **18121131**	**Taifur Rahman** **17121027**

Approval

The thesis/project titled "Hybrid Power Sharing System of Grid and Solar Photovoltaic Using Microcontroller" submitted by

1. Mohammad Naib Rayhan (ID: 18321002)
2. Taifur Rahman (ID: 17121027)
3. Habibur Rahman (ID: 18121131)
4. Saif Sayeed (ID: 18121130)

of Fall, 2021 has been accepted as satisfactory in partial fulfillment of the requirement for the degree of Bachelor of Science in Electrical and Electronic Engineering on 09th January,2022.

Examining Committee:

Academic Technical Committee:
(Chair)

____
A.S. Nazmul Huda, PhD
Assistant Professor, Department of Electrical and Electronic Engineering
Brac University

Coordination Committee:
(Chair)

____
Abu S.M. Mohsin, PhD
Assistant Professor, Department of Electrical and Electronic Engineering
Brac University

Departmental Head:
(Chair)

____
Mosaddequr Rahman, PhD
Professor and Chairperson, Department of Electrical and Electronic Engineering.
Brac University

Abstract

This project focuses on the rising demand for electricity in Bangladesh and what can be done to meet the rising demands by sharing Solar power with the national grid, thus reducing dependence on the grid. In the context of Bangladesh, where the booming demand for electricity, its spiraling costs, along with the rising levels of greenhouse gas emissions have contributed to the search for alternative energy sources and alternative systems of generating electrical power and sharing power to the grid, thus reducing the dependence on the grid and dependence on fossil fuels. So, renewable energy sources like solar, hydro, biomass, wind etc. can be used to generate electricity of which solar power is the most abundant and has huge potential. However, the typical solar systems that we have do not share any power with the grid and does not play any role in reducing our dependence on the grid. So, there is a lot of scope for work to be done in this sector. One of the main reasons for this is not using an automatically controlling system to have better efficiency. Another major issue with the typical solar system is that a lot of solar energy gets wasted when the battery gets full and loads are getting power from the grid and when the grid is available, there is no use of solar though lots of solar energy is being produced. So, we need a system which will be able to control the total power system of a family utilizing the both power supplying sources solar and grid with a better way so that minimum grid power would be used and maximum solar power would be used from the same system. Even though a lot of work has been done on grid-tie inverters, there are still the issues related to synchronization of the output fluctuating DC voltage from the solar panels used in grid-tie inverters, especially into the research articles that we have looked into before. So, in order to address these issues, the use of a microcontroller-based solar power-sharing system is a very suitable solution. Hence, our proposed Hybrid Power Sharing System of Grid and Solar Photovoltaic Using Microcontroller can possibly fulfill all these parameters and help solve all these issues.

Acknowledgement

Writing this report has been one of the most daunting and intimidating tasks of my life. My heartfelt gratitude goes to my ATC panel, consisting of Assistant Professor Dr. A.S. Nazmul Huda and lecturers Aldrin Nippon Bobby and Tasfin Mahmud respectively. It is with their support, helpful insights and their course materials that triggered me to think critically and with new viewpoints. I also thank all of my faculties of the Department of Electrical and Electronic Engineering for making me grow as a person and for opening new realms of thoughts which I couldn't perceive before. My heartfelt thanks also goes to my friends who gave me the support that I needed when I broke down. Last but not the least I would like to thank my family for being helpful and supportive throughout this year so that I could concentrate on finishing my Final Year Design Project report.

Table of Contents

List of Figures:

List of Tables

List of Abbreviations

RE	Renewable Energy
AC	Alternative current
DC	Direct current
PV	Photovoltaic
SPWM	Sinusoidal Pulse Width Modulation
SPST	Single Pole Single Throw
DPDT	Double Pole Double Throw
IGBT	Insulated Gate Bipolar Transistor
MOSFET	Metal Oxide Semiconductor Field-Effect Transistor
KWh	Kilowatt-Hour
NPC	Net Present Cost
HES	Hybrid Energy System

Chapter 1:

Introduction

1.1 Introduction

Bangladesh is a very much densely populated country where a huge quantity of energy for living and production needs. As a result, to fulfill the demand, lots of electricity is needed and most of the electricity is generated from conventional sources. Conventional sources are the general term applied to the production of electrical energy from coal, oil, or natural gas using the intermediary of steam. Another source from where electricity is being generated is non-conventional which is known as renewable energy sources that are renewed by natural processes on a continual basis. Solar energy, wind energy, bio-energy, hydropower, and other RE sources are some examples of sustainable energy sources [1].

In the very beginning, we will be talking about the problem statement of the current condition of our society related to the electricity generation and usages. Then the background study of this matter will be discussed to know about the running development of this and finding the gaps of appropriate research to reach a better solution to minimize the problems [1]. Moreover, before designing a project, measuring the relevant to the current and future industry perspective is also very important. The technical and non-technical issues, specifications, objectives, requirements etc. are also very important to discuss in the very beginning for getting a proper understanding of project planning.

1.1.1 Problem Statement

Rapid increasing of population over the world causes a huge demand of electricity that can't be fulfilled with the limited amount of conventional energy as it can be estimated by the researcher that by 2030, electricity demand will be double in the coming years. In Fig. 1, it is shown the increasing status of energy of which most of the demand is fulfilled by unsustainable energy sources. It is a matter of great concern that the recent power demand is being supplied by quick rental power plants which involve expensive liquid fuels and cause severe harmful effects on the environment.

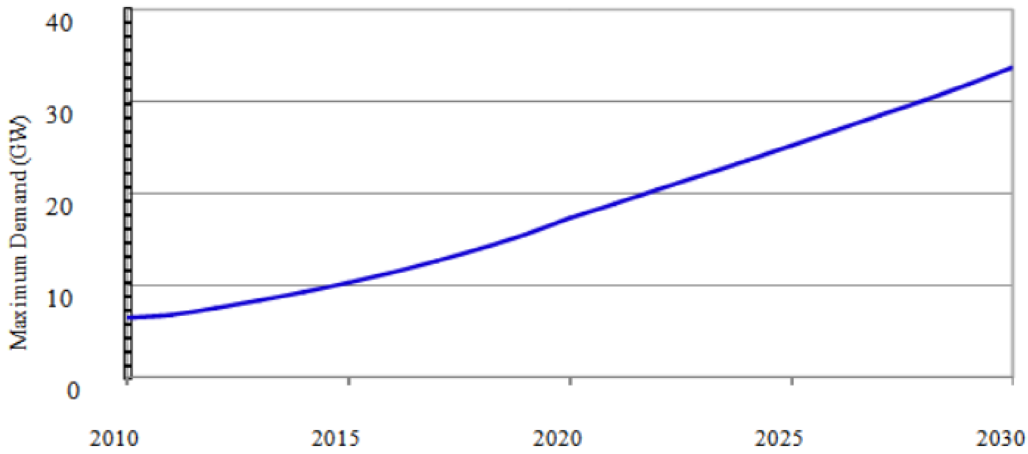

Fig 1.1: Demand of electricity with the time

There are some renewable energy sources like solar, hydro, biomass, wind etc. which can be used for generating electricity from which solar energy is the most usable source from where electricity is being produced nowadays which is at most 54.80% [1]. But it is a matter of sorrow that the efficiency level of today's solar system is very low as 15-20% [1] energy can be utilized from the solar system. One of the main reasons for this inefficiency is not to use automatically controlling the system to have better efficiency. The problem with the typical solar system is that a lot of solar energy gets wasted when the battery gets full and loads are getting power from the grid and when the grid is available, there is no use of solar though lots of solar energy is being produced. So, we need a system which will be able to control the total power system of a family utilizing the both power supplying sources solar and grid with a better way so that minimum grid power would be used and maximum solar power would be used from the same system [1].

1.1.2 Background Study

Till now, a lot of research work has been done on the manufacture of grid-tied solar inverters, both with transformers and without transformers, in both three phase as well as single phase. Multiple designs of Grid-tied inverters have been developed, with each design having different Power Ratings and varying frequencies of the output voltage. Some designs have included different types of LCL filters and MPPT (maximum power point tracker, MPPT DC-to-DC converter) [2]. All these different designs have attempted to ensure a constant output DC Voltage from the inconsistent DC voltage coming in from the PV Solar Panels [2]. The main objective of synchronization is to ensure that the output voltage from the Grid-tied solar inverter has to have the same magnitude, frequency and phase as the grid voltage [2], in order to be able to be sent to the grid. In different types of Grid-tied inverters, different designs of inverters have been implemented, some using IGBTs, whilst others use MOSFETs. Some design use Buck Converters [2], whilst other use a system of SPWM and Square waves, which are generated from the output voltage, which are essentially used for the purpose of synchronization.

1.1.3 Literature Gap

Having gone through several of these research articles, it has become apparent that several issues have still remained unresolved in terms of detecting the presence of electricity coming in from the grid and how to regulate the different components of our system in an efficient manner [2]. Another very important issue that we found was the lack of galvanic isolation between the inverter and the Grid Load in transformer-less systems [2], making the system less safe for the user. Furthermore, the regulation of the output Power and supplying it to the grid load, in case of power cuts, have not been given importance to, especially in many of the previous research articles that we had looked into before. Also, issues related to ensuring constant DC voltage also remain, based on the fluctuating DC voltage coming in from the PV Solar arrays. A simpler solution has to be sought for ensuring a more constant output DC voltage. We have done further research in this regard [2] and have worked to address these issues involves in our background study of the project.

1.1.4 Relevance to Current and Future Industry

Bangladesh is a country with a large population. As the country progresses more and more the electricity demand of the country increases proportionally. This means a large amount of fossil fuels will be needed to be burnt in power plants to meet increasing energy demands. This will result in fast depletion of fossil fuels and issues like huge amounts of contribution to global warming. As days pass people are looking for alternative or renewable sources of energy to meet their energy demand.

Nowadays, in every sector microcontrollers are being used to make the system easy and user friendly as this method is allowing us so many features and lots of ways to modify the system according to our desire. Microcontroller makes the system flexible by reducing the size and cost compared to a design that uses a separate microprocessor, memory, and input/output devices, microcontrollers make it economical to digitally control even more devices and processes. So, the utilization of micro controller in any system is very much acceptable and appreciable for current and future industry as it is very much useful and high demanded thing for the users

1.2 Objectives, Requirements, Specification and Constant

1.2.1. Objectives

The proposed project is basically a micro controller based project that will control the power share of grid and solar. The main objective of this project is to minimize the energy loss of solar and to become less dependent on grid supply. Also, our purpose is to ensure minimum use of grid power to contribute to the electricity crisis of the country and to come back to a sustainable energy source to cope up the electricity demand of the country for developing a better environment. The other objectives of this project are given below:

1. To provide a combinational sharing of solar and grid supply for household works.

2. To create Microcontroller-based controlling system of power sharing to ensure better efficiency.

3. To find a cost-effective system for the poor rural people.

4. To keep a backup supply source to supply to the loads in case of a lack of power [3].

Outcomes that will provide after achieving the objectives:

1. The energy that will be generated by solar panels will be used to power up the different types of AC loads of household works.
2. The generated solar energy will be used to power up the grid loads when the grid supply is not available.
3. When the grid supply is available but solar power is not available, the grid loads and the non-grid loads will be energized by grid supply

4. When the grid and solar power is available but solar power is not that much to support the grid and non-grid loads, combined share of solar and grid energy will be supplied to the both loads. Solar power will go to the grid connected loads and grid power will go to the non-grid loads.
5. If the solar power is high enough to power up the grid loads and non-grid loads, solar will supply energy to the grid and non-grid loads though the grid supply is available.

1.2.2 Functional and Nonfunctional Requirements:

Functional Requirements:

1. The solar panel should be installed at the rooftop of the house so that it can consume the sunlight.
2. The charging amount of the battery has to be controlled manually or automatically to avoid the damage of the battery because the battery loses its life time if the charging amount crosses a certain quantity and also it is not good for the battery to allow charge below a certain quantity.
3. The DC to AC inverter has to be the same or higher rated as the system rating because if the inverter's rating is below the system rating then the inverter will be damaged and also the other components will be hampered.
4. The DPDT relays need to be powered up by 12V supply as they don't operate in 5V.
5. Fuses or circuit breakers have to be used in the grid and AC supply sides to protect the system from overload and short-circuit situations so that when there is a fault in the circuit, the fuses or circuit breakers can open the circuit to protect the components from being damaged [3].

Nonfunctional Requirements

1. The battery can be placed in a low tempered place where there is a less chance to overheat the battery and get a suitable place to cool down.
2. Manual switching should not be done as frequently as it causes more power losses and decreases the lifetime of the devices.
3. Solar panels with good efficiency can be installed to get a better outcome.
4. Proper insulation to all parts of the project should be ensured to get a better safety arrangement.

1.2.3 Specifications

Table 1.1: Table of the Specifications

SL No	System	Required Components	Specifications	Comment
01	Solar Energy Collecting System	Solar Panel	• 50W output power. • 3.05A SC current. • 18V maximum voltage. • 150*125mm dimensions. • 1000 W/m2 irradiance, Tc =25.	Used to collect the photons from sun and convert it into DC electricity.

02	Solar Energy Storage System	Battery	• 12V lithium battery. • 7.5AH storage capacity. • 2.8A output current.	Store the DC energy coming from the solar panel.
		SPDT Relay	• Single pole double throw (SPDT). • 5V input DC voltage. • 250V (max) output voltage.	Used for controlling the charge flowing from the solar to the battery.
		Voltage Sensor	• Input voltage: 0 to 25V • Voltage detection range: 0.02445 to 25. • Analog voltage resolution: 0.00489V.	Provide the voltage status of the battery and solar to the Arduino.
03	Power Conversion	Inverter	• 100W power rating. • DC-AC type.	Convert the DC voltage of battery for AC appliances usage.
		Transformer	• Step up transformer. • 12V input voltage. • 220V output voltage.	Used for stepping up the inverter's AC voltage.
04	Power Sharing System	Arduino	• Microcontroller: ATmega328P, 16MHz quartz crystal frequency. • Operating Voltage is 5V. • Input Voltage (recommended): 7-12V. • Input Voltage (limit): 6-20V. • DC Current per I/O Pin is 20 mA.	Provide the appropriate commands to the controlling devices for power sharing according to the given code.
		DPDT relays	• Nominal Voltage 12Vdc. • Maximum switching voltage is 277V AC. • Maximum switching current is 30 A. • Maximum switching power is 8310 VA.	Used to choose between two different power sources for connecting with a single load according to the code.
		SPDT relays	• Single pole double throw (SPDT). • 5V input DC voltage. • 250V (max) output voltage.	Connect the DPDT relays with the Arduino.
		Grid detection relay	• 200V to 270V sensing limit	Send the grid line status to the microcontroller.
05	System Protection	Fuses	• Current Rating: 0.5A-15A. • Voltage: 220V	Protect the devices from overload and short-circuit situations.
06	System Monitoring	LCD display	• 20*4 type module. • HDD44780 liquid crystal module.	Used to display the status of all devices.

1.2.4 Technical and Non-technical consideration and constraint in design process

Technical considerations:

- **A.** Appropriate location/site assessment based on the solar resources should be found out and necessary surveying also should be done [3].
- **B.** Solar energy resource assessment for the selected location will have to done properly.
- **C.** Choosing proper size of the battery bank is also a very big concern to store proper power during the sunlight hours.
- **D.** The size of the inverter will have to be selected according to the solar panel capacity and the power rating of the system.
- **E.** Selecting proper cable size.

Technical Constraints :

1. Sun-shine hours should not be used as its not same as peak-sun hours or insulation.
2. Average annual sun-shine hours should be avoid as it is equivalent to insolation.
3. Should be aware about the dust accumulation, shading etc. as these reduce the output.
4. Because of shading, hot spots are generated in the SHS that reduces the operating life [3].

Non-technical Considerations:

- Gathering information dissemination and consumer awareness about energy conservation and RE [3].
- Choosing the most energy efficient and cost effective system.
- Adequate workforce skills and training should be acquired.
- Maintaining adequate codes, standards, and interconnection and net-metering guidelines for better output.
- Removing Poor perception by the public of renewable energy system aesthetics e, standards, and codes [4].

1.3 Systematic overview/summary of the proposed project

In our proposed project, there will be two power sources from where electricity will come, one is grid and another is solar. There will be two types of loads, one is grid load, and another is non-grid load. We will have a system which will use the combined power of the solar and grid for the two kinds of loads according to the availability of the power of each supply. First of all, the solar DC power is being stored to the battery and there is a DC to AC converter in between loads and battery to convert the DC power to AC so that it can be suitable for the AC appliances. This power sharing will be done by the microcontroller named Arduino which will command the activities according to the given conditions [4].

For example, if the sun is giving proper solar energy and storage of the battery is full and the grid power is on which are being sent by voltage sensors to the Arduino, then Arduino will give command to the relays to close the connection of solar power for the both loads and open the terminal of grid line so that solar can provide the electricity to both grid and non-grid loads as solar is capable of powering both loads and grid connection remains off as there is no necessity to use the grid power [5]. But if the solar power stored in the battery is not enough to supply the both loads and grid power is present there, then one relay will close the solar terminal with the grid load terminal and another relay will close the grid line terminal with the non-grid load terminal so that solar can power up the grid load and grid can power up the non-grid load [6]. Moreover, if solar is available and grid is not available then Arduino will switch the solar power line with the both loads so that solar can supply the both loads in absence of grid power. When the solar power is absent and grid power is present, sensors will detect the status and send to the Arduino, Arduino will command the relays to close the terminals of both loads with the terminal of grid line so that both loads can be powered up by the grid supply.

1.4 Conclusion

In Bangladesh, nowadays most of the energy demand is fulfilled by unsustainable energy sources which are quite impossible for the future as the electricity demand will double by 2030. So, we should also focus on sustainable energy sources like solar, wind, biomass etc. The solar systems that are being used in our country most of them are off-grid and those are analog types. So, we have thought of making it digital type which means the total system will be controlled by a microcontroller and also it will contribute to the grid power indirectly so that we can become less dependent on the grid and use the grid power as minimum as possible.

Chapter 2

Project Design Approach

2.1 Introduction

A project is an achievement that needs lots of hard work. But a project will be successful if it builds with the best ideas, minimum cost and has user friendly features. To build an optimal design solution for the desired outcome, multiple design approaches should be done so that it can be obtained which design is giving the better result in case of cost, features, build quality etc. So, before going to the hardware work of developing a project, it is necessary to work with different types of methods to build the project focusing on the same outcome. In this chapter, we will discuss about the identification of multiple design approaches [7] and will describe the design particularly with the systematic methodologies of their building process. Then we will analysis the multiple design considering their advantages and constraints.

2.2 Identification of Multiple Design Approach

According to our desired purposes of designing, we were willing to implement a system which will be able to provide efficient power generation and supply system where sustainable energy sources will get priority and will reduce the reliability on the unsustainable energy sources. Moreover, our aim is to build a project that will help to provide better power efficiency and reduce the cost of the system [7] so that the poor rural people will be able to implement the system to their own. To achieve these goals, we are considering two design approaches.

2.2.1 Grid-tied solar system: Grid-tied solar system is the grid connected system where solar panels connect directly to an inverter, which ties into your main household electrical panel and sends power into the home to run appliances and turns back the meter with excess energy [8]. It’s a very efficient system which helps to reduce the power losses as the excess electricity is given to the grid after fulfilling the demand of the household works. In this system, the generated electricity from the solar will go to the battery which will send the DC power to the grid-tie inverter so that it converts the DC voltage to AC synchronizing with the grid then supplies to the home loads [8] according to the necessity and sends the extra electricity to the grid. Also, when there is an unavailability of solar power, grid can supply back to the loads. That is how an efficient power sharing is happening.

2.2.2 Hybrid sharing system of grid and solar photovoltaic using microcontroller: As our aim is to be more habituate with the solar energy and minimize the use of unsustainable energy sources, hybrid power sharing system of solar and grid can be an another design. In this design approach, we will produce electricity from the solar and will create an indirect inter-connection with grid and solar which will be control and monitor by the microcontroller [9]. The household loads will be connected with solar line and grid line and power will be given to the loads according to the availability of the sources. In this system, we will be able to reduce the losses of solar energy and will able to reduce the usage of grid power. Also, this system is very much cost efficient.

2.3 Description of Multiple Design Approaches

2.3.1 Grid-tied solar system

2.3.1.1 Methodology: The proposed grid-tied solar system will consist of PV arrays, a step-up dc–dc inverter, a grid-tie inverter and an automatic AC transfer switch. First of all, solar energy is converted into electric energy by solar panel then the step-up dc–dc converter boosts the array voltage to a higher level and grid-tie inverter converts the DC power of the solar into the AC that will be aligned with the power quality and voltage requirements of the grid. For this, the inverter gets the reference voltage from the grid and get the PWM signal of similar frequency and amplitude from the inverter control circuit where phase matching circuit [10] is used to match the voltage phase with the grid line phase and from here generated PWM signals send to the H bridge inverter which is used to the mosfets input that coverts the DC voltage of the solar side to AC equal to the grid considering the grid frequency then the transformer is used to step up the voltage to the grid level by which converted voltage is synchronized with the grid. After that, the transfer switch changes supply source and also selects serving loads according to availability [11].

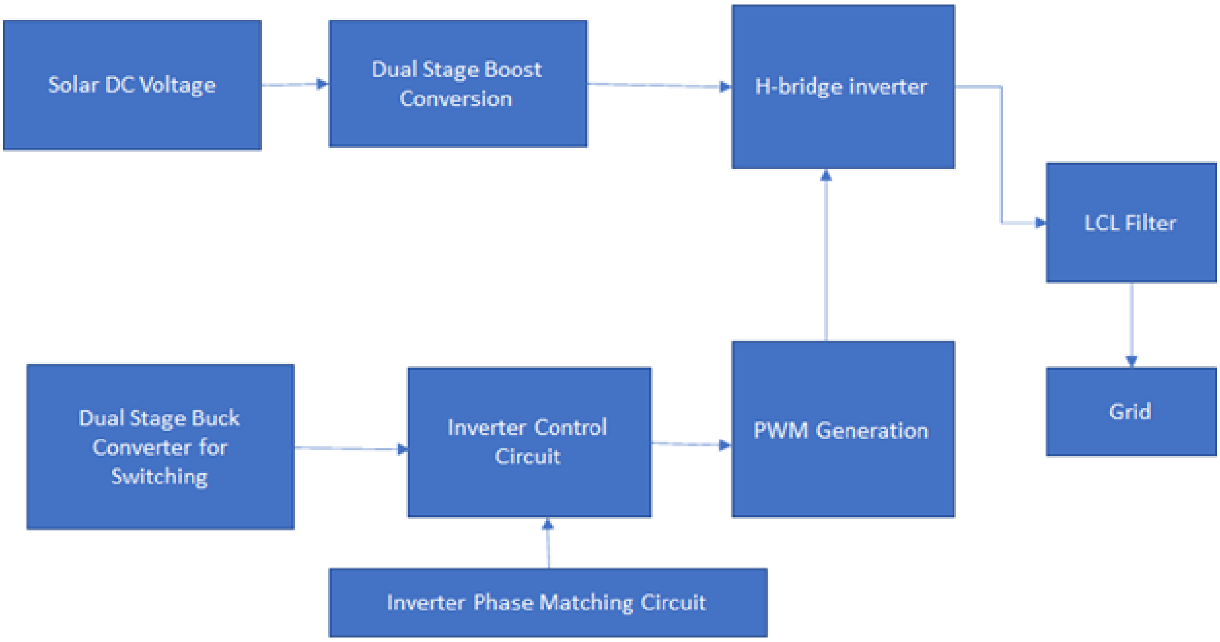

Fig 2.1: Configuration of proposed grid-tied system

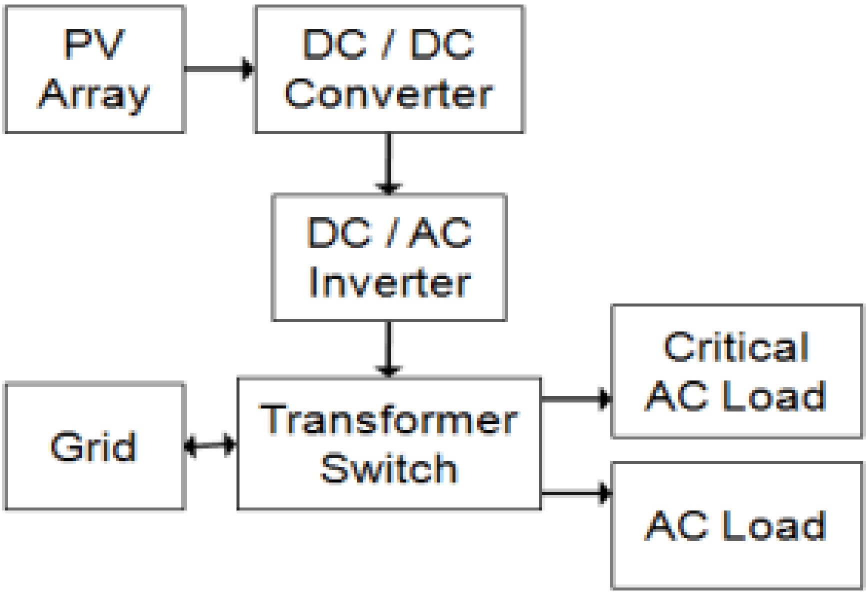

Fig 2.2: Block diagram of the grid-tied inverter.

2.3.1.2 Controlling scheme: The energy management of the simulated grid-tie PV system is shown in the below flowchart. In the beginning, the model updates generated solar power ($Psolar$), required load ($Pload$) and also the SOC of the battery ($SOCbat$). If any change occurs, then the extent or lack of solar power is determined. After serving the required load, if there are extents of energy then it is stored in the battery. But for better management of battery, its SOC is not permitted to exceed 80%. If battery is fully charged, then the extra energy if exists is sold to the grid [11]. On the contrary, when the solar radiation is low, the generated power from PV is not enough to supply the required load. So other energy source is required to meet the load. If grid is available the required energy ($Prequired = Pload - Psolar$) is purchased from the grid. In case of failure of grid, the required energy can be fed to the load from storage battery. For proper management of battery, it is carefully operated so that its SOC cannot be lower than 20%. If the SOC goes lower than 20% then there's no option exist except shedding of non-critical loads [12].

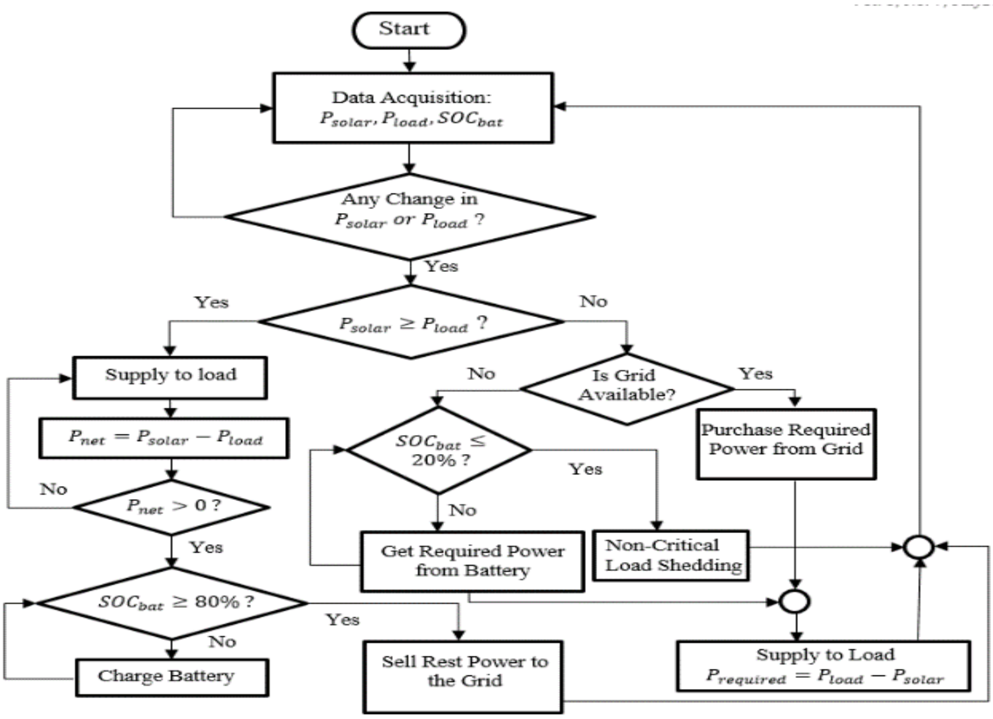

Fig 2.3: Flowchart of the proposed algorithm for the grid connected PV system

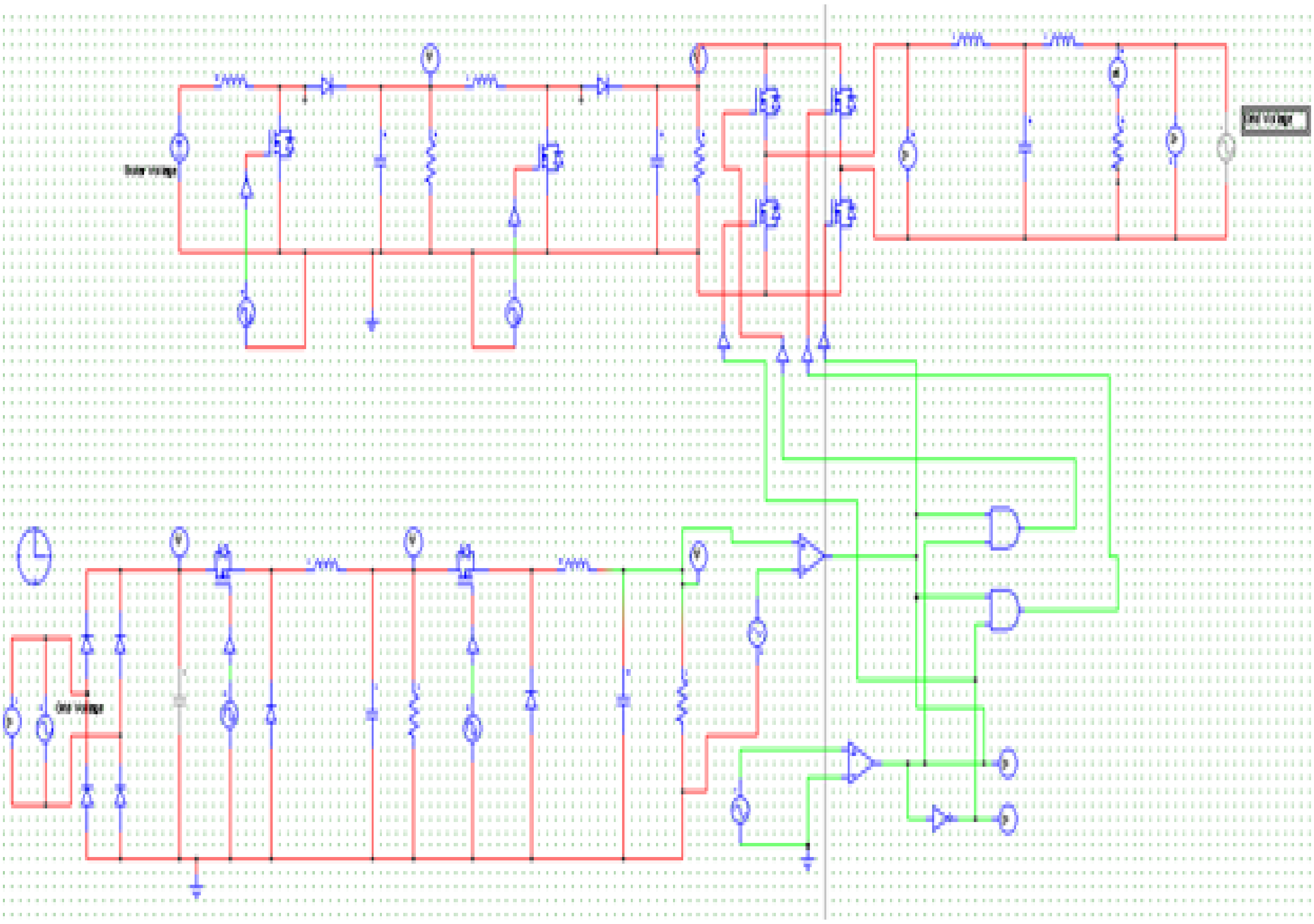

Fig 2.4: Circuit diagram of the design

2.3.2 Hybrid sharing system of grid and solar photovoltaic using microcontroller

2.3.2.1 Methodology: In the hybrid power sharing system, main methodology is using microcontroller to controlling the sharing process. The status of the solar panel, battery, grid etc. are monitored by the microcontroller and give appropriate commands to these devices to conduct the power sharing. Different types of relays are being used to conduct the controlling scheme. To control the charging flow of the solar to battery, SPDT relay is being used, then to conduct the power sharing of solar and grid, DPDT relays are being used [12] which are being commanded by the microcontroller according to the given code.

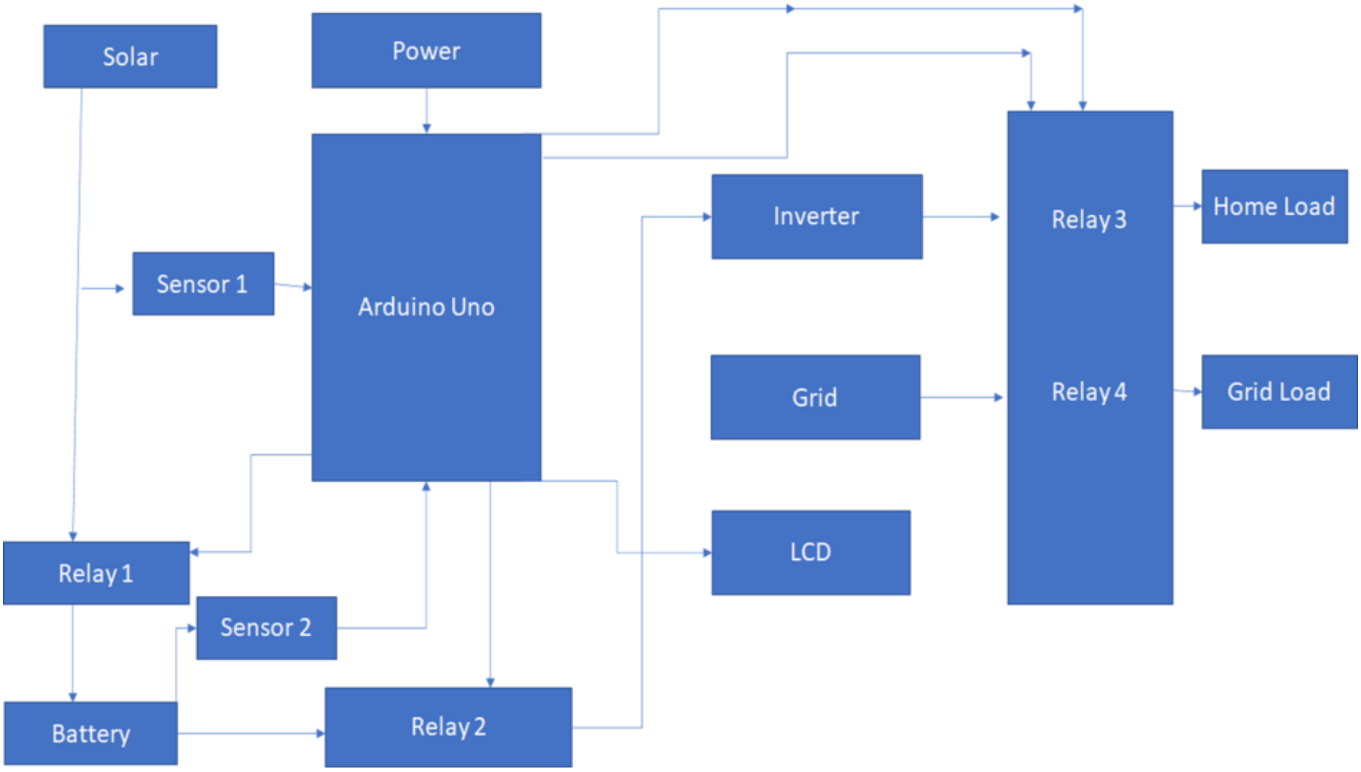

Fig 2.5: Block diagram of the hybrid sharing system.

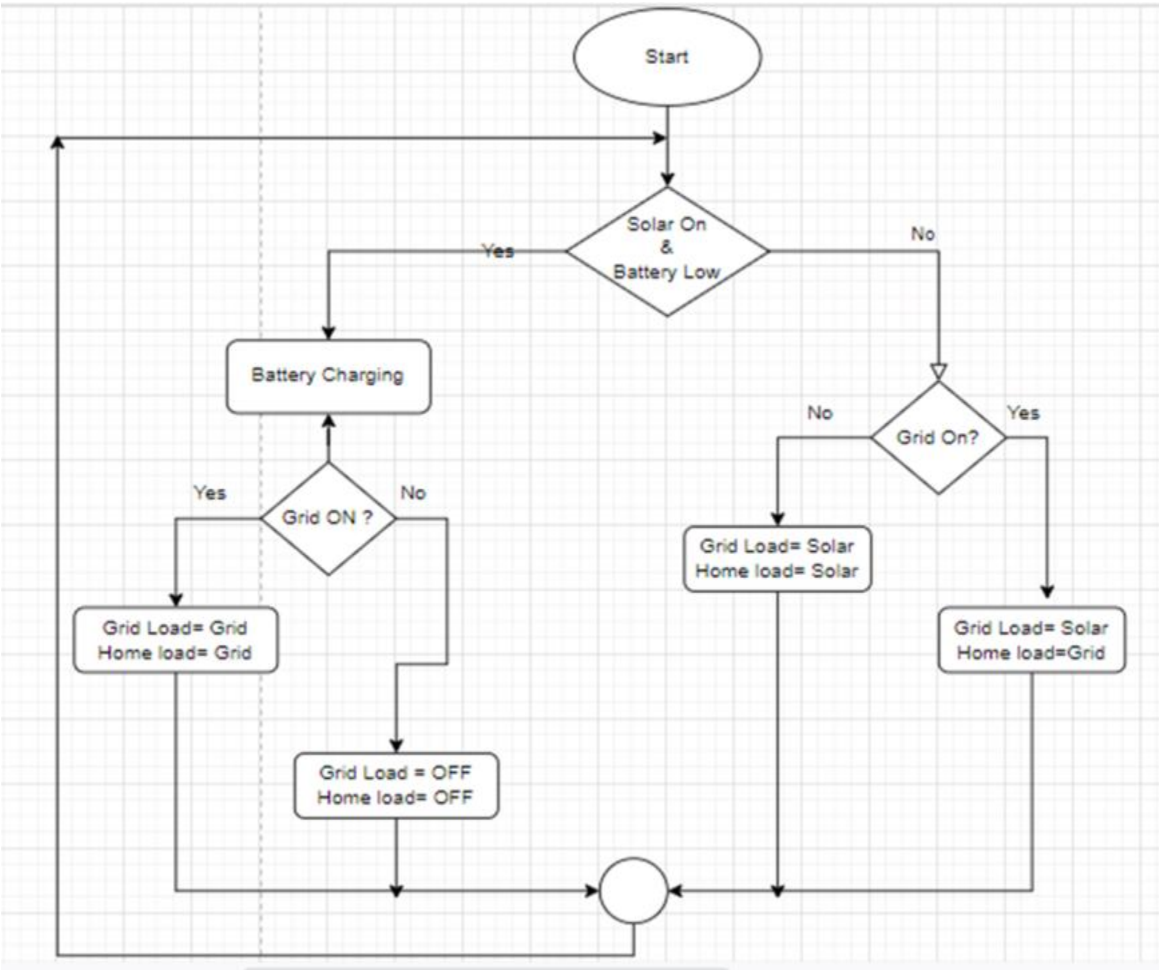

Fig 2.6: Flowchart of the controlling scheme of hybrid sharing system

This design is implemented in Proteus Software, as we found that this software can easily implement our circuit and considering all the constraints and can be used to simulate both the home load and the grid load. This design has been designed in such a way that it shares the voltage with the grid. It is more of a grid – sharing system rather than a conventional grid-tied system. Here, the Arduino controller is used to charge up the battery .A controller that can monitor the output of the solar panel and the battery, control the output of two loads, one is the home load and the other is the grid load. If the grid line on and battery voltage is not full, grid load and home load will run from the grid line [12]. If battery level is low the controller will turn on the charging of the battery from solar.

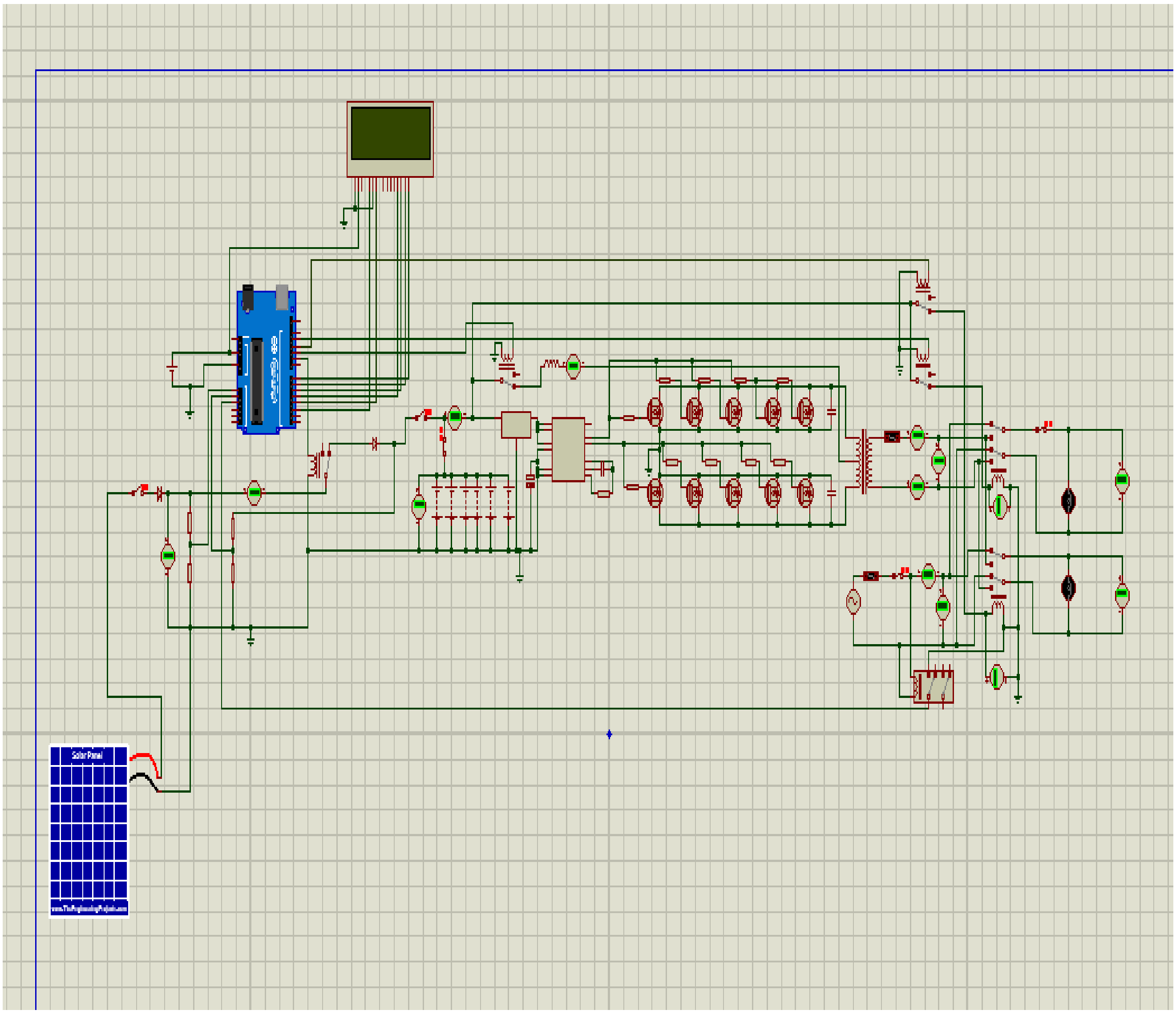

Fig 2.7: Proteus Circuit Diagram

If battery voltage is full and grid line on, battery will power the grid load. (We can say it's a sharing of power), if grid line off, battery will power the home load. By, simulation, the output voltage here is 220V AC supply, which is the same as the grid supply. Although this is not exactly a Grid-tied inverter system per se, it works exactly in the same manner as the grid-tied inverter system; also this system uses a battery for storing the voltage output. The most critical part of this simulation design is the ARDUINO microcontroller [12], which controls the charging up of the battery and also supplying the electricity to the grid. The ARDUINO, by controlling the Relay switch, control the flow of electricity between the home load and the grid load.

2.4 Analysis of multiple design approach

2.4.1 Grid-tied solar system : the diagram below shows the simulated output voltage of our grid-tied solar system, which is approximately 220V A.C. (same as the grid supplied voltage).

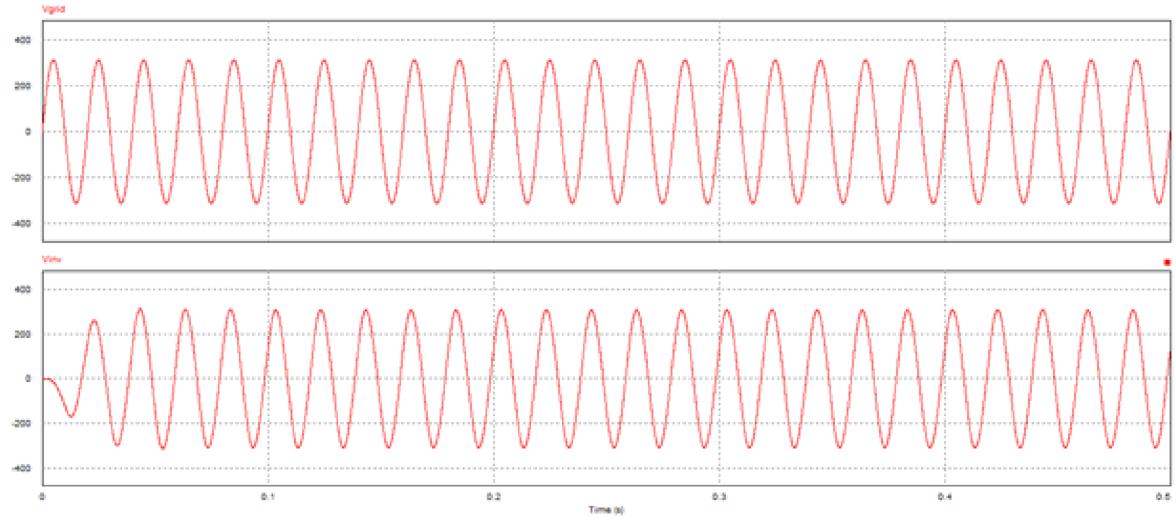

Fig 2.8: Simulation result of the grid-tie system

2.4.1.1 Key Advantages of Proposed Grid-Tie System

1) Properly configured, this grid-tied system allows the owner to use an alternative generation from solar energy. If the alternative power being produced is not enough, then the power will be drawn from grid.

2) Net-metering system allows homeowners to get profit for any electricity that the system sends to the grid.

3) The system will continue to supply home loads if the grid is not available.

4) Owner can remove the expense of the large battery bank as in grid-tied system, battery is not mandatory.

5) This system is more power efficient than a conventional system which uses a battery power bank for electricity storage.

6) As batteries degrade with time and need replacement, proper disposal requires extra care. The use of battery system thus is not normally considered as a viable option since the disposal of batteries may also cause other environmental problems.

7) Grid-tied inverters are scalable which allows to add more solar panels with additional grid-tie inverter in parallel permits scaling up power capability [13].

2.4.1.2 Disadvantages

There are several technical issues in the grid-tie solar system like harmonics, voltage fluctuations, frequency fluctuations, Storage, Protection issues, Islanding and cost issue which are given below [13]:

Harmonics

- Frequency disturbance
- Waveform distortion

Low Power Factor

- Low power factor causes equipment damage
- Increases in Energy bills

Transients in Power System

- Produces distortion like impulse and notches
- Long and Short duration event

Electro Magnetic Interferences

- Interference between electric and magnetic field
- High frequency phenomenon

Power Frequency Disturbances

- Low frequency phenomenon
- Produces voltage sags and swells

2.4.1.3 Cost issue

- Needs 800-1000W power rating system to implement grid-tied inverter.
- Very much inefficiency in case of performance and cost for lower power rating.

2.4.2 Power sharing system:

2.4.2.1 Advantages of Power Sharing System

- Grid power and solar power can be used simultaneously to the loads without direct connection which allows a safe power sharing system.
- Synchronization with the grid line is not required that can helps reduce the complexity of the hardware circuit and can reduce the internal losses.
- Proper usage of produced solar energy is ensured because of automatic controlling system using microcontroller.
- Take less electricity from the grid which causes less electricity bill.
- Very much cost efficient so that any rural family can afford.
- Have minimum risk to implement as direct grid connection is not here [13].

2.4.2.2 Disadvantages of Power Sharing System

- Power cannot be sent to the utility grid.
- Need extra battery backup which can be expensive for high power ratings.
- Battery lifespan decreases more quickly as its working mode is always on.

2.5 Conclusion

After having the discussion of multiple design approaches, we have come to a solution that both designs have their own advantages and disadvantages. The optimal solution depends on the various criteria of the particular situation. For some perspective, the grid-tied system is beneficial and for some perspective hybrid power sharing system is appropriate.

Chapter 3
Use of Modern Engineering and IT Tool

3.1 Introduction

Engineering and IT tools are the helping hands for developing a project. The usages of these tools make the design more easy and accurate. There are a lot of free and paid IT tools that are currently available on the market. Some of them are quite expensive and need to be cracked in order to be downloaded and used. Throughout our courses we have learnt a lot of IT tools, coding and simulation in order to do small or big assignments and projects. Here is some list of software that are available which can be used for design, coding and simulation. We have listed some software which we wanted to use or have tried and used in various stages of our project development: -

3.2 Engineering and IT tools

At first Proteus was used to design our system and then we had to code for it in Arduino software. The code is then uploaded to the Arduino using a USB jack. Then we had to implement it in our hardware portion. We used a breadboard to put the lcd panel and connect all the jumper wires. Then for safety reasons we had to glue the components to the breadboard with a glue gun. Some of the wires were needed to be connected to switches as well. To connect wires to the terminals a hot soldering iron which uses melted metal at high temperature was used. The relay modules had screws which needed to be opened using a screwdriver to connect the wires to it [14]. The outputs of the inverters were also needed to be measured to check whether they are giving the desired output or not. Multimeters were used to measure output from the inverters that were connected to the loads. There are lots of wires needed in our prototype. The wires were checked using a multimeter to make sure that their terminals are shorted properly. Our project prototype is situated on a hard wooden board which is cut using a saw.

3.3 Use of modern engineering and IT tools

The usage of our required tools is given below:

Table 3.1: Software Tools

SL No.	Tools	Use
01	Proteus	Used to build the circuit design virtually to ensure the proper working of the proposed approaches.
02	Arduino IDE	Used to write the code for the microcontroller controlling.
03	PSIM	Used to simulate the alternative design to analysis the outcomes.
04	MATLAB Simulink	Needed to design the inverter in the very beginning.

Table 3.2: Hardware Tools

SL No.	Tools	Use
01	Multi-meter	Used for measuring the voltage status of the terminals, battery or other components.
02	Soldering Iron	Used for soldering the wires, components of the hardware design.
03	Glue Gun	Used to binding the multiple wires, attaching the components with the hardboard and keeping them separate from other components.
04	Screw Driver	It's used to tight the screws of the devices.
05	Wire Strip	Used for separating the insolation of the wires to join the wires.
06	Utility Knife	Used to cut the wires or the wasted things
07	Voltage Tester	Used for instant check of the wires to ensure that the wires are working or not.
08	Hand Saws	Used for cutting the hardboard.

3.4 Conclusion

A lot of experience in coding, microcontrollers, and hardware were needed in our project. One of the most important things was visualization. We needed to learn about a social problem that is quite prevalent in our society and then using our knowledge, skills, and experience we proposed a solution that can play a good role to mitigate this problem. Good knowledge about electronics, like relay switching and their rated and operating conditions were needed to be studied. In short, we needed theoretical and practical knowledge that we have attained throughout our university life for idea-generating and developing our project prototype.

Chapter 4

Optimization of Multiple Design and Finding the Optimal Solution

4.1 Introduction

To design a project, the developer always tries to find the optimal solution so that he can get the best outcome with the highest efficiency. Optimal solution means the solution that gives the most accurate and fast result with more sustainability and less cost.

4.2 Optimization of multiple design approach

We have tried to design two projects to make sustainable energy more usable for the people and reduce the dependency to unsustainable energy. Firstly, we had tried to design a grid-tied solar system which will produce electricity from solar and will provide it to the grid as well as to the household works. But this design is very expensive, time consuming and difficult to implement practically as synchronizing with the grid is necessary [15] for this system but it is the most difficult part to do. Also, there is another problem which is the high cost for this grid-tie system which will be unaffordable for the rural poor people. As we are focusing on the problem of rural people, this project is not that friendly for them. Our second design is hybrid power sharing of grid and solar photovoltaic system where we have tried to use both solar and grid energy to be shared in a combine way so that we can minimize the grid power usage and maximize the solar power [15]. This system is budget friendly and can be implemented in rural areas. So, we have chosen our optimal solution is the microcontroller based combined solar and grid power sharing system. Furthermore, our system has also been tested under various operating conditions, ranging from when there is power coming in from the grid to when there is no power, also under conditions where there is no solar power, on a rainy day for example, and observed how our system operates under these varying conditions to supply electricity both to the Home Load and the Grid Load.

4.3 Optimal design approach

Our optimal design solution is the hybrid power sharing of grid and solar photovoltaic system using microcontroller. Block diagram of this system is given below

Block Diagram:

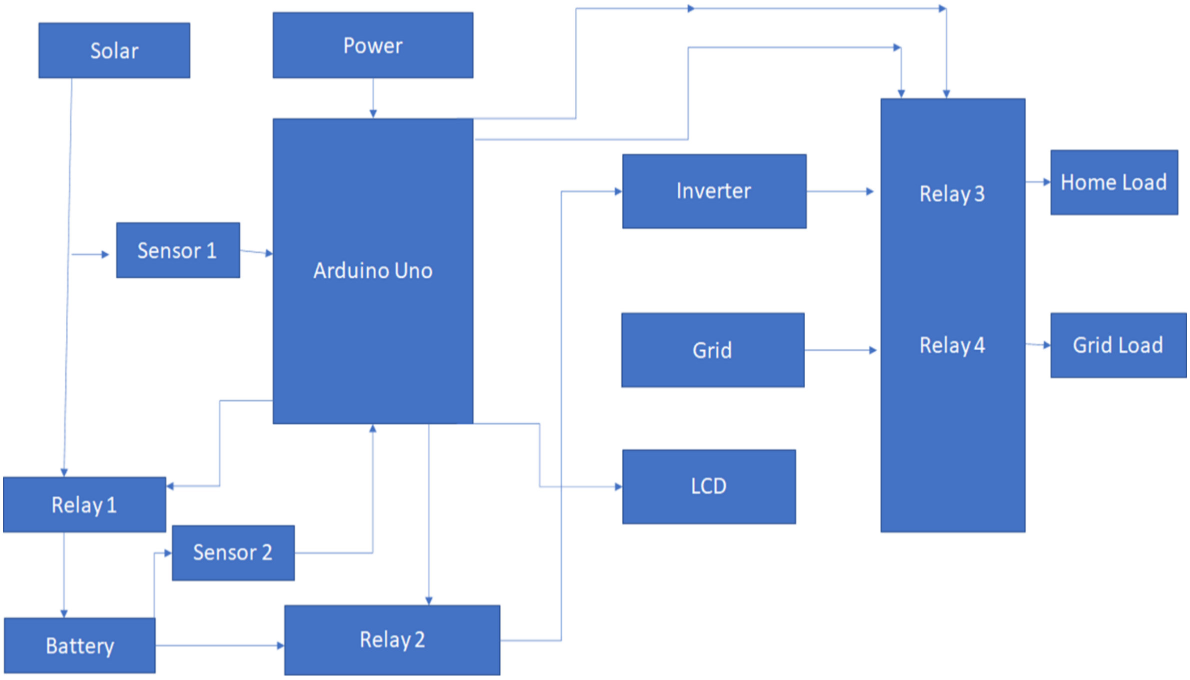

Fig 4.1: Block diagram of optimal design

This is the block diagram of the total system where Arduino is controlling the total system. At the beginning, solar is connected to the battery via a relay and sensor1 is sending the voltage of solar to the Arduino. Sensor2 senses the voltage of the battery [16] and sends it to the Arduino. Relay2 is used to control the switching of battery power to the loads and send the power to the inverter from where solar AC power goes to the desirable load to supply power. Relay3 and relay4 are used to control the current flow of grid line and solar to the loads. LCD is used to show all parameters and status.

Software simulation circuit:

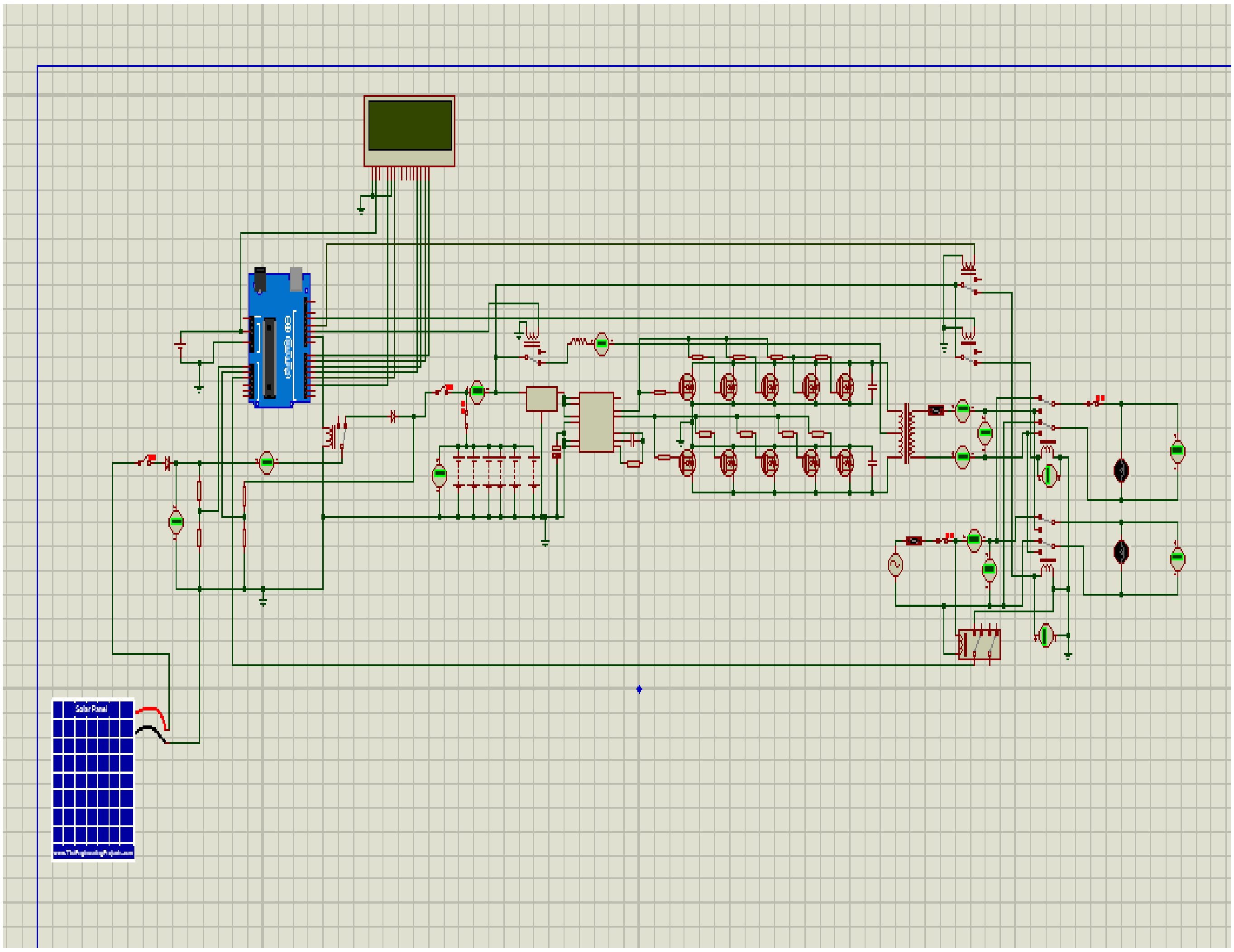

Fig 4.2: Proteus diagram of optimal design

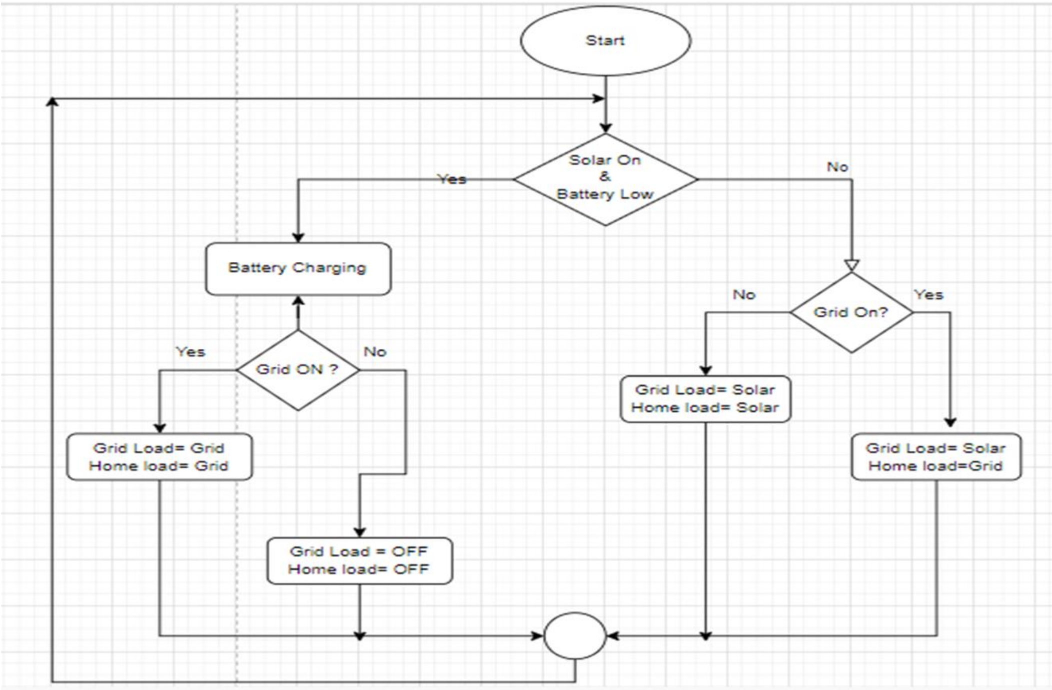

Fig 4.3: Flowchart showing the operation of solar sharing system

Software Simulation Result:

Condition 01: When grid and solar available but battery is not full, Grid Load is powered by Solar power and Home Load is powered by Grid, as shown in the system diagram below

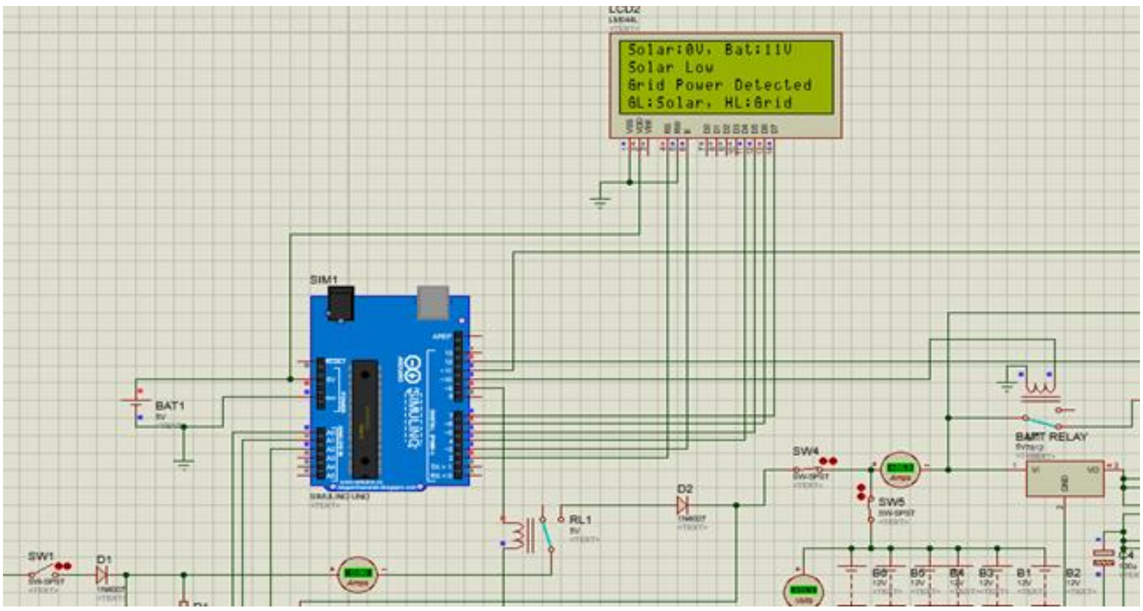

Fig 4.4: System diagram when grid and solar available but battery is not full

Condition 02: When solar power is available and grid power is not available , both Home Load and Grid Load are powered by Solar Power as shown in the system diagram below

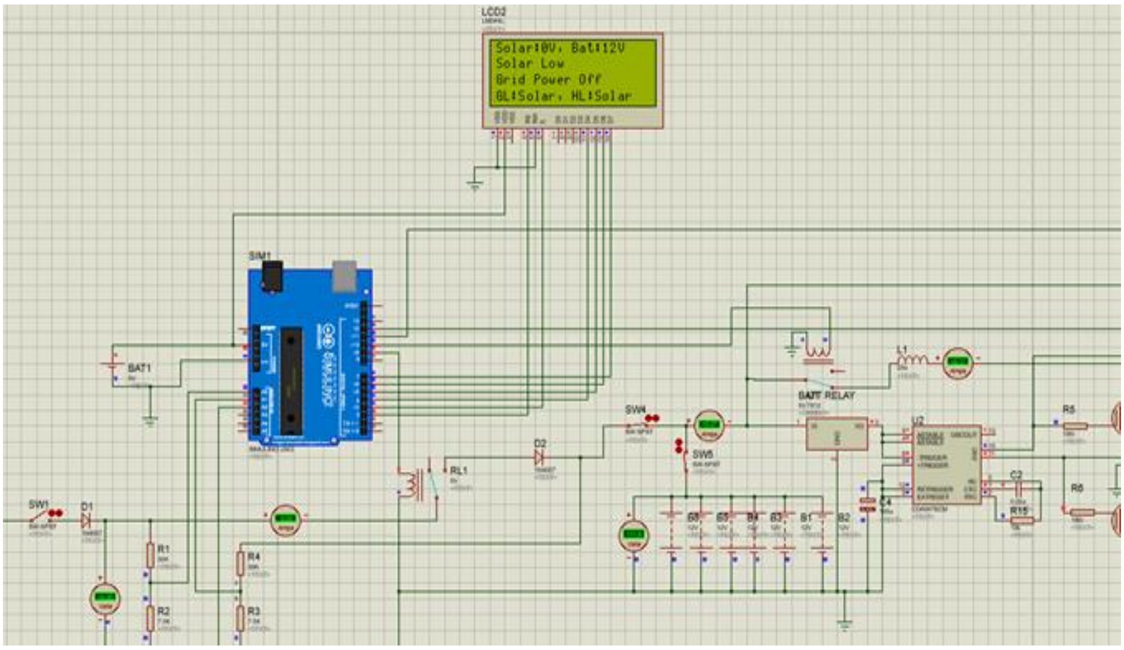

Fig 4.5: System diagram when solar power available but grid power is not available

Condition 03: When both grid and solar power are both available, both Home Load and Grid Load are powered by solar power as shown in the system diagram below

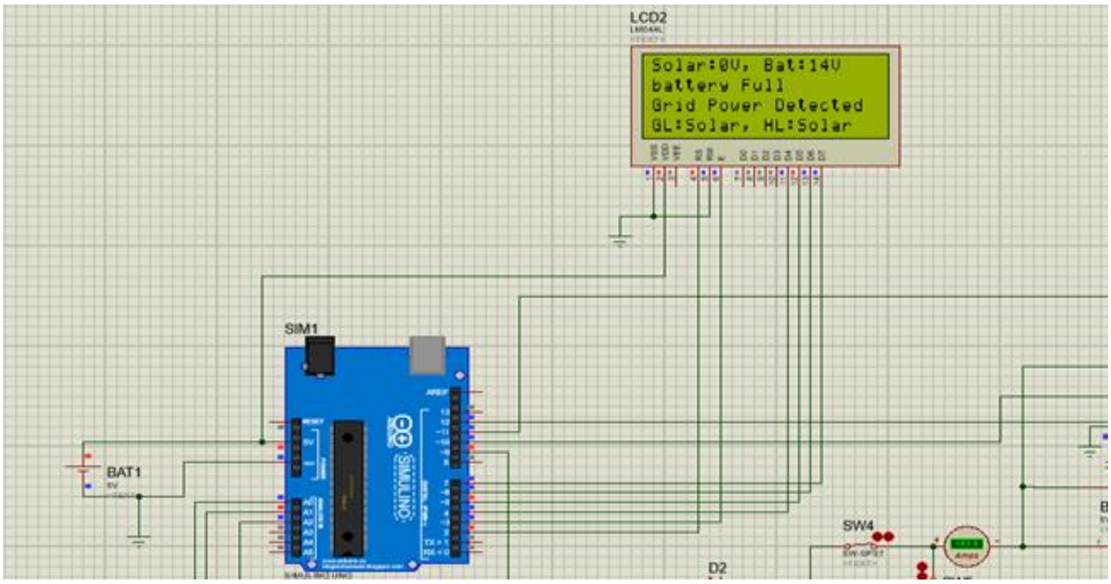

Fig 4.6: System diagram when grid and solar available but battery is high

Condition 04: When solar power is not available and grid power is available, both Home Load and Grid Load are powered by the grid as shown in the system diagram below

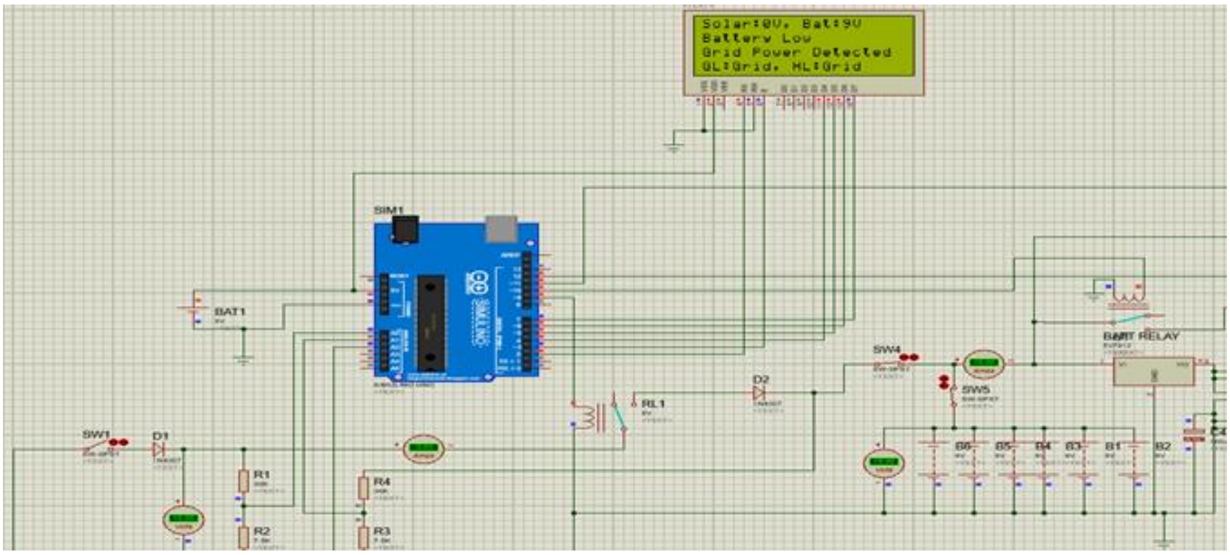

Fig 4.7: System diagram when solar power is not available and grid power is available

Hardware Circuit Setup:

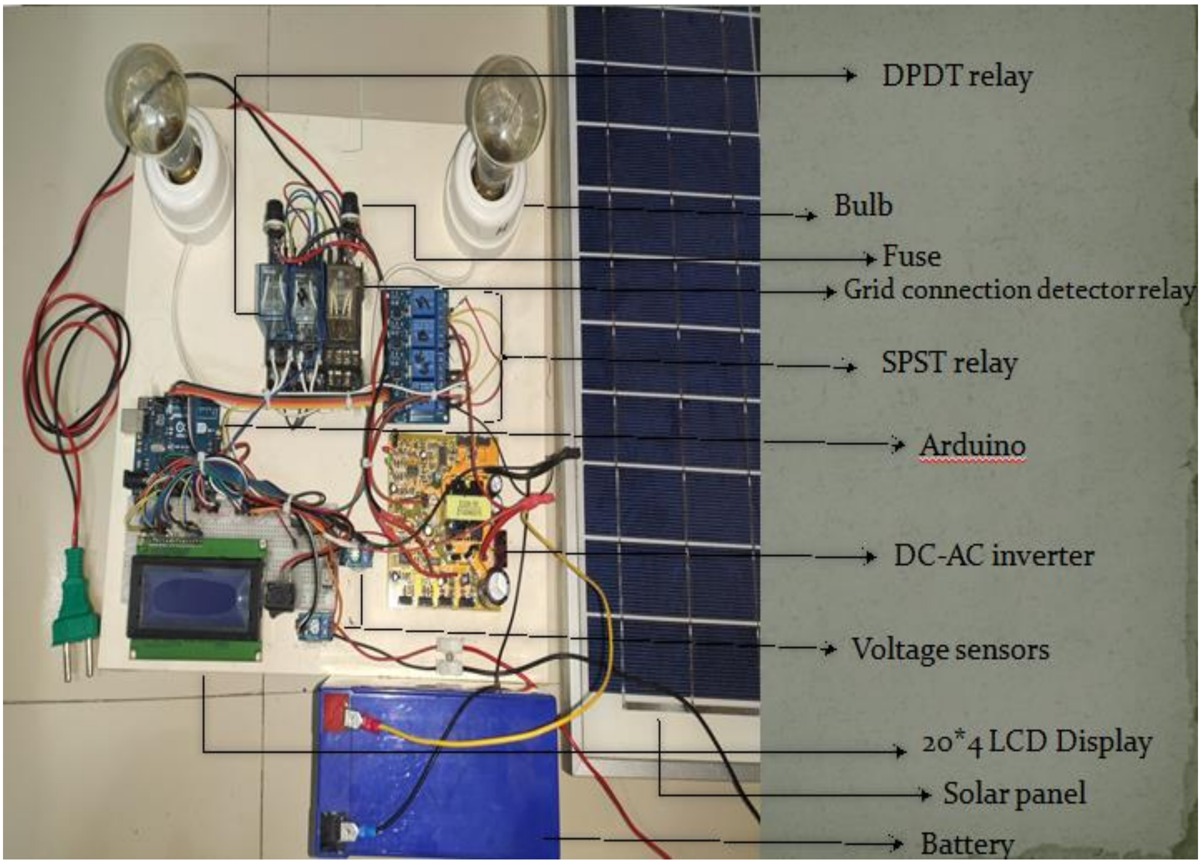

Fig 4.8: Hardware Circuit Setup

Circuit descriptions: First of all, the solar panel and battery are connected with Arduino through two voltage sensors respectively to send the voltage status to the Arduino and Arduino is coded to display the status to the LCD. Solar panel is connected with the battery to charge it and in between these two; a relay is controlling the charging. The battery is connected to the inverter through another relay channel to make the dc voltage to ac. All the relay switching is controlled by the Arduino coding. The inverted power and grid line power are sent to two DPDT relays from where the power share is done according to the conditions [16]. The grid load is connected to the both power sources solar and grid through a DPDT relay and the non-grid load also connected to the solar and grid line through another DPDT relay. Another sensor relay is used to detect the availability of grid line and send it to the Arduino. All the status of the system is displayed in LCD [17].

4.4 Performance evaluation of developed solution

From the software simulation, we can have the evaluation of the project. In the below table, the project outcome is given.

Table 4.1: Performance evaluation of the project

SL	Battery Voltage level Volts	Grid Status	Battery Status	Grid load power	Home load power
01	< 10V	Unavailable	Low	Off	Off
02	< 10V	Available	Low	Grid	Grid
03	> 10V	Unavailable	Charging	Solar	Solar
04	10V≤Battery≤12V	Available	Low	Solar	Grid
05	>12V	Available	Full	Solar	Solar

4.5 Conclusion

Taking into consideration all the design requirements of our project, we have successfully chosen our Optimal design and run it through various levels of trials and errors to arrive at the desired outputs for the varying test conditions of our prototype. It now seems that our project works effectively.

Chapter 5
Completion of Final Design and Validation

5.1 Introduction

Through numerous trials and simulations, the final implemented design and we have gone through several rounds of testing especially with the relays that we had used for the switching. It seems that we required an entire system of relays for switching between home and grid load**.**

5.2 Completion Of Final Design

Previously the design solution was able to give four output features but another thing has to be added which is to power up the both loads from solar if there is enough power to supply to the loads though grid power is available. To acquire this feature, the extra code has been added to the arduino which is that if battery voltage is higher than 12V, then solar will provide power to the loads keeping the grid power off [18]. Moreover, as all solar systems use MPPT charge controllers to control the charge flow of the solar to the battery to store the battery. But in our project, we have added the controlling code using a relay which will substitute for the charge controller [18].

5.3 Evaluation Of The Solution To Meet Desired Need

After having the software simulation, we implemented the hardware setup with necessary adjustments like modifications of the code according to the desired solution and troubleshooting the faced problems during the implementation. After implementing the hardware setup, we got the results shown in the system diagrams below. One of the bulbs is used to represent the Home Load, whist the other bulb is used to represent the Grid Load.

Condition 01: When the battery is low on charge and grid power is off, both the Home Load and Grid Load are off as shown in the figure below

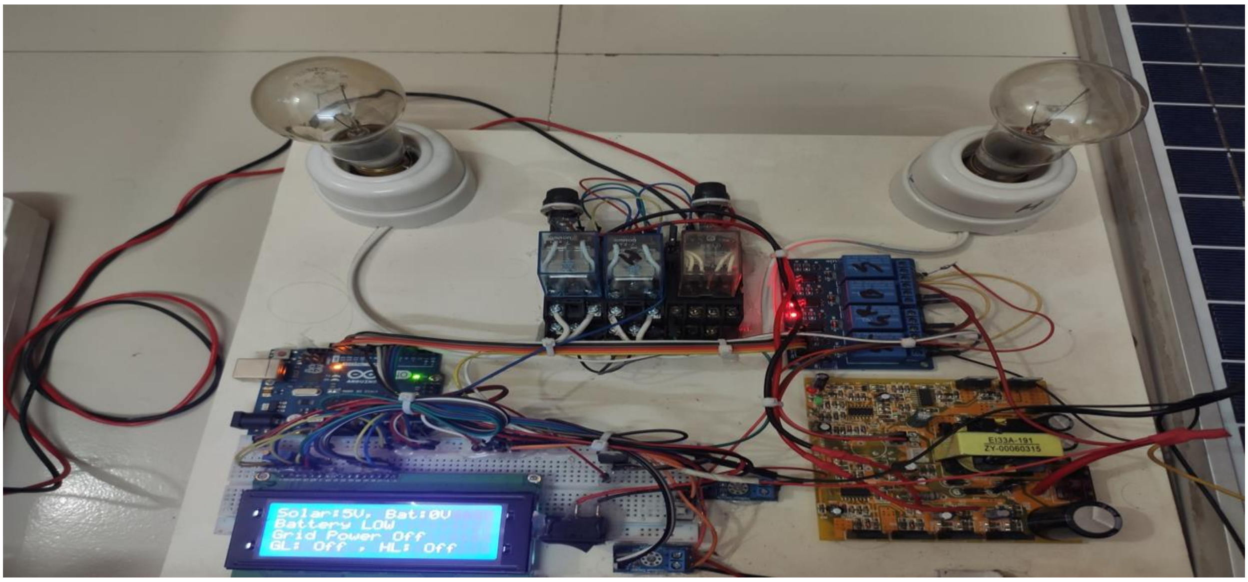

Fig 5.1: System diagram when solar is low and grid is off

Condition 02: When solar is available and grid power is on, Grid Load is powered by solar power and Home Load is powered by the grid as shown in the figure below.

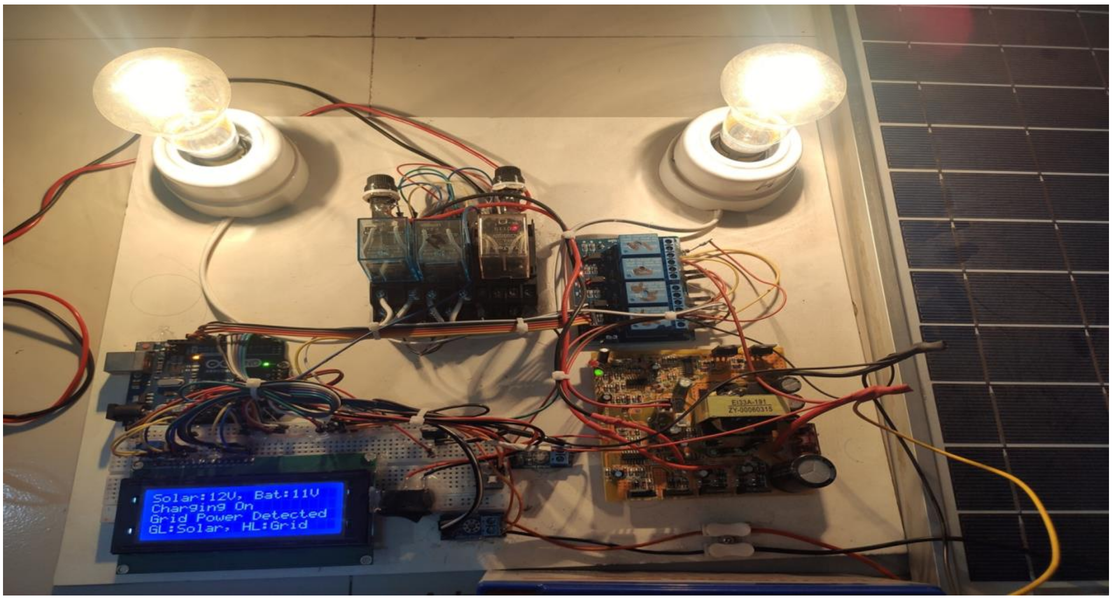

Fig 5.2: System diagram when solar is available and grid is on

Condition 03: When solar power is available and grid is off, both Home Load and Grid Load are powered by solar power, as shown in the figure below.

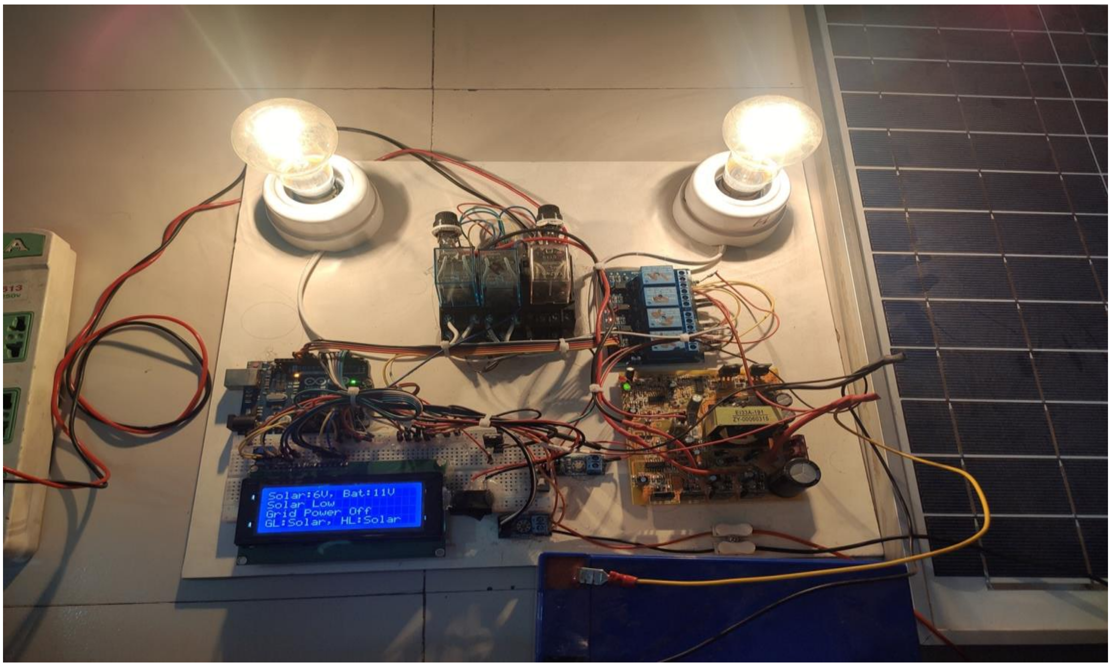

Fig 5.3: System diagram when solar is available and grid is off

Condition 04:

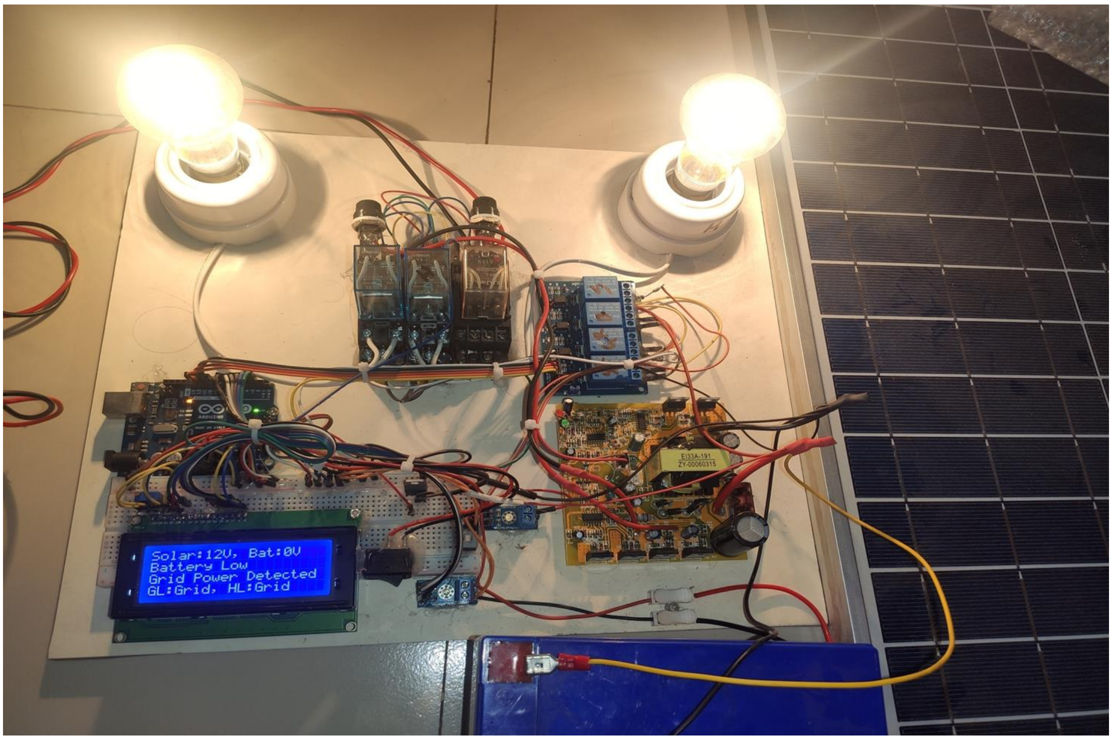

Fig 5.4: System diagram when solar is not available and grid power is on

After completing the software part having successfully simulated. Hardware setup is done. The code is developed according to the availability of power in solar and grid.

The first situation is when solar power is below 10V and grid power is off [19]. At this time the inverter will not operate and also the four paths of the two DPDT relays will remain open and no power will go to the loads which can be seen in fig04.

When the battery voltage is equal or higher than 10V and equal or below than 12V, also the grid power is available then the corresponding relay of grid load will be shorted with solar power and corresponding relay of non-grid load will be shorted with grid line [19] so that the grid load will be powered up with solar power and non-grid load will be powered up with grid power.

When the battery voltage is below 10V and grid power is available, the corresponding relay of grid load will be shorted with grid line and also the corresponding relay of non-grid load will be shorted with grid line so that the grid load and non-grid load will be powered up with grid power [20].

When the grid power is absence and battery voltage is above or equal 10V, the corresponding relay of grid load will be shorted with solar power line and also the corresponding relay of non-grid load will be shorted with solar power line so that the grid load and non-grid load will be powered up with solar power [21].

When the battery voltage is above 12V and grid power is present, the corresponding relay of grid load will be shorted with solar power line and also the corresponding relay of non-grid load will be shorted with solar power line so that the grid load and non-grid load will be powered up with solar power as the solar power is now capable to give power to both of the loads [22].

5.4 Conclusion

It is now clear after several rounds of testing that our final design is the optimal one as this design is giving us a very cost effective and efficient solution as we can observe after the run of the system. It can be very user-friendly system as it is a automated system which can be controlled by the desired code and also the features can be changed if the user wishes.

Chapter 6

Impact Analysis and Project Sustainability

6.1 Introduction

Most of the power we use comes from burning of fossil fuel in power plants. (Uddin, Rahman, Mofijur, Taweekun, Techato,2018) on his article 'Renewable Energy in Bangladesh: Status and Prospects' says that one-third of Bangladesh's power production is based on expensive imported fossil fuel energy supplies, while 65 percent is based on the country's natural gas reserves, which will be depleted at some point in the future. Furthermore, insufficient electricity production has resulted in the country's de-industrialization [23].

6.2 Impact of The Solution

Societal: Our project encourages the use of renewable energy. One of its objectives is that it brings up the concept of being dependent on hybrid system. It presents us with a system to get used to solar energy which is a clean, green and renewable source [24]. Renewable energies are critical in the planet's future energy growth because of the benefits they provide in their use, in addition to the fact that they are limitless; they are employed in a variety of ways, including heating, electrical energy, and electrochemistry, among others. These energy sources have had a societal influence by creating jobs, enhancing the quality of life in remote places, and improving health by lowering pollution, in addition to the levels of knowledge attained not just by professionals but also by the general public.

Health: Our project, if implemented on a large scale will have a positive impact on human health. It will reduce the emission of harmful gases in the earth's atmosphere. Because NOX and SO2 levels are reduced, many major diseases will be reduced [25]. By 2030, the number of heart attacks will be lowered by 490–720% [25]. By 2030, different forms of asthma will be reduced by 320–470 each year. Emission reductions have a negative influence on health, as seen in Table 1.2. We may conclude from this section that PV-based energy has significant environmental benefits when compared to other energy sources. This technology has a favorable environmental impact (e.g., CO2 emissions are reduced, there is no noise, and there are health benefits, among other things).

Table 6.1: Health issues

Scenario	2015(Minimum)	2015(Maximum)	2030(Minimum)	2030(Maximum)
Total PV installed	5	10	70	100
Cases reduced				
Death	22	50	300	450
Chronic Bronchitis	16	35	205	301

Heart stock	40	82	495	720
Respiratory problem				
Asthma	3	4	25	37
Pneumonia	7	16	100	150
Total	10	20	125	187
Cardiovascular problem				
All cardiovascular	9	21	125	181
Visit to Emergency Room for Asthma	25	50	325	470
Acute bronchitis	35	78	479	697
Lower higher respiratory symptoms	716	1612	9849	14326
Loss of working days	2540	5708	34895	50750

Safety issue: There are various safety issues that need to be considered while working with our project. First and foremost, one is the handling of high voltage. Proper trained and experienced technicians will be needed to assist us while installation of the project.If the solar panels are needed to be installed in rooftops then strong ladders should be used. The ladders should be made of insulating material. The workers should use a guardrail system to protect them from falling. While working with the mains electric system rubber gloves should be used. Water and equipment with broken insulation systems should be avoided [26].

Legal Issues: There are lots of legal considerations for this project. One of this is the Periodic Payment by the user. Here the provider is responsible for providing solar energy via the PV system on the user's roof, and the user must pay the provider a price for this service on a regular basis. This remuneration allows the service provider to recoup his purchase and investment in the items made available during the course of the contract (i.e. the PV system).

But what if the user, through no fault of his own, fails to meet his obligations and ceases paying? What are the options available to the provider? Only performance in kind is permitted under Belgian contract law in the event of non-compliance with a monetary obligation. Payment delays are penalized by the imposition of moratoria, which begin to accrue following notification of default. As a result, the compensation in this situation is made up of the periodic compensation plus the legal interest.

Cultural Issues: The cultural issues related to projects that involve solar or any kind of renewable energy focus mainly on aspects as follows:

Economic: Market value, operating costs, and revenue are all economic factors [27] to consider while managing a sustainable building. In addition, we must consider the communal values associated with the structure in its environment. The building's market worth is, of course, determined by its operating costs and income. Even though this relationship is difficult to quantify, culture heritage values generally have a favorable effect on market value. Culture heritage value affects revenue values in the same way as market values do, whether through direct utilization (e.g. admission fees) or indirect utilization (restaurants, motels, and lodging). When it comes to energy saving measures, the main motivating force is usually operating costs [28].

Ecological: The usage of energy and other resources is linked to a portion of the ecological values. Prudent energy efficiency measures can improve the energy efficiency of this type of structure, increasing its worth as a resource for sustainable development. Solar energy would reduce the usage of non-renewable resources in most circumstances, increasing the ecological value. More importantly, ongoing usage of the building would result in continued consumption of the building's energy [29].

Chapter 7
Engineering Project Management

7.1 Analysis

Bangladesh is a country with a lot of load-shedding in rural areas. Rasel,T.A(2020) in his article 'Severe load-shedding in rural areas' on *The Daily Star* writes that there are even 10-12 hours of load-shedding in some rural areas of Bangladesh. Though the urban areas, industrial zones and small towns enjoy a relatively better service of electricity there is not a significant progress that can be observed for rural areas, even though the rural areas have a low power consumption rate. This is the thing that pushed us to think for a solution that might improve the lives of rural areas of Bangladesh to some extent. We wanted to design a solution that uses renewable energy sources that will fill up their required energy demand which they are not getting from the grid.

7.2 Planning and activities

Research: At the very early stage of our project development we had to research and gain enough knowledge. We had to surf through the internet, talk to experienced person and had to discuss a lot of issues that we were facing with our ATC.

Design: To design our project, we needed to know how we can deploy two power sources one is the power coming from the grid and another one is the power coming from the grid which in our case is the household power supply coming from the mains electric supply. Then we have come up with the idea of switching which is the determination of which load and when it will be powered by a grid or battery which has energy stored from an inverter.

Simulation: Simulation is a very important part of any electrical engineering project. To implement it in real life at first we needed to simulate it many times to find out whether it gives us the expected result. This saves a lot of unnecessary work and trouble as we have some idea of what our hardware implementation would look like in real life. The closer the hardware is to simulation the more time, energy and cost are saved. We tried to do our simulation as accurately as possible so that we can implement the hardware in a very short time. After doing the simulation we learned what parts give us desired outputs and what items we would use so that we can go straight to the market without much time delay. This also means that we know what parts we would buy for our project and we can see the cost of those items so that we can predict the budget as close as possible to reality.

Checking hardware items: After buying the hardware components we checked whether each and every item was working correctly. Like after buying the relay we gave the input to it and checked whether it was working correctly or not. Then for the solar panel a multimeter was used to check its output voltage and operating current. Then we charged the battery to full potential and measured the output. The built-in inverter module was also checked by attaching loads to it and whether the brightness of the bulbs were perfect to some extent. The microcontroller was checked by uploading several codes to it and whether it was giving outputs correctly and taking analog inputs.

Crisis Management: While developing and building our project we found out that the inverter which we have simulated in proteus is really tough, complex and requires high level knowledge and skill to build in real life. We as students do not have that much of experience or skill to build an inverter on our own without the help of someone who is expert in this area. There are a lot of theories, power switching and calculations that are needed to design and make an inverter on our own. So we searched for a solution for this problem that we were facing as inverters are a very important part of our project. Then we have found a ready-made sine wave inverter module which is pre-built by experts who have been working in this area for years.

7.3 Project progress

The Gantt chart that we tried to follow during our project period: -

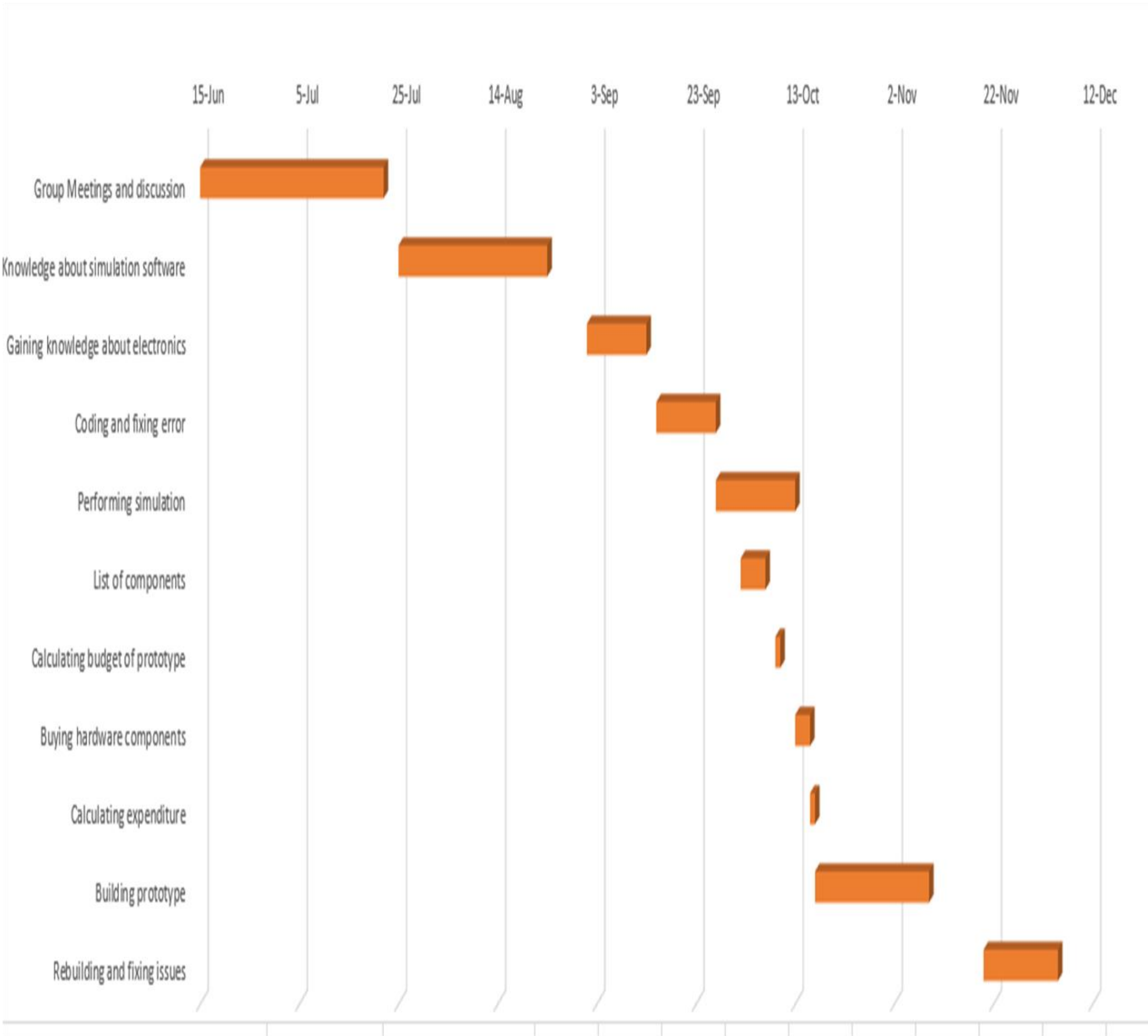

Fig 7.1: The Gantt chart

Chapter 8
Economical Analysis

8.1 Introduction:

In the context of developing countries like Bangladesh, where there is a rising demand for electricity [29], there is huge pressure on the existing national grid to meet these energy demands of the people, especially living in the rural areas of Bangladesh , with rising per unit cost of electricity and there has risen several issues of trying to generate the necessary power output from the grid and create distribution systems to meet the demands of the customers, especially the customers living in the rural areas of the country , especially for people in the lower and lower-middle income bracket because of the rising per unit costs of electricity. Furthermore, power-cuts in these rural areas and load-shedding is still a very significant issue in various Bangladeshi regions. Since Bangladesh is an energy-scarce country, the continuous supply of electrical power is a very critical issue for the country's economic growth and long-term prosperity [29]. As a result, including renewable energy into the power supply and generation system is essential. Furthermore, inclusion of renewable energy in to the power generation system can reduce dependence on fossil fuels as well as the national grid. Furthermore, the literature does not adequately discuss the possible applicability of HES [30] in various Bangladeshi regions. So, our proposed Hybrid-grid connected Solar System works to solve these issues in power generation and costs involved, thus reducing costs for the end-user and reducing demands for fossil fuels, by sharing the excess power generated with the grid therefore reducing costs for the end-user. For the purpose of the hardware implementation of our project, we have had to go through and reviewed several engineering solutions to try and find the most optimal and economical engineering solution to meet the required specifications of our project.

8.2 Economic Analysis:

For the purpose of accessing the viability of our project, we have had to analyze all the economic aspects involved, ranging from costs of designing and building the system, to marketing our system and then finally, taking into account the costs of operation, maintenance and any economic benefits for the end users involved. Because for practical use for the end user, we will have to scale up and make the necessary modifications for our prototype. So, the costs involved will be different. System upgrades, cost analysis, and correlation among different components are taken into account based on the cost of vitality, pay-back period, and ecological discharge, among other aspects. Bangladesh has solar radiation that ranges from 1575 to 1850 kWh/m2 [31], which is 50-100 percent more than Europe. First of all, we have taken into consideration the costs involved in building our prototype based on the purchasing costs of all the components that make up our prototype. Below is a table showing all the costs involved in building our prototype:

Table 8.1: Components and costs involved in making our prototype

Name of components	No. of components	Price
1.Arduino Uno	01	700 tk
2.Solar panel	01	2500 tk
3.Display module	01	450 tk
4.Battery	01	1000 tk
5.Inverter module-100watt	01	1400 tk
6.Relay module-5V 4 channel	01	450 tk
7.Relay-12V 8pin	02	250*2=500 tk
8.Bulb	02	120tk
9.Fuse	02	100tk
10.Breadboard	01	100tk
11.Voltage sensor module	02	400 tk
12.220v relay	01	200tk
13.Diode	01	40tk
14.Jumper Wires (m to F-F to M)	01	150tk

15.Potentiometer	01	20tk
16.Plug	01	50 tk
17.Bulb Holder	02	100 tk
Total Cost of prototype		8500 tk

Based on our prototype, our system can be scaled up to meet the requirements of the end user to be used by the people living in different parts of the country, especially in rural areas of the country, where load-shedding and power-cuts are a huge issue, especially for people living in remote areas of the country, like Rajshahi, Khulna, Bagerhat etc. which are located in the northern and southern part of Bangladesh respectively [32]. Also, this system can also be implemented in other parts of the country where there is a lot of sunshine and issues of power distribution and the effects of global warming are evident. Since our prototype has a power rating of only 100W, the costs for our prototype are given in the table above. For the purpose of making our system for the end-customer, we will take into consideration different power ratings of these systems and their associated costs involved. Since our system having different Power ratings, can be used for different customers, in order to power different loads. In hybrid system design, a realistic total electrical load is critical, and other considerations are taken into account while developing a load profile. Because historical load demand is not accessible, in this study, the electric load required is carefully calculated based on a survey of the places under consideration. As a result, to estimate the load profile, a lot of things are taken into consideration, like: consulting experts in the power sector, consulting the electrical companies or authorities supplying power to the homes etc. In addition, when determining the load, the region's income level, social standing, household work habits, and commercial activities are all taken into account. Furthermore, data from similar studies in Bangladesh is used to determine the load requirements for residential applications in the studied areas. Although many homes in rural areas do have Solar PV systems, most of these are, however, Off-grid, and only supply power to the Home Loads, but not to the grid. Unlike the Off-grid Solar System, our designed system can share power to the Home Load as well as the Grid Load. So, we have taken into consideration a range of possible home appliances, that can be used by a lower income, a lower middle income and middle-income appliances in a typical rural household in Rajshahi district [32].

Table 8.2: Power usage according to the income

Income status of potential users(Approximated)	No. of Appliances used and their Power Ratings
Lower Income Family	2 Lights(50W) and 1 Ceiling Fan(70W) Total Power Rating – 120W
Lower Middle-income family	2 Lights(50W) and 2 Ceiling Fans(140W) Total Power Rating- 190W
Middle Income Family	One 30 inch LED TV(50W) and 3 Lights(75W) and 3 Fans(240W) Total Power Rating- 365W

The information provided about the social class and the number of appliances used by the families above is just rough estimates of the total required power rating and the load required to be provided by our system. In reality, the costs involved will vary based on other factors, like the no. of appliances used, the no. of hours the appliances are used etc.

8.3 Cost Benefit Analysis

For the purpose of verifying the economic and financial benefits of our Hybrid Grid-Connected Solar System, we have decided to compare the estimated costs of building our proposed system with a similar system used to supply power to the Home Load, even though it is not Solar-Based. It supplies power to the Home Appliances in case of load-shedding or Power-Cuts, in case there is no electricity coming home from the grid. So, we have considered an IPS(Instant Power Supply). IPS stands for "Instant Power Supply" [32]. It is an electrical device that supplies electrical power to the home appliances when there are power cuts. Here, we have used an IPS system [32] for comparison since both systems supply back-up power to the home appliances and operate since there is no electricity to the grid, whereas an OFF-grid Solar System only power to the home appliances and are not connected in any way to the grid and also an off-grid solar system only supplies power to the home.

The components of an IPS are as follows: Charger circuit, a battery, an oscillator circuit and an output circuit.

When there is no power from the grid, the IPS battery supplies the power [32]. The system differs from traditional generators in a number of ways. It is completely automated. It does not necessitate the use of fuel, like a generator does. It also does not pollute the environment in the same way that a generator does. It's the precession IPS, which was created in accordance with our power line. Condition. There are several brands of IPS in the market, of which Rahimafrooz IPS [33] is the most prominent. So we have chosen Rahimafrooz IPS [33] brand of varying Power Capacity to compare with our proposed system to analyze the cost-benefits of our proposed System for comparison, on the ground that, both systems provide power to the Home Load, when there is no power coming in from the mains or grid supply. In fact, both of the systems provide back-up power to the consumer in case of power outage. So, we can now compare the Rahimafrooz IPS [33] having varying power outputs, along with the number of appliances that the IPS can operate in case of power outage. For the sake of a fair comparison,

We have considered the power rating of the Rahimafrooz IPS and our proposed System and the number of appliances that both the systems operate to be the same.

Taking all these things into consideration, we can then compare the costs of both the Rahimafrooz IPS [33] and our proposed system.

Table 8.3: Cost comparison of our system and Rahimafrooz IPS

Power Rating	**Rahimafrooz IPS** **Total costs involved**	**Total costs of Our Hybrid grid connected system**	**No. of appliances it can operate**
180W	Tk.14,700	Tk.14,500	2 Lights and 1 Ceiling Fan
280W	Tk.28,500	Tk.21,000	2 Lights and 2 Ceiling Fans
400W	Tk.36,000	Tk.33,000	3 Lights and 3 Ceiling Fans
500W	Tk.44,100	Tk.39,000	3 Lights and 3 Fans , One 30inch LED TV

From the table, it is evident that the estimated costs of our Hybrid Grid-Connected solar System are less than the Rahimafrooz IPS systems currently available in the market. Thus, our proposed system is a much more cost-effective measure for our customers, especially those living in the rural areas, who are farmers and middle-income families, who have a fixed monthly income.

8.4 Evaluate economic and financial aspects

. In order to assess the economic and financial aspects of our proposed Hybrid Grid-Connected Solar System, we considered the per unit costs of electricity involved, as well as the cost savings that sharing the extra electricity produced by our system with the national grid can provide for the end-user. We have also taken into account the costs of our system, as well as the price of the components of our suggested system and the costs of the battery. The cost of our suggested system and the component costs are shown in the table below.

Table 8.4: Components cost of our Hybrid Grid-Connected Solar Sharing system for different power rating

Power Rating	**Our Hybrid Grid connected System**	**Battery capacity**	**Battery Cost**	**Circuit and other Cost**	**Inverter cost**	**Solar Panel**
	Total cost					
180W	Tk.15,560	60ah, 12V	Tk.4,000	Tk.4,560	Tk.2,500	4500
280W	Tk.22,500	100ah, 12V	Tk.7,000	Tk.4,700	Tk.3,800	7000
400W	Tk.33,000	150ah,12V	Tk.13,500	Tk.4, 500	Tk.3,000	12000
500W	Tk.39,000	200ah, 12V	Tk.16,000	Tk.5,000	Tk 4,000	14000

Then, we also have to take into consideration the amount of money and savings our proposed system can provide to the end-user in terms of sharing the electricity with the national grid. The electricity meters in our homes can measure the amount of electrical power our home uses and the amount it can supply to the grid, thus helping to reduce the electricity bills for the end-users. So, now we have to take into account the per-unit cost of electricity in Bangladesh now.

In order to calculate the NPC of electricity, the following formulas are used:

1) Energy consumption = E(kWh/day) = P(W) × t(h/day) / 1000(W/kW)

2) Electricity cost = E(kWh/day) × Cost(per unit rate) [34]

So, at first we consider the retail rate at which electricity is supplied into our homes, based on the new electricity bill approved by the DPDC (Dhaka Power Distribution Company) imposed tariffs effective from 1st March, 2020 [34] .

Now, we compare the cost savings and financial benefits made by our system for the end-user in terms of supplying electricity to the national grid, by comparing a home which does not have Our Hybrid Grid-Connected Solar System with a home which does have our proposed system. Here, we take into account the units of electricity consumed by a home in terms of kWh/day to find the electricity bill for one month. So, we have taken into consideration a home in the Dhaka division of Bangladesh for this comparison. According to the government decision, the demand charge as set by the DPDC, the per unit cost for 0 to 75 units at 4.19 Tk/kWh.

Table 8.5: Cost savings made per month using our proposed system

Power Rating	**No. of appliances operated in a typical home**	**Typical Solar System Power Consumption (kWh/day)**	**Solar Sharing Power Consumption (kWh/day)**	**Power supplied to the grid daily(kWh/day)**	**Electricity cost savings made per month**
180W	2Lights and 1Ceiling Fan	1.44	0.96	0.48	Tk.492.336

280W	2Lights and 2Ceiling Fans	2.24	1.52	0.72	Tk.522.504
400W	3Lights and 3Ceiling Fans	3.2	2.28	0.92	Tk.547.644
500W	One 30inch LED TV and 3Lights and 3 Fans	4	2.92	1.08	Tk.567.756

From the table above, it is evident that our proposed system helps to reduce the electricity bill of the consumer by a significant amount every month. It is important to note that these values are estimates and will vary, depending on whether or not our system is receiving electricity from the national grid or not. Even though our system is not exactly a grid-tied inverter, it works in exactly the same way as a typical grid-tied inverter [34]. For the sake of a fairer comparison, we have also decided to compare our system, with a typical off-grid solar system that is I use in rural areas of the country, where it does not have any connection to the grid to compare the economic and financial aspects of our proposed system, the tables provided below are used to compare the costs involved for a typical of grid Solar system at Power rating of 180W with our proposed Hybrid Grid-Connected Solar Sharing system also at a power rating of 180W.

Table 8.6: The cost of a typical 180W solar system

SL	Components	Price(tk)
01	Solar Panel 180W	4500
02	Battery 60AH	4000
03	Inverter	2000
04	Charge controller	3500
05	Other expenses	1000
	Total	15000

Comparison with the typical solar system: From the tables above, it is evident that, even though the cost benefits to the end user of our system are not all that significant, our proposed Hybrid System has several advantages over the typical Off-grid Solar Sharing system , that makes it a viable option for the end-user of our system.

Our designed Hybrid Solar Sharing system has the following advantages over a typical Solar system:

1) Typical Solar System can only power Non-grid Loads, whereas Hybrid Grid-connected Solar Sharing System can power both Home loads as well as Grid loads.

2) The typical Solar System cannot take power to the grid, whereas the Hybrid Grid-Connected Solar System can take electricity from the Grid Load when there is no Solar Power.

3) Irrespective of whether or not there is electricity coming from the Grid or Not, Our Hybrid Solar Sharing System uses Solar Power.

4) Hybrid Power Sharing System of Grid and Solar Photovoltaic Using Microcontroller.

5) Our Hybrid Power Sharing System of Grid and Solar Photovoltaic Using Microcontroller can help to reduce electricity bills, whereas the Typical Solar System is not capable of doing so.

Considering all these advantages of our system, we believe that our proposed Hybrid Power Sharing System of Grid and Solar Photovoltaic Using Microcontroller will be a much more viable option compared to the normal off-grid PV system [35].

8.5 Conclusion

In this chapter , we have reviewed the economic and cost benefit analysis of our proposed Project and we have found that our final design prototype is a much more financially feasible option for the end user, based on the cost estimates and financial and economic aspects that we have discussed in great detail in this chapter, thus fulfilling the requirements of our Final Year Design Project, as it helps the customer in rural areas , with a fixed income to reduce costs and is viable option for the users of our proposed system.

Chapter 9

Ethics and Professional Responsibilities

9.1 Introduction

For the sake of the implementation and completion of our project, we have taken into account several ethical considerations and factors, which influence the implementation of our project. We have taken into account the efficiency, safety of use for our end users as well as the professional responsibilities involved in the hardware implementation of our project following all the necessary rules and regulations applicable for the purpose of our project [36], like the Guidelines for the Solar Power Development Program in 2013 .So, we focus on various aspects of ethical issues involved and Professional responsibilities, like: Safety, Rules and Regulations, efficiency, professional responsibilities [36] etc. For the purpose of writing the report, we have taken into account the ethical issues and professional responsibilities of writing this report [36], like plagiarism and we have not resorted to any unfair attribution in the paternity of the papers and information we have used in writing the papers, by providing appropriate references and all the data and information that we have presented in our paper are authentic and have been collected from online, the resources of which we have mentioned in this report.

9.2 Identify ethical issues and professional responsibility

In this project, we have identified several issues related to ethics and professional responsibilities, which are mentioned below:

Ethical issues No.1: the first major ethical issues that we have had to consider for our project are as follows: the formulation of design requirements and criteria. The main issue had been to formulate the necessary design requirements and criteria [37] based on the objectives of our project. The main objective of our project has been to develop such a system which supplies power to both the Home Load as well as the Grid Load. So, the main issue has been to design our prototype in such a way so as to meet the objectives of our project [37]. So, the design requirements of our project have been to design such a system that can detect whether or not there is electricity coming in from the grid and to regulate the transfer of electricity from our system to the grid [37]. The other major problem has been converting the DC voltage that we get from the PV cells into the AC supply required to operate the Home Load supply and supply power to the Grid. Another important criteria that we have to fulfill is to ensure that the output voltage of our system matches with that of the electricity coming into homes from the grid (220V A.C.) [37]. The most crucial criteria is to design our system in such a way so as to ensure public interest and safety for the end-user and also to do it at an affordable cost.

Ethical issues No.2: The 2nd major issue of our project has been the issue of trade-offs between the different criteria. The first design of our project (LCL Single Phase Grid-Tied Inverter) [37] had the major issues of synchronization problems with the main grid i.e. our output voltage should match the Grid in magnitude, frequency and phase, although this problem can be solved but our design would have to become much more complex and expensive, which is another major issue of this particular design is the fact that this design is prohibitively expensive for practical use. The whole prototype, along with the solar panel, would cost around tk.100, 000; which would not be a very feasible option for the stakeholders involved, primarily the manufacturing companies for our system and especially for the users. Another major issue would have to be the safety requirements for our project. We would have to design our prototype in such a way that it is safe for the end-user and protect them from electric shock (due to the high voltages involved). Furthermore, the 1st design [37] has no galvanic isolation between the Home Load and Grid Load of our system [37]. So, the biggest trade-offs that we would have to achieve in order to implement our project prototype would have to be between reducing the costs involved, whilst at the same time developing a design that that can operate efficiently under the different conditions as specified by our design requirements and in such a way that it is safe for the user [38].

Another import issue that would be very important to consider would be the issues related to professional responsibilities which would be involved in our project implementation and how would we would follow these professional responsibilities, and the professional responsibilities involved in terms of following the rules and regulations in our country in terms of implementing our project and how we have written our project report in an ethical and responsible manner without resorting to unethical practices.

Professional Responsibilities involved: One of the major issues in terms of professional responsibilities in terms of the Hardware implementation of our project has been adhering to the Guidelines for the implementation of Solar Power Development Programme (2013) [39], since this is a solar power-based project:

i. The prosumer must be a current client of the utility that is in charge of the area's electricity supply;

ii. There should be no outstanding arrears in the area where the applicant wants to use the Net Metering System.

iii. Any unused space on the roofs of buildings, factories, industries, parking lots, and other structures may be exploited.

iv. The prosumer must utilize the electricity produced by the renewable sources, and only export the excess amount to the grid;

v. Interconnection standards shall comply with the interconnection rules and standards set by the Utility or other relevant governing authority;

The rules and regulations for exporting the electricity to the grid are as follows: .

. i. In relation to the consumer's sanctioned load, the renewable energy converter's output AC capacity can be up to 70 percent of the total input capacity of the system.

ii. The installed RE system's maximum output AC capacity for NEM cannot exceed 3 MW.

9.3 Apply ethical issues and professional responsibility

Solution to Ethical issues No.1: In order to meet the design requirements and criteria of our project, we had to change our project design to Hybrid Grid-Connected Solar Sharing System using a Microcontroller , which works in exactly the same way as a typical Grid-tied Solar inverter, even though our system design is different from our initial design. Furthermore, we also have included a 220 V AC DPDT (Double Pole Double Throw) Relay to detect whether or not we have electricity coming in from the grid. Even though electricity from the grid varies through a range of voltages, ranging from 210V to 230V AC, as electricity coming in from the grid may vary, due to issues like voltage fluctuations or low voltage. The Microcontroller used here acts as the main controlling center of our system, which gets data input from a sub-system of sensors and the Microcontroller sends instructions to the other components of our system to operate them. We have 4 SPST relays in our Final design, which have the following functions:

i) Control the switching between supplying power to the Home Load and Grid Load,

by controlling the operation of the two 12V DPDT relays in our system.

ii) To control the charging of the battery from solar power.

iii) Control the operation of the inverter, to switch between powering the Home Load with either Solar Power or battery power.

The DC voltage coming into the system from the PV arrays is converted into AC supply by use of the inverter and it is stepped up to the required voltage of the AC grid supply (220V A.C.) by using a step-up transformer. This is how we have tried to address the 1^{st} set of ethical issues involved in our project.

Solution to Ethical issues No.2: Taking into consideration the trade-offs and conflicts of interest between different criteria, we have had to change our design and move to our final design for the purpose of hardware implementation of our project, which is Hybrid Power sharing system of Solar and Grid using Microcontroller. The main issue of synchronization had to solved by changing our design to our Final design as it is simpler to implement and it is also safer for the end-user. Safety-related concerns are also a major issue and costs are also very critical issues related to ethics. So, in order to solve the safety issues related to high voltages and make it safe for the user, we have installed a system of fuses and circuit breakers in our prototype so as to minimize the risks of electric shock to the end-user. In order to make things simpler, we have installed a system of relays to control and regulate the different components of our system and we have also employed a 15V DC battery to store the energy generated by the solar panels when grid power is available but battery power is low. When necessary, the battery is also used to supply power to the Home Load and Grid Load. In terms of prices, our final design prototype is a significantly less expensive system, costing roughly Tk.8, 500 for a 100W power rating. This means that our Final design has successfully addressed the ethical issues and professional responsibilities involved for the hardware implementation of our project.

Professional responsibilities involved: As far the rules, regulations and codes of practice of our project are concerned, we have had to build our project in accordance to the Guidelines for the Implementation of the Solar Power Development Programme Guidelines (2013) [39].

The guidelines of the Solar Power Development Programme Guidelines (2013) which we have followed for the implementation of our project are as follows:

1) In terms of Site selection : In terms of site selection, the most appropriate site for the implementation of our project would be in rural areas of the country.

2) Technical aspects: The user of this system will be responsible for generating the power and for maintaining this system.

3) In terms of Electricity tariffs: To make the electricity tariffs affordable to the consumer, the IDCOL (Infrastructure Development Company Limited) will will provide area based tariffs for the customers [39].

We have maintained the ethical standards in writing our report, we have gone through several journal articles for the purpose of our project and we have not unfairly attributed to the paternity of a paper as we have provided the appropriate references of our project. We have also not hid any conflicts of interest for the implementation of our project. Rather, we have tried to mitigate all these conflicting issues for the implementation of our project. We have strived hard to avoid plagiarism as much as possible. We have clear objectives in terms of developing and sharing our prototype.

Now in terms of focusing on the professional responsibilities of our project, we have worked in a coordinated manner to achieve the objectives of our project and we have considered all the possible constraints and other risks to our project.

9.4 Conclusion

In our project, we have tried to maintain ethical standards in terms of recognizing the ethical issues and maintaining the ethical standards and professional responsibilities in terms of developing our project, to make it a viable, environmentally-friendly , safe and cost-effective project for our end-user or consumer, to ensure that it meets the needs of the customer and is in line with the national regulations of our country Bangladesh and we have also applied the necessary compliance, standards and codes of practice for the purpose of our project. As far as professional responsibilities are concerned, we have tried our best to comply with the necessary rules and regulations of our country and have worked hard to do research online through the review of articles and avoid issues related to plagiarism, falsely attributing to the authors of these articles etc.

Chapter 10
Conclusion and Future Work

10.1 Project summary/Conclusion

Hybrid systems are seen as a suitable alternative to utilities or traditional fuel-based electricity in distant places around the world. On the other hand, the need for clean energy and improved alternative energy technologies has a lot of promise for widespread adoption of such systems. To ensure widespread adoption of this new technology, solar photovoltaic energy technologies must be gradually developed and improved in order to reduce the cost of hybrid power systems. In Bangladesh, the majority of energy demand is met by non-sustainable energy sources, which will be hard to meet in the future as electricity demand doubles by 2030. As a result, we should also concentrate on renewable energy sources such as solar, wind, and biomass.

Firstly, for the purpose of the project we need to generate power. Then there will be two power sources for electricity, one from the grid and the other from the sun. The loads will be divided into two categories: grid load and non-grid load. We'll have a system that uses the combined power of solar and grid for the two types of loads [40], depending on the availability of each supply's power. First and foremost, renewable solar energy is stored in a battery, and a DC to AC converter is installed between the loads and the battery to convert the DC power to AC, making it appropriate for AC appliances. This power sharing will be handled by the Arduino microcontroller, which will control the activities based on the conditions. For example, if the sun is providing adequate solar energy, the battery is fully charged, and the grid power is turned on, as indicated by voltage sensors, Arduino will instruct the relays to close the solar power connection for both loads and opens the grid line terminal, allowing solar to provide electricity to both grid and non-grid loads. However, if the solar energy stored in the battery is insufficient to supply both loads and grid power is available, one relay will connect the solar terminal to the grid load terminal and another will connect the grid line terminal to the non-grid load terminal, allowing solar to power the grid load and grid to power the non-grid load. Furthermore, if solar is available but the grid is not, Arduino will connect the solar power line to both loads, allowing solar to feed both loads in the absence of grid power [40]. When solar power is unavailable and grid power is available, sensors will detect the situation and transmit a signal to the Arduino, which will instruct the relays to connect the terminals of both loads to the grid line terminals, allowing both loads to be powered by the grid supply. We also had issues dispersing the loads because the load we assumed was so large that we had to work with the minimal load that could be generated to solve the problem. We were able to effectively complete the job after overcoming all of the obstacles. We've also talked about the upcoming future work briefly down below.

10.2 Future Work

The government of Bangladesh has established a goal of delivering power to everyone by 2022, as well as ensuring a dependable and high-quality supply at a reasonable and affordable price. We wish to expand this small-scale project to a larger size and apply it in any of Bangladesh's rural districts, including Khulna, Patuakhali, Barisal, Rangpur, and Chittagong. This project is a wonderful option for rural people who have been experiencing power outages for a long time owing to natural calamities, power load failure, and excessive bills, among other things [40].
Our aim is to include the monitoring system of power generation, power dissipations, voltage drop of the loads. To provide extra electricity to the other households and measuring the quantity.
Moreover to include the grid tie inverter to share electricity to the national grid whereas both the customer and government will be benefitted. Lastly, It can share and create a peer to peer solar energy like Solshare which will create a massive impact and hopefully it will supply electricity at an affordable price.

Chapter 11
Identification of Complex Engineering Problems and Activities

11.1: Identify the attribute of complex engineering problem (EP)

Table 11.1: Attributes of Complex Engineering Problems (EP)

	Attributes	**Put tick (√) as appropriate**
P1	Depth of knowledge required	√
P2	Range of conflicting requirements	√
P3	Depth of analysis required	√
P4	Familiarity of issues	
P5	Extent of applicable codes	√
P6	Extent of stakeholder involvement and needs	
P7	Interdependence	√

11.2: Provide reasoning how the project address selected attribute (EP)

P1-The project addresses the depth of knowledge as far we had to gain detailed knowledge about the solar photovoltaic, grid, inverter, rural areas current situation of electricity, voltage measure components required and many other things.

P2-Solar power generation has recently made a significant contribution to the global growth of renewable energy sources. Researchers are increasingly interested in improving the dependability and availability of solar photovoltaic (PV) systems. We have taken into consideration this system based on the high levels of reliability, availability, maintainability that it offers in its operation.

P3-The in-depth analysis of this project has been taken into consideration and has been mentioned in our report. We have taken in consideration all the factors and knowledge required for the safe operation of our system. The components of this system and the sub-systems that they make up have been explained in detail in this report.

P5-Here we had to go through many codes which fulfill our extent of codes problem.

P7-The essential input data comes from rural and different databases of failures and repairs of various subassemblies under a variety of climatic situations. In order to determine the optimal probability density function for each sub-assembly, a novel approach is also described. Monitoring the essential parts and components of a PV system increases the prospect of not only enhancing the system's availability but also lowering maintenance expenses. It will also keep the operators updated on the status of the system's numerous subsystems which leads to its interdependency.

11.3 Identify the attribute of complex engineering activities (EA)

Table 11.2: Attributes of Complex Engineering Activities (EA)

	Attributes	**Put tick (√) as appropriate**
A1	Range of resource	√
A2	Level of interaction	√
A3	Innovation	√
A4	Consequences for society and the environment	√
A5	Familiarity	

11.4 Provide reasoning how the project address selected attribute (EA)

A1-In this project we had a range of resources as we have gone through many journal research paper,codes ,hardware component study.our group member were able to come up with a topic and its solution.

A2- In level of interaction we had interact with the faculty members senior tutor, seniors which became very helpful. we had gone through different other researchers and seniors who had a great knowledge about solar or renewable energy.

A3-We have created a code and the proteus file which leads to our innovation of creating a grid tie inverter with a solar photovoltaic system.

A4- Our project will be sustainable for society and the environment as we were working with the renewable energy. it will be eco-friendly and no harmful or risk will be there. We have managed to tackle all the operating conditions through the code and we have assured the risk factor management. Society especially rural people those have lack of electricity due to various issues and most of them cannot afford due to excessive bill they will be very helpful and side by side national grid will be benefitted as the solar will be connected through the inverter.

13. References:

1. Uddin, M. N., Rahman, M. A., Mofijur, M., Taweekun, J., Techato, K., & Rasul, M. G. Renewable energy in Bangladesh: Status and prospects. *Energy Procedia*, Vol.*160*, pp. 655~656, Aug 2019.

2. A. Chakraverty , "Design and implementation of a Grid Tie Inverter", Dept. Elec. Eng., Case Western Reserve University, Cleveland, Ohio, Rep. 25, 2011.

3. Taheruzzaman, M., & Janik, P. "Electric energy access in Bangladesh", *Transactions on Environment and Electrical Engineering*, Vol. 1, Issue No. 2, pp. 6~17, July 2016.

4. D.H. Moore, H.M. Abdar, A. Chakraverty, J.M. Murray, K.A. Loparo, "Design and Implementation of a specific Grid Tie Inverter for an Agent-Based Microgrid", in Conf. Energytech, Cleveland, Ohio, May 2012, pp. 1~7.

5. A.Kumar, N.Gupta,V.Gupta, "A Comprehensive Review on Grid-Tied Solar Photovoltaic System", *Journal of Green Engineering*, Vol. 7, Issue No. 2, pp. 213~254, Jan 2017.

6. Masri.S; Kwang.T.K.;' Single phase grid tie inverter for Photovoltaic Application', In Proc. IEEE Conference on 'Sustainable Utilization and Development in Engineering and Technology , KL, Malaysia, 2010, pp 1~7.

7. Yan, V; "Grid-Tied Solar System", Dept. Elec. Engr., CALIFORNIA STATE POLITECHNIQUE UNIVERSITY, San Luis, C.A., Sci Rep. 4, 2018.

8. A.E. Shahat, J.H. Rami, C. Joseph, M. Austin, M. Aaron," Solar-Powered House System Design", In 2019 Southeast Con, San Jose, C.A.,2019, pp: 513~518.

9. R. Margolis & J. Zuboy, "Nontechnical Barriers to Solar Energy Use: Review of Recent Literature", NREL, Co, Denver, Rep. 1301, 2006.

10. D. Saurav and M.S. Khosru, "Design and Implementation of One kW Capacity Single Phase Grid-tied Photovoltaic Inverter", Presented in ICEEICT, Dhaka, Bangladesh, 2014, pp. 1~5.

11. N.R. Gbalimene, A.O. Henry, T.A. Ekubo, A.I. Olanrewaju, "Grid Integration of Renewable Technology: A Techno-economic Assessment", American Journal of Mechanical Engineering, Vol.4, Issue No.5, pp. 182~190, Aug.2016.

12. N.E. Mabunda , M.K. Joseph, "Microcontroller-Based Strategies for the Incorporation of Solar to Domestic Electricity", Electrical and Electronic Engineering Technology, University of Johannesburg, 2000 Johannesburg, South Africa, Rep. 25, 22 July 2012.

13. S. Das, D. Chowdhury, M.A. Razzak, "System efficiency prediction of a 1kW capacity grid-tied photovoltaic inverter", Vol.12, Issue No.2, pp. 1177~1186, Jun 2021.

14. W. Ali, H. Farooq & A. U. Rehman, "Design Considerations Of Stand-Alone Solar Photovoltaic System", In International Conference on Computing, Electronic and Electrical Engineering, Quetta, Pakistan, 2018, pp. 222~232.

15. T. Hasan and K. Roy, “Grid connected hybrid power system design using HOMER”, Presented in Proc. of 3rd ICAEE, Dhaka, Bangladesh,2015 pp. 125~134.

16. R. R. Mojumdar, A. M. W. Bhuiyan, H. Kadir, M. N.l H. Shakil & A. Rahman, “Design & Analysis of an Optimized Grid-tied PV System: Perspective Bangladesh”, IACSIT International Journal of Engineering and Technology, Vol.3, Issue No.4, August 2011.

17. T. V. Muni & S.V.N.L. Lalitha, “Technical Issues of Grid Connected Solar Photovoltaic Cell – A Survey”, I J C T A, 10(0) 2017, pp. 913~920.

18. M.N. Hasan, “Rahimafrooz IPS-2020”, Rahimafrooz., Dhaka., Bangladesh., Rep. 45, 2022.

19. Chilán, J. C. H., Torresb, S. G. P., Machucac, B. I. F., Cordova, A. J. T., Pérez, C. A. M., & Gámez, M. R. “Social impact of renewable energy sources in the province of Loja: Ecuador”, *International journal of physical sciences and engineering*, Vol.2, Issue No.1, pp.13~25, Oct 2018.

20. Uddin, M. N., Rahman, M. A., Mofijur, M., Taweekun, J., Techato, K., & Rasul, M. G. “Renewable energy in Bangladesh: Status and prospects”, *Energy Procedia*, Vol.*160*, pp. 655-661, Feb 2019.

21. M. Gautum, G. Joshi, R.P. Bhatta, S. Chettri, “Design and fabrication of Grid-tied PV inverter with Net-metering”, Dept. Elec. Eng., Tribhuvan Univ., Rep. 32, 2015.

22. A.Sayed , M. EL-Shimy, M. El-Metwally & Elshahed “Reliability, Availability and Maintainability Analysis for Grid-Connected Solar Photovoltaic Systems”. *Energies*, Vol. 12, Issue No. 7, pp. 1-18, Mar 2019.

23. M.N. Uddin, M.A. Rahman, M. Mofizur, J. Taweekun, K.Techato, M.G.Rasul et al., “Renewable Energy in Bangladesh: Status and Prospects”, In 2nd International Conference on Energy and Power, Sydney, Australia, pp. 655~661.

24. B.K. Das, M.A. Alotaibi, P. Das, P.K. Das, M.S. Islam,” Feasibility and techno-economic analysis of stand-alone and grid-connected PV/Wind/Diesel/Battery hybrid energy system: A case study”, " Energy Strategy Review," Vol.37, Issue No. 100673, pp. 1~15.

25. M. Xue , Y. Zhang, Y. Kang, Y. Yi, S. Li, F. Liu et al , “Full Feedforward of Grid Voltage for Discrete State Feedback Controlled Grid-Connected Inverter With LCL Filter,” IEEE TRANSACTIONS ON POWER ELECTRONICS, Vol. 27, Issue No. 10, pp. 4234~4247. October, 2012.

26. A. Mahbub , H. Kabir, J.I. Khandaker , M.A.M. Chowdhury, “Design and Development of Instant Power Supply,” IOSR Journal of Applied Physics (IOSR-JAP), Vol. 2, Issue No. 2, pp.01-04, Sep-Oct. 2012.

27. Broström, T., & Svanström, K, “Solar energy and cultural-heritage values”, In World Renewable Energy Conference, Linköping, Sweden, 2011, pp. 2034~2040.

28. R. R. Mojumdar, A. M. W. Bhuiyan, H. Kadir, M. N.l H. Shakil & A. Rahman, “Design & Analysis of an Optimized Grid-tied PV System: Perspective Bangladesh”, IACSIT International Journal of Engineering and Technology, Vol.3, Issue No.4, August 2011.

29. V.G. Anke and D.P.I.Van, “ Ethical Considerations in Engineering Design Processes”, IEEE Technology and Society Magazine,Vol.20, Issue No.3,pp.15~22, Feb 2001.

30. S.A. Chowdhury, "Guidelines for Net Energy Metering in Bangladesh for Integrating Distributed Renewable Energy Systems into the Grid", Centre for Energy Research, United International University, Dhaka, Bangladesh, Rep. 54, 2017.

31. Y. Beck, B. Bishara, D. Medini, “Connecting an Alternative Energy Source to the Power Grid by a DSP Controlled DC/AC Inverter”, Inaugural IEEE PES Conference and Exposition, Durban, South Africa, 11~15 July 2005, pp. 121~124.

32. R.K. Mohammad, “Bangladesh Electricity Bill per Unit 2022”, in Electricity Tariffs in Bangladesh 2022-2023, Dhaka, Bangladesh: Liton, 2022, ch. 5, pp. 135-137.

33. M.N. Hasan, “Rahimafrooz IPS-2020”, Rahimafrooz., Dhaka., Bangladesh., Rep. 45, 2020.

34. N. Sharmin, “Electricity Tariff Rates 2019-2020”, DPDC., Dhaka., Bangladesh., Rep. 25, 2020.

35. S.A. Choudhury, “Net metering Guidelines-2018’, PDB., Dhaka., Bangladesh., Rep. 30, 2018.

36. M. Hosenuzzaman., N. A. Rahim, J. Selvaraj, A.A. Malek, , & A. Nahar, “Global prospects, progress, policies, and environmental impact of solar photovoltaic power generation”, Renewable and Sustainable Energy Reviews, Vol. 41, pp. 284~297, Dec 2015.

37. G.V. Anke & A.V. Poel., “Ethical considerations in engineering design processes”, *IEEE Technology and Society Magazine,* Vol. 20, Issue No. 3; pp. 15~22, February 2001.

38. K. Neupane, T. M. Undeland, “Smart Controller Design for Solar-Grid Hybrid System”, Dept. Elect. Eng., Norwegian University of Science and Technology Trondheim, Norway, Rep. 50, 2002.

39. S.I. Pilu ,“Guidelines for the Implementation of Solar Power in Bangladesh 2013”, REB., Dhaka., Bangladesh., Rep. 22, 2013.

40. T. K. Kwang, S.B. Masri , “Grid Tie Photovoltaic Inverter for Residential Application,” Modern Applied Science, Vol. 5, Issue No. 4;pp.1~13, August 2011.

Appendix

Code:

```
#include &lt;LiquidCrystal.h&gt;

LiquidCrystal lcd(2,3,4,5,6,7);

int solar; // Solar Output

int bat1; // Battery voltage

int srelay=9; //Solar Charging Relay

int batrelay=10; // battery output relay

int solarrelay=12; // Solar Load Relay Control

int gridrelay=11; // grid Load Relay Control

int gridvolt=16; //grid voltage detection pin

void setup()

{

lcd.begin(20,4); // lcd initiate

pinMode(gridvolt,INPUT_PULLUP);

pinMode(srelay,OUTPUT);

pinMode(batrelay,OUTPUT);

pinMode(solarrelay,OUTPUT);

pinMode(gridrelay,OUTPUT);
```

```
digitalWrite(srelay,HIGH);

digitalWrite(batrelay,HIGH);

digitalWrite(solarrelay,HIGH);

digitalWrite(gridrelay,HIGH);

}

void loop(){

{

solar=analogRead(0)/4.092/10; //solar out

bat1=analogRead(1)/4.092/10; //batt out

int grid=digitalRead(gridvolt); // HIGH= No grid detected, LOW = grid detected

lcd.setCursor(0,0);

lcd.print(&quot;Solar:&quot;);

lcd.print(solar);

lcd.print(&quot;V, Bat:&quot;);

lcd.print(bat1);

lcd.print(&quot;V&quot;);

if(solar&gt;bat1 &amp;&amp; bat1&lt;14){

digitalWrite(srelay,LOW);

lcd.setCursor(0,1);

lcd.print(&quot;Charging On&quot;);
```

```
delay(500);

}

else if(bat1&gt;=13){

digitalWrite(srelay,HIGH);

lcd.setCursor(0,1);

lcd.print(&quot;battery Full&quot;);

delay(500);

}

else if(bat1&gt;solar){

digitalWrite(srelay,HIGH);

lcd.setCursor(0,1);

lcd.print(&quot;Solar Low&quot;);

delay(500);

}

else{

digitalWrite(srelay,HIGH);

delay(500);

}

if(grid==LOW){ // if grid volt found

lcd.setCursor(0,2);
```

```
lcd.print(&quot;Grid Power Detected &quot;);

if(bat1&lt;10){ //if battery is low

lcd.setCursor(0,3);

lcd.print(&quot;GL:Grid, HL:Grid&quot;);

digitalWrite(batrelay,HIGH);

digitalWrite(gridrelay,HIGH); //connected to grid

digitalWrite(solarrelay,HIGH); //connected to grid

lcd.setCursor(0,1);

lcd.print(&quot;Battery Low&quot;);

delay(1000);

}

else if(bat1&gt;12){ //if battery is working voltage

lcd.setCursor(0,3);

lcd.print(&quot;GL:Solar, HL:Solar&quot;);

digitalWrite(batrelay,LOW); // batt connected to inverter

digitalWrite(gridrelay,LOW); //Grid load connected from solar battery

digitalWrite(solarrelay,LOW); //Home load connected to Solar

delay(1000);

}

else if(bat1&gt;10 &amp;&amp; bat1&lt;=12){ //if battery is working voltage
```

```
lcd.setCursor(0,3);

lcd.print(&quot;GL:Solar, HL:Grid&quot;);

digitalWrite(batrelay,LOW);

digitalWrite(gridrelay,LOW); //Grid load connected from solar battery

digitalWrite(solarrelay,HIGH); //Home load connected to grid

delay(1000);

}

}

else{ //if grid line off

lcd.setCursor(0,2);

lcd.print(&quot;Grid Power Off&quot;);

digitalWrite(gridrelay,LOW); //connected to solar, that means home load is powered by solar

digitalWrite(solarrelay,LOW); //connected to solar, that means home load is powered by solar

if(bat1&gt;=10){

digitalWrite(batrelay,LOW); // if batt volt is ok then load will be on

lcd.setCursor(0,3);

lcd.print(&quot;GL:Solar, HL:Solar &quot;);

delay(1000);


}
```

```
else{
digitalWrite(batrelay,HIGH);
lcd.setCursor(0,1);
lcd.print(&quot;Battery LOW&quot;);
lcd.setCursor(0,3);
lcd.print(&quot;GL: Off , HL: Off &quot;);
delay(1000);
}
}
delay(3000);
lcd.clear();
lcd.begin(20,4);
}
}
```

Logbook

FYDP (C) FALL 2021 Summary of Team Log Book/ Journal

	Final Year Design Project (P) Summer 2021		
Student Details	**NAME & ID**	**EMAIL ADDRESS**	**PHONE**
Member 1	Mohammad Naib Rayhan ID : 18321002	Mohammad.naib.rayhan@g.bracu.ac.bd	01874041349
Member 2	Taifur Rahman ID: 17121027	Taifur.rahman@g.bracu.ac.bd	01849206734
Member 3	Saif Sayeed ID: 18121130	Saif.sayeed@g.bracu.ac.bd	01704858401
Member 4	Habibur Rahman ID : 18121131	habibur.rahman1@g.bracu.ac.bd	01757328650
ATC Details:			

ATC 1	Dr. ASN Nazmul Huda	Nazmul.huda@bracu.ac.bd	
Chair			
Member 1	Aldrin Nippon Bobby	nippon@bracu.ac.bd	
Member 2	Tasfin Mahmud	Tasfin.mahmud@bracu.ac.bd	

General Notes:

1. In addition to detail journal/logbook fill out the summary/key steps and progress of your work
2. Reflect planning assignments, who has what responsibilities.
3. The logbook should contain all activities performed by the team members (Individual and team activities).

Date/Time/Place	Attendee	Summary of Meeting Minutes	Responsible	Comment by ATC
17.03.2021	1.Rahim 2.Karim 3.Abdul	1.Need to finalize title. 2.Need to finalize problem statement. 3.Need to prepare a draft concept note	Task 1: Rahim Task 2: Karim and Abdul Task 3: Rahim, Karim and Abdul	N/A as it was an introductory meeting.
				Task 1: completed. Task 2: partially completed. Task 3: have not started yet.
7.11.2021	1.Habib 2.Saif 3.Naib 4.Taifur	We discussed about how we will implement the final design prototype, and the skills and knowledge we had to gain.	All group members	Prepare the final design prototype.
14.11.2021	1.Habib 2.Saif 3.Naib	We discussed about how to control the switching process between the Home and Grid Load	All group members	Discussed about how to achieve this design requirement.

	4.Taifur			
21.11.2021	1.Habib 2.Saif 3.Naib 4.Taifur	.We discussed about how we can make the prototype work efficiently and solve the switching problems.	Habibur Rahman	Solve the issue and prepare for the progress presentation.
12.12.2021	1.Habib 2.Saif 3.Naib 4.Taifur	Discussed about what ethical issues could be involved and how to address them	Naib Rayhan	Ethical issues related to costs, safety requirements etc
24/12/2021	1. Habib 2.Taifur 3. Saif 4. Naib	Discussed about the final implementation of our project for the final presentation.	All group members	