Design of a Smart Agri-voltaic system for irrigation purposes considering major crops

By

Shoheb Abul Hossain

18121037

Kasshaf Ahmad

18121082

Md. Tamzid Hossain

18121110

Afia Raidah Ariya

18121048

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

Spring 2022

Declaration

It is hereby declared that

1.The project submitted is my own original work while completing degree at BRAC University.

2.The project 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 project does not contain material which has been accepted, or submitted, for any other degree or diploma at a university or other institution.

4.I have acknowledged all main sources of help.

Student's Full Name & Signature:

Shoheb Abul Hossain 18121037	Md. Tamzid Hossain 18121110
Kasshaf Ahmad 18121082	Afia Raidah Ariya 18121048

Approval

The project titled “Design of a Smart Agri-voltaic system for irrigation purposes considering major crops” submitted by

1. Shoheb Abul Hossain (18121037)
2. Kasshaf Ahmad (18121082)
3. Md. Tamzid Hossain (18121110)
4. Afia Raidah Ariya (18121048)

of Spring, 2022 has been accepted as satisfactory in partial fulfillment of the requirement for the degree of Bachelor of Science in Electrical and Electronic Engineering on 30 August,2022.

Examining Committee:

Academic Technical Committee:
(Chair)

____

Prof. Dr. Md. Mosaddequr Rahman,
Professor and Chairperson, Dept. of EEE
BRAC University

Final Year Design Project
Coordination comittee:
(Chair)

____

Assistant Prof. Dr. Abu S. M. Mohsin
Associate Professor, Dept. of EEE
BRAC University

Departmental Chair:

____

Prof. Dr. Md. Mosaddequr Rahman,
Professor and Chairperson, Dept. of EEE
BRAC University

Abstract

Products and farming equipment's are continually being upgraded. In Bangladesh, physical labor is used primarily in farming. Here, automated farming has not yet been implemented. Our initiative aims to implement a fundamental strategy to combine solar power and smart IoT systems for farming in our nation. It is an automated farming system created as an Android application that is used to select the best crop before the cultivation process begins based on the area of the producing land. According to studies, PV systems in agriculture are the greatest ways to meet the agricultural needs of rural places. The use of solar energy offers the potential to offer emissions-free energy services. It has a plentiful supply because it is a renewable energy source. The solar power pumping system can be employed in Bangladesh's distant or rural areas where there isn't much access to energy. A solar-powered pumping system can transport water or be used for irrigation. Dieselpowered pumping systems have a low initial cost, but their upkeep and operation are expensive and challenging. The solar-powered pumping system, however, operates almost entirely in the other way. Although it costs a lot up front, operating it is significantly less expensive. An effective, straightforward, and dependable solar pumping system will be created. This method can meet the need for water in agriculture and will be economically viable.

Keywords: Irrigation, Smart Agri Voltic, IOT based irrigation, Solar power, DC-AC pump Structure, Solar system for irrigation, Irrigation on Major crops.

Dedication

We would like to dedicated this project to our parents who raised us and encouraged us throughout our academic journey. Also, our respected supervisors who have been supporting us from the start and enlighten us the right path to complete the journey of this thesis/project

Acknowledgment

At first, all thanks to Almighty Allah for whom we completed our project without any major obstacles. Also, we would like to thank our respected supervisor, Prof. Dr. Md. Mosaddequr Rahman, Professor and Chairperson, Department of Electrical and Electronic Engineering, BRAC University for his guidance and supervision. Moreover, we are our co-supervisor, Mohaimenul Islam, Lecturer, Department of Electrical and Electronic Engineering, BRAC University who gives us his constant support, motivation and encouragement which helps us to overcome several drawbacks that could impact our journey throughout the whole project.

Table of Contents

List of Tables:

List of Figures:

List of Acronyms List of Acronyms

PV Photo Voltaic
IoT Internet of Things
Wh watt-hour
DOD Depth of Discharge
LCD Liquid-crystal display
RET Screen Renewable Energy and Energy Efficiency Technology Screen
SWOT Organization's strengths, weaknesses, opportunities and threats

Other meanings /Full forms of acronyms are attached with the mentioned acronyms.

Chapter 1: Introduction

1.1 Introduction

One of the main prongs of Bangladesh's economy is agriculture, and the development of agriculture is directly and indirectly related to the fluent supply of electricity. But the main power source of Bangladesh, the nation grid connected energy still not distributed in rural or remote areas. The Farmers of those areas are bound to use analog system irrigation which hinders their economic growth as well as require hard labor. Since Bangladesh is 6 seasoned country, renewable energy like solar energy is mostly suitable for this country. Using solar energy for irrigation and other farming machinery will be an easier Solution for the farmers of rural areas.

1.1.1 Problem Statement and Background Research

In Bangladesh electric energy access is the far-way dream for many families in the rural area in developing countries, about 80% of the population are living in the rural and remote areas where only 25% of electricity is available for people for which the farmers are struggling for not getting power to run the necessary equipment and farm machineries for agriculture [1]. Therefore, to provide adequate electricity to every corner of the country is a challenge to a developing country like Bangladesh. In addition, Farmers turn to alternatives such as generators, which are costly and depend on a nonrenewable resource that is hazardous to the environment, because they are unable to rely entirely on the national power supply. At the same time, the threat of climate change is changing the energy strategy. A shift from fossil fuels towards renewable energies is unavoidable and necessary to curb the climate crisis. Solar energy has the potential to set a significant fraction of non-renewable electricity demands globally. It is currently the fastest growing power generating technology. However, ground-based solar

PV panels will increase the pressure on agricultural land and compete with agriculture. The installation of photovoltaic power plants on agricultural land is therefore an important opportunity to increase the share of renewable energy in the energy mix. However, this should not be done at the expense of agricultural production. That is why it is important to develop synergies between food and energy as we need both of them [2].

Farmers in our country are investing their valuable time and receiving poor and ineffective outcomes for inefficient irrigation systems. As a result, we are developing a smart standalone PV system which is efficient, sustainable, and automated in order to reduce farmers' hard work and prevent water loss. Moreover, there is a need for Big Data Analytics in smart farming. Collecting data from a single person's agriculture farm may aid in the growth of that person's farm. However, data from a single place isn't very relevant for a government or agricultural officer concerned with the agricultural output of the entire country. They should, ideally, collect data from every agricultural farm they can.

The Internet of Things (IoT) is here to help reduce the amount of physical labor required to acquire these critical agricultural data. If manual labor is used, we will have to send tens of thousands of people to various agricultural sites every day to collect the tedious readings, and there will be no guarantee of data integrity because, as humans, we may become inert and manipulate the data, potentially leading to incorrect expert conclusions.

Using these data, a government can make useful decisions and announcements on country's agricultural throughput like: how was past year's output, how it is going to be next year, how individual farmers can improve their production with current climate situation and even how much a government need to allocate monetary fund for next financial year for agriculture

1.1.2 Literature Gap

The implementation of Agri voltaic systems involves changes in cropping practices. Light reduction has not necessarily been a harmful effect on crops that can adapt, however there is a lack of studies on the effect of the shade on the large majority of plants like rice.[3] Because few screening studies of crop tolerance to shade have been conducted, there is limited data on most crop species' tolerance to shade.[4]

No specific data provided regarding the water requirements on different kinds of crop. For example, for the cultivation of Boro rice in one paper it was mentioned that the level of water needed is 8.5 cm whereas We also couldn't find enough geographical data about soil absorption due to lack of field work as this information as this information is very vaguely found on the internet about Bangladesh

Not enough data analysis tools or techniques are available to implement precision agriculture techniques. In addition, adoption of the new emerged technologies is yet to be available in real life full-fledged, thus making it hard to take ideas and examples to initiate [5]

1.1.3 Relevance to current and future Industry

Today, the people of the 21st century, trying to rely on renewable energy more. A research study shows in 2020 the Solar PV power generation increased 156 TWH which means from 2019 the growth percentage is 23%.[6] From this study we can say if power generation from Solar PV continuously grow rapidly, hopefully this project which is directly connected with Solar panel usage will be applicable in agriculture field at present as well as in future.

1.2 Objectives, Requirements, Specification and constraint

1.2.1 Objectives

The main purpose of designing a Smart Agri-voltaic System for Irrigation project is to simplify and automate the farming of Bangladesh with IoT based tools for different seasons. Our goal would be to find the optimum solution in reducing the complexity and maintenance during operation, to design a cost-effective system; analyzing the environmental impact and sustainability.

1.2.2 Functional and Nonfunctional Requirements

Functional Requirements:

Before starting designing a complex project, we need to set some basic functional requirements which will help us to inspect if all the requirements are included in the project or not. To design a smart Agri Voltic system for irrigation must require -

- smart IOT systems for complexity of the project
- Smart monitoring system to reduce wastage
- Continuous Connection of internet
- Selection of most suitable hardware components

Non-Functional Requirements:

To successfully design any project, a project planner needs to set some non-functional requirements beforehand to run the project smoothly. For a Smart Agri Voltic irrigation system we need to require a proper idea of the land to undergo the project. At first, we need to select a qualified land to run the project. We need enough knowledge of soil and water supply which will be needed in that particular land so we are using soil and water flow sensors to build a smart system. On the other hand, we must determine whether the system is budget friendly, considering the foreseeable future. Selection of crops based on marketing opportunities, investment requirements, profit margin and irrigation needs are also some important factors. After setting up the whole system we have to educate consumers, industry representatives, farmers and the general public about solar energy technologies, so that they can easily use the system. Lastly, legal documentation is important to initiate the project (e.g.- Legal paperwork)

1.2.2 Specifications:

Fig 1: Project Location

Location of the project	**Naopara, Netrokona**, Bangladesh (GPS Coordinates: 24°41'46.1"N 90°50'03.4"E)
Type of Crop	Rice (Boro)
Area	10,000 m^2 (Assumption) (1 hector)
The required average water height for Boro rice	8.5 cm
No of times for irrigation	25
Number of beneficiary (farmer)	1
Total Water required for one hectare of Boro irrigation	(Required water height) × (Area)× (No: of irrigation) =0.0085× 10000 × 25 = 21250m^3/h
Total average water required per day per hectare	(21250m^3 × 1000l)/75days = 2, 83, 333l/day.
Mean Flow rate of 3HP Irrigation Water Pump (2.24kW) 4”by4”	42m^3/h
Approximate amount of water pumped each day	(Flow Rate) × (Active Hours) = 42× 6.5 = 273m^3/day =2,73,000 l/day

Table 1: Specification of required factors

Initially, we calculated the amount of water required for 1 hectare of land for Boro rice cultivation and found out the total water required for irrigation of Boro Rice is 21250 m^3/h and the water requirement distributed in 75 days is about 2,83,333*l/day*. [7] Then a suitable motor was selected based on the water requirement, which is a 3HP motor centrifugal pump at 6 to 7 hours of active irrigation time. This pump requires a power rating of 2.24kW. So, we designed our PV array to produce about 3.1kWp. Our main design will take into account the different water requirements at different stages of the rice crops as shown in the table ____.

For this project we found the required parameters for solar generation at our project site Netrokona from PV Watts calculator, from the website of NREL (National laboratory of the USA department of Energy). [8] The PVWatts® energy estimate is based on an hourly performance simulation using a typical-year weather file that represents a multi-year historical period for a Fixed (open rack) photovoltaic system. The kWh range is based on analysis of a nearby data site described.[9] The number of solar panels installed was calculated based on the total energy produced per day at Noapara, Netrokona.

1.2.3 Technical and Non-technical consideration and constraint in design process:

To run the project, we need to consider some factors which include both technical and nontechnical issues. It is not only beneficial for the project but also for the consumers and workers.

Technical Consideration:

- Finding suitable Land for the project.
- Availability of all components.
- 24 hours monitoring system to avoid machinery dysfunction.
- Overall maintenance system.
- cost effective project with good payback.

Non-technical consideration:

- Legal documentations
- Ensuring safety of consumers and workers.
- Maintaining ethics on selecting components

Constraints:

On the other hand, the project might face some difficulties and constrains. Here is the overview of potential and limitations of PV systems

Area	**Limitation**	**Potential**
Equipment and investment of the PV panels	High unit investment costs (Wp)	PV mainly competitive in low energy use range in remote, unelectrified areas Need for financing mechanisms (Also due to low capital availability in rural areas)
Operation and Maintenance of PV Panels	Back-up or storage is required for use at night and on days with low insolation. The battery is the weakest point in the PV system.	PV systems often competitive on life cycle cost basis
Organization	More user engagement is required for PV projects than for grid expansion initiatives.	Need for institutional changes in the energy sector for PV rural electrification projects
Environmental implications	Disposal of battery is a major environmental issue	Possible (co)financing from climate change funds

Table 2: overview of potential and limitations of PV systems

Land Acquisition and Aggregation: Given the scarcity of land and the fact that agricultural land cannot be utilized for power generation, this is a big difficulty. Land acquisition for solar projects is difficult since the actual price is significantly greater than the market value. Furthermore, land acquisition is a difficult process in and of itself. Potential multilateral lenders, particularly at the end, want to know about the gap between the acquisition price and the market price, rehabilitation, and so on. [10]

Other limitations:

- To be able to recover/reinstall the entire PV system if natural calamities occur
- Leakage of such information either through unauthorized access or by an insider can cause potential threats
- Proper Maintenance of lead–acid batteries are needed in controlling the charging and discharging if good life and a large number of charge/discharge cycles are to be obtained.

- Cleaning issue if the structure is too high. If the structure is not high heavy machineries like tractors
- Increase in structure cost due to additional mounting height of the PV panels
- Uncontrolled vegetation interferes with maintenance and casts shadows on PV arrays, resulting in hot spots and energy generation loss. It also poses a safety risk since it serves as a home for large insects and animals.
- Complete removal of this undesirable plant requires a greater soiling rate as well as a large amount of personnel, limiting productivity and drawing higher cleaning frequencies.

1.2.4 Applicable compliance, standards, and codes

Required Devices	**Standards and codes**	**Definition**
LEAD- ACID Batteries	IEEE 1013–1990	Methods for sizing both vented and valve-regulated lead-acid batteries used with terrestrial photovoltaic (PV) systems are described. Iterative techniques to optimize battery costs, installation, maintenance, safety, testing procedures and consideration of battery types other than lead-acid are also described here.
PV systems	IEEE 1361–2003, IEEE 937–2007	• In Std 1361–2003, Stand-alone photovoltaic (PV) system parameters and operating conditions are discussed in relation to battery characteristics and expected system performance. A performance test to verify the battery selection and system parameters is provided, including discussions on how to interpret test results. • In Std 937–2007, considerations and procedures for storage, location, mounting, ventilation, assembly, maintenance of lead-acid secondary batteries for photovoltaic power systems, Safety precautions and instrumentation considerations are provided.
Converter	IEEE 936-1987	In this standard is described how converters are using switching devices that have turn-off capability, such as transistors or gate turn-off thyristors, interruption of the current results in a voltage that commutates the current to another branch, circuit-commutated thyristors, the commutating voltages required to transfer current from one branch to another are normally supplied by capacitors.

Motor	IEEE P1017.4	It defines the procedures and test values for testing and rating of Electrical Submersible Pump (ESP) motors as well as installation and handling practices. The specified procedures and test values apply to ESP motor systems rated 3 kV through 8 kV (phase to phase).
Charger Controller	IEEE 2030.1.1-2015	Discussed about every type of charge controller and the requirements.
Sensors	IEEE 2700-2017	The Sensor performance specification terminology, units, conditions, and limits is provided in this standard.

Table 3: Standard codes of required devices and definitions

Standards applicable overall the project:

- All the electronic equipment should be grounded properly, in order to protect locals from injury by electric shock.[11]
- lighting protection should be installed, as in rural areas lightings can damage equipment often.[12]
- The overcurrent protection and short circuit protections should be provided in the machineries.[13]
- The components should be environmentally friendly

1.3 Systematic Overview/summary of the proposed project:

After going through a staggering number of research papers and data, we could narrow down our designs for the project. But to advance, we had to decide the optimal solutions to the multiple designs. For this, we did several kinds of calculations and data analysis, via different software tools on the internet. And to our end result, taking all the factors discussed above into account we have chosen the design- A smart standalone PV system with inverter and battery. We hope to finish the project within due time and make an impact to the prosperity of the society.

Chapter 2: Project Design Approach

2.1 Introduction

For smart Agri-voltaic irrigation, there are different types of approaches available. But we need to select some of the approaches which are qualified to complete our objective and requirements. Thus, we selected 3 Design approaches to analysis and finalized our optimal design solution.

Background Study:

Before working on the designs, we gain a vast knowledge about solar irradiation, angled solar panels, pumps along with water and soil requirements. Which helped to select perfect machineries for designing the 3 different approaches.

Pump Selection and Water Requirement

All irrigation pumps have 3 main components: Motor that drives the pump Impeller that spins around pushing the water from the inlet at the center of the impeller away from it. Diffuser which is a casing around the impeller that collects the moving water and moves it to the outlet.

Submersible pumps

In Submersible the motor and the impeller are placed under the water. The motor spins the impellers in the diffuser and this forces the water up the pipe and into the irrigation system. Submersible pumps are designed for medium flow application. The submersible pump has an inbuilt protection against dry run. However, the surface pumps are very sensitive to dry run. A dry run of 15 minutes or more can cause considerable damage to a surface pump. Submersible pumps are easier to install and are better protected from the environment.

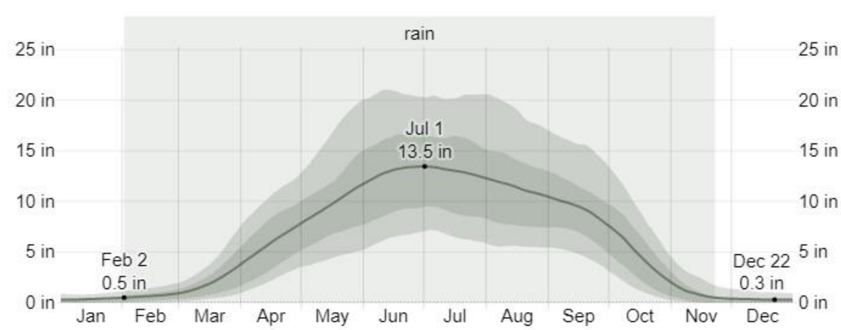


Fig 2: Average Rainfall Netrokona

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.4″	0.6″	1.9″	5.9″	9.8″	13.1″	13.0″	11.4″	9.5″	4.6″	0.8″	0.3″

Solar Irradiance and Incident Energy Calculation

Factors affecting the incident energy

- Geographic location (Latitude, Longitude)
- Tilt angle β
- Time of the day (ω: $Hour\ angle$)
- Time of the year ($\delta - Declination$)
- Atmospheric condition (Ozone, Clouds, Scattering etc.)

Solar Irradiance and Incident Energy Calculation

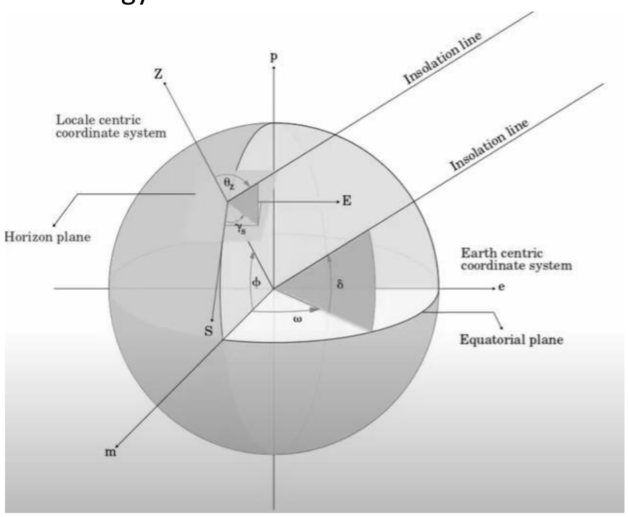


Fig 3: Solar Irradiance and Incident Energy Calculation

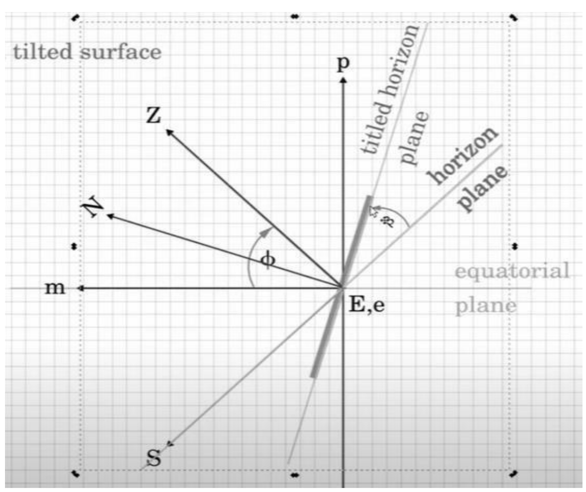


Fig 4: Solar Irradiance and Incident Energy Calculation

$$L = L_m + L_e + L_p$$

$$L_N = L_m. cos(\phi - \beta) + L_p. sincos(\phi - \beta)$$

$= L \quad . cos\delta. cos\omega cos(\phi - \beta) + L. sin\delta sin(\phi - \beta)$ Cumulative Incident Energy, H_{ot}

$= 2 \int_0 \quad \omega^{srt} \quad ^2/day$

$H_{ot} L_N d\omega \quad kW\ radians/m$

$$H_{ot} = \frac{24. k. L_{sc}}{\pi} \int_0^{\omega srt} L \quad . cos\delta. cos\omega cos(\phi - \beta) +. sin\delta sin(\phi - \beta) d\omega$$

$$= \frac{24.k.L_{sc}}{} \int_0^{\pi} \quad \omega srt \quad L \quad . cos\delta. sin\omega_{srt} cos(\phi - \beta) + \omega_{srt}. sin\delta sin(\phi - \beta)$$

ω_{srt}: Sunrise angle for tilted flat plate minimum of (ω_{sr}, $\omega_{sr\beta}$)

$\omega_{sr} = cos^{-1}(-tan\phi. tan\delta)$, $\omega_{sr\beta} = cos^{-1}(-tan(\phi - \beta). tan\delta)$ L_{sc}:

Solar Constant

Atmospheric Effects on Incident Radiation

When skies are clear, the maximum radiation strikes the earth's surface when the sun is directly overhead, and sunlight has the shortest path length through the atmosphere. This pathlength can be approximated by

$$AM = \frac{1}{cos\theta_z}$$

This pathlength is usually referred to as the Air Mass (AM) through which solar radiation must pass to reach the earth's surface.

When θ_z= 0, the Air Mass equals 1 or 'AM1' radiation is being received; when θ_z= 60°, the Air Mass equals 2 or 'AM2' conditions prevail. AM1.5 (equivalent to a sun angle of 48.2° from overhead) has become the standard for photovoltaic work.[14]

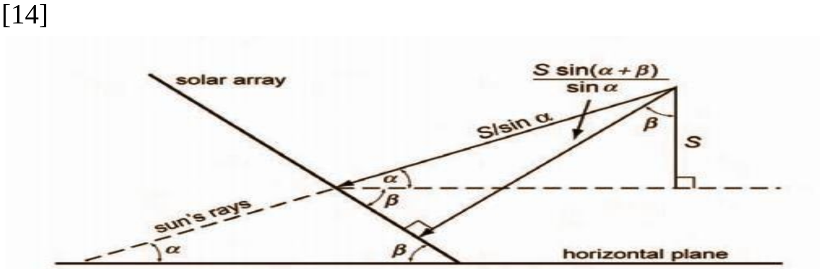


Fig 5: Light incident on a Surface tilted to the horizontal (after Mack 1979)

Maximum Light Intensity in sunny days $\alpha = 90 - \theta - \delta$, $\theta = Southern\ Latitude$

$$I_{si} = 1.353 \times 0.7^{AM\ 0.678} \times 1.1 \times sin(\alpha + \beta)$$

The units are kW/m^2, α is the noon-time altitude of the sun for month i,β is the angle of inclination of the array on which I_{si} is incident, AM is the air mass (1/sinα) and the factor 1.10 allows for the inclusion of the diffusion

Maximum Light Intensity in cloudy days for month i is estimated from

$I_{ci} = 1.353 \times 0.7^{AM\ 0.678} \times 0.20$

Taking the effects of attenuation into consideration

$$R15 = X \times S15 + Y \times C15$$

R15: average cumulative incident energy for 15th day of the month

S15: average cumulative energy for sunny day for 15th day of the month

C15: average cumulative energy for cloudy day for 15th day of the month

X and Y are the percentages of sunny and cloudy weather

Optimized tilt angles

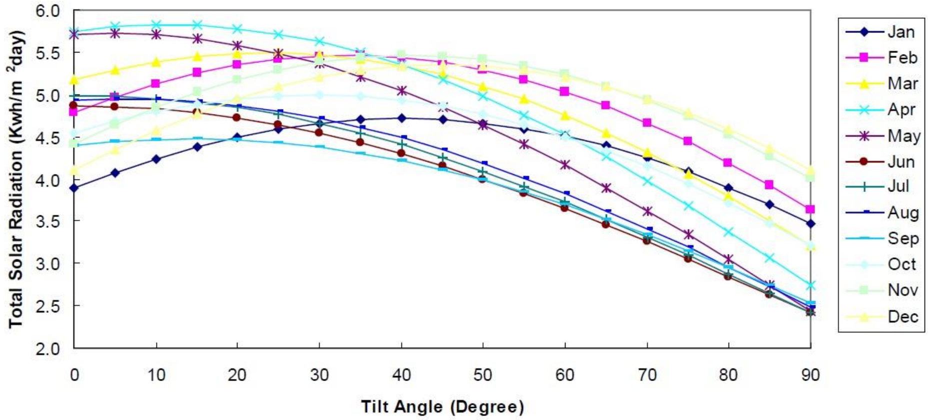


Fig 6: the variation of monthly averaged daily total solar radiation for various optimized inclination angles of Netrokona, Bangladesh.

Optimization Period	Tilt Angles (λ)	Optimization Period	Tilt Angles (λ)
January:	33.6°	August:	18.6°
February:	28.6°	September:	23.6°
March:	23.6	October:	28.6°
May:	13.6°	November	33.6°
April:	18.6°	December	38.6°
July:	13.6°		

Table 4: optimal tilt angles by month

Optimal tilt angles by season:
Spring: 23.6°, Summer: 8.6°, Fall: 23.6° & Winter: 38.6°

Optimal tilt angle refers to such an angle for which the value of solar radiation on that surface becomes highest.

Photovoltaic system designers often need estimates of the insolation expected to fall on arbitrarily-tilted surfaces. Separated direct and diffuse components are usually required for estimation of the effects of module tilt, but these need to be estimated from global values if not separately measured. November is considered a critical month for pump design.

2.2 Identify multiple design approach

The selected design approaches are,

1. Design 1: Direct coupled water pumping system
2. Design 2 Agri-voltaic System with Power Storage Capacity
3. Design 3: Stand-alone Agri-voltaic System with Inverter

2.3 Describe multiple design approach

2.3.1 Design 1: Direct coupled water pumping system

In this system the water pump system will be directly connected with soler panel and whole system will run by DC system.

Design Methodology:

The general approach to designing a directly coupled system can be summarized as follows:

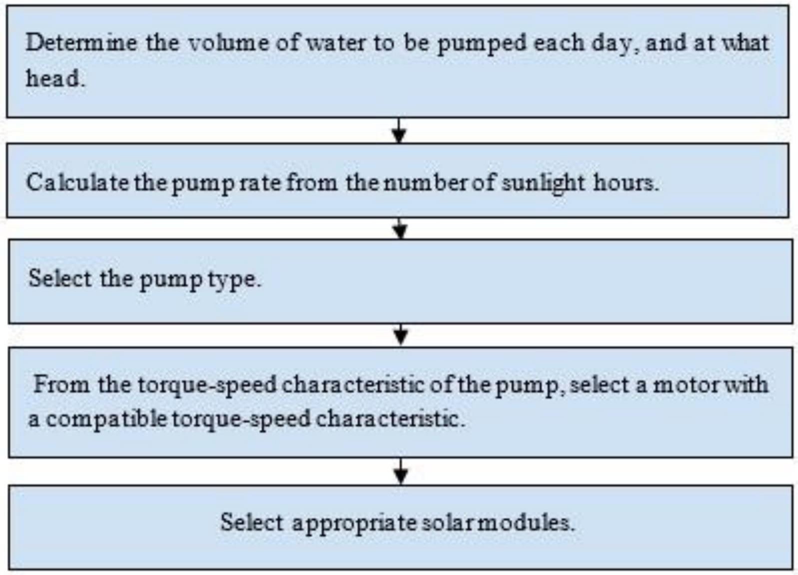


Fig 7: Design 1 methodology

Design a directly-coupled pumping system (no batteries or power conditioning circuitry) for irrigation purposes in Netrokona (latitude 24.85° N). The only months of interest are April-June and November-January, during which period 2.83 million liters/day are required to be pumped.

The series DC motor has the field windings connected in series with the armature windings. This configuration has a severe limitation when being driven directly by photovoltaic panels because a drop in motor current accompanying a fall in light intensity on the solar panels affects both the field and armature windings. On the other hand, they tend to be able to pump more water than shunt DC motors on sunny days

Block Diagram:

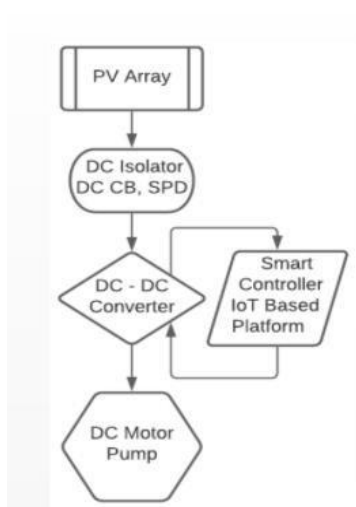


Fig 8: Block Diagram of Directly Coupled PV system

Circuit Diagram:

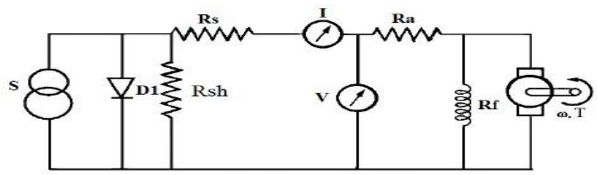


Fig 9: Circuit diagram of Directly Coupled PV system

There are three PV arrays, 3 DC series pump-motors and a control panel. Each unit of solar array contains four panels of 12V each and the capacity of the total array is 2 kWp. Three pipes are connected to the 6” main bore well which has a depth of 120 feet and the static water level is 20 to 25 feet. There was also a storage tank to enable us to preserve and use the irrigation water during periods when the sun radiation is not received sufficiently or during hours of darkness at night. The three motors will start to work at minimum 24V. From 7am-12 pm, at the start of the day with low insolation at least one motor with a small boring will start to run. From 12pm- 3pm, at the middle of the day two motors can run equally. With the availability of sufficient insolation 3 motors can operate simultaneously. The excess water can then be stored in the storage tank for later use.

Parameters:

Parameter	Value
No. of Pumps	3
Pump rated power	1 kW
Pump motor type	DC series motor
Total Power of the solar Panel	2 kWp
System Voltage	48 60V DC
Type of Panel	Mono Crystalline
No. of Cells per panel	72
Bore hole	Shallow 6 Inch pipe, 120 feet depth
Static water level	30 feet

Suction Pipe Size & Delivery Pipe	1.5’’,2’’&3’’
Total Water Lifting	1.2 -1.72 million / day

Table 5: parameters with required amount

2.3.2 Design 2 Agri-voltaic System with Power Storage Capacity

In design 2 we are using an additional storage system with the previous system,

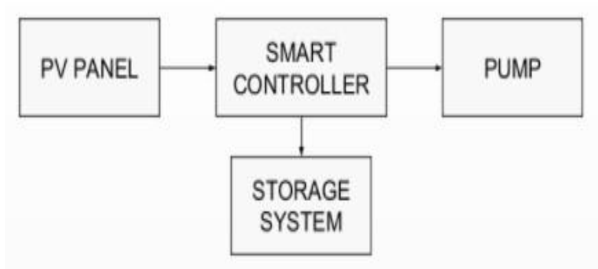


Fig 10: Agri-voltaic System with Power Storage Capacity

Battery-coupled water pumping systems consist of photovoltaic (PV) panels, charge control regulator, batteries, pump controller, pressure switch and tank and DC water pump. The electric current produced by PV panels during daylight hours charges the batteries, and the batteries in turn supply power to the pump anytime water is needed. The use of batteries spreads the pumping over a longer period of time by providing a steady operating voltage to the DC motor of the pump. Thus, during the night and low light periods, the system can still deliver a constant source of water.

Design Methodology:

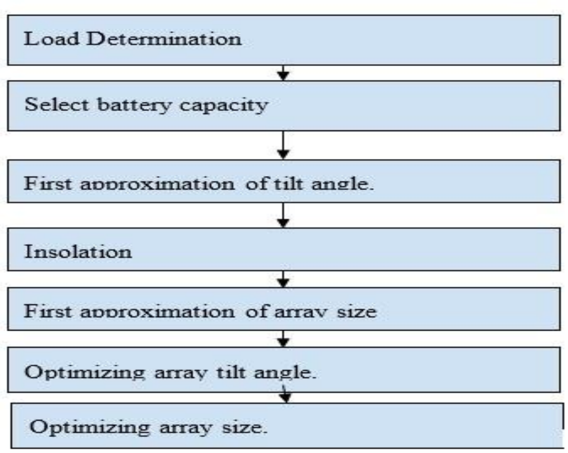


Fig 11: Design 2 methodology

Block Diagram:

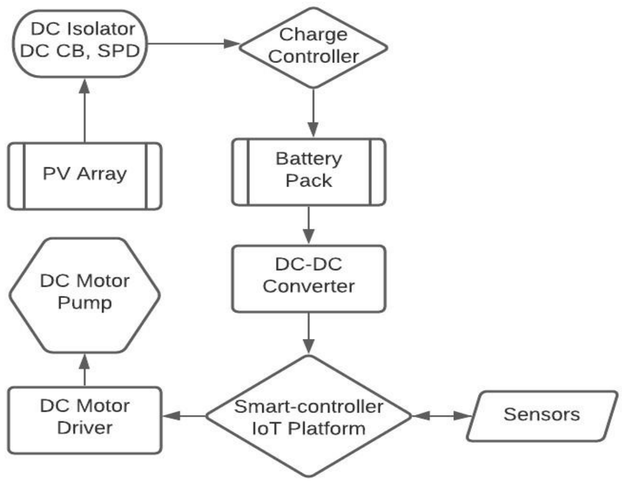


Fig 12: Block diagram of Agri-voltaic System with Power Storage Capacity

2.3.3 Design 3: Stand-alone Agri-voltaic System with Inverter

In this approach, we are using an AC pump and to convert the DC Power to AC, we are using an inverter.

Design Methodology

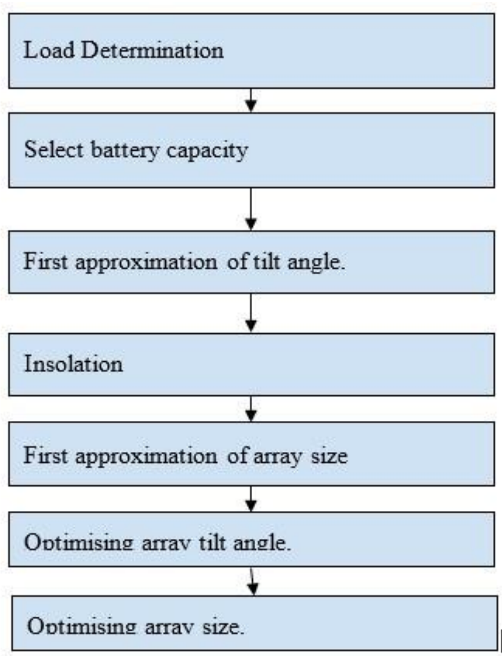


Fig 13: Design 3 methodology

Block Diagram

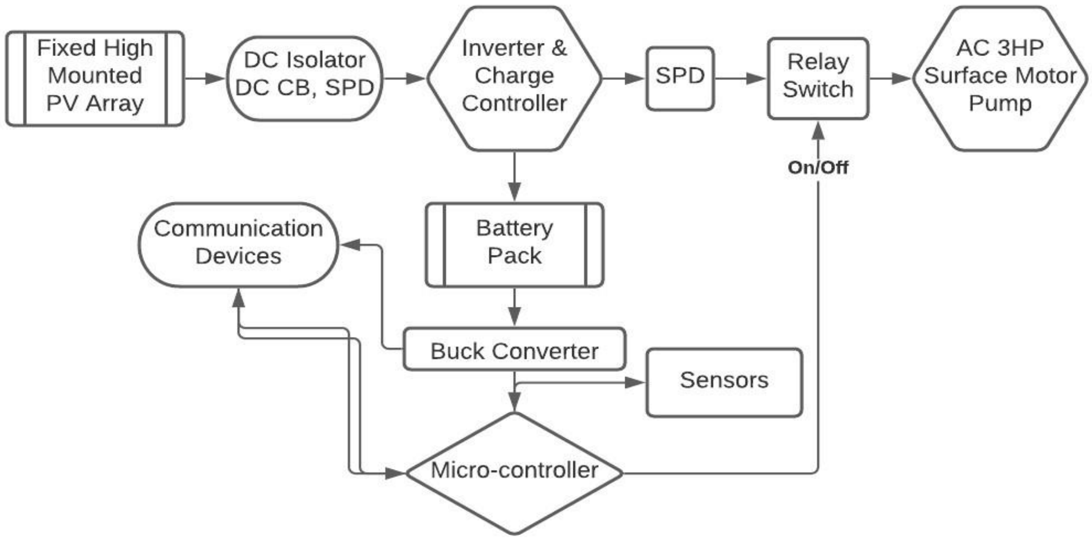


Fig 14: Block Diagram of Stand-alone Agri-voltaic System with Inverter

2.4 Analysis of multiple design approach

We go through multiple analysis for design 1 such as economic analysis, payback analysis and load analysis along with the advantages and disadvantages for each design.

2.4.1 Analysis of Design 1: Direct coupled water pumping system

Economic Analysis:

Name of the equipment	**Unit Price**	**Quantity**	**Cost (USD)**
Solar Panel total 2kWp	1/Wp	2000	2000
Motor	125	3	375
Pump	-	3	187.5
Boring Well	-	-	1250
Panel Structure	-	-	500
Electrical Wiring and Misc Cost	-	-	625
Installation Charge	-	-	125
Total in USD = 5062.5			
Total in BDT = 4,05,000			

Table 6: Required budget of design 1

Season	**Type**	**Area of Irrigated land**	**Cash Inflow (BDT)**	**Cash Inflow (USD)**
January-April	Boro	½ ha	19840/2=9920	124
April-June	Any crop	¼ ha	4960	62
July-August	Rainy season	No irrigation needed	-	-
September-Nov	Any crop	¼ ha	4960	62
November-March	Boro/ Wheat/Mustard	½ ha	9920	124
Total		3/2 ha	29760	372

Table 7: Yearly Cash Inflow of the project

Payback Analysis:

IDCOL (Infrastructure Development Company) Bangladesh and donor agencies give 40% of total cost as grant to encourage solar irrigation. So, setting up a solar irrigation system would cost less than the costing shown here for this project. Table shows the related cost for the set up in BDT and the
total amount is 4, 05,000 BDT
To calculate a simple payback period, we need to know the cost of irrigation per area of land to calculate yearly cash inflow of the project.
From the above Table, we have calculated the average cost of irrigation per hectare of land. In Table, we have shown the yearly total amount of irrigated land by the project and total cash inflow of the project. Now we have calculated the payback period as follows:

$$Simple\ payback\ period = (Initial\ Investment)/(Yearly\ Cash\ inflow)\ )$$
$$= (630\ 000(BDT)/(29\ 760(BD0T = 13.6\ years$$

Disadvantages of Solar Powered Pumping System:

The main disadvantage to using a solar pump is that it must have several hours of direct sunlight every day to work. If the crop field has shade most of the day, then a solar pond pump may not work. Also, the solar panel will need regular cleaning to keep it running efficiently.

2.4.2 Analysis of Design 2: Agri-voltaic System with Power Storage Capacity

Load and battery capacity determination:

To design this system at first, we need to determine the load capacity. In this system we are using 3 Dc series pump motors which need 1.5kw power and the sensors and microcontroller need to use 500W power.
So, for day time:

Daytime load (10 hrs.):
Wh (day) = 1500×3+ 5×10 = 1550Wh Night
time load (14 hrs.):
Wh(night) = 5×14= 70Wh

Peak Load= 1500+ 50 = 1550
Maximum current may be drawn = 6.8+0.2= 7A
So,
Voltage (Battery) = 12 V
DoD= 0.8 (80%)
Battery Efficiency = 0.7 (70%)

Wh (load) = Wh(peak) ÷ Efficiency = 2215 Wh
Battery Ah needed = 72÷ (0.8×12) = 190 Ah
Average Current drawn = (6.8+0.2) ÷2 = 3.5A
Therefore, we need to select a battery that can provide 200 Ah.
Thus, we have chosen, SAIF POWER IPS SPECIAL BATTERY 200AH 12V

Parameters:

Name	Specification	Quantity
PV Cells	Mono Crystalline 10 panels of Dimensions-1.5x0.665x0.035 *m*, Mass-11kg 1 panel Dimensions-2.063x1.026x0.035 *m*, Mass-24kg	10 + 1 = 11 panels
Battery backup	Lead–acid batteries Tubular batteries 200Ah	3
motor type	DC series motor	3

Pump	DC 3HP pump	3
Soil moisture Sensor	YL-69 Soil Hydrometer Module / Soil Moisture Sensor	10
Humidity Sensor	DHT11	10
Temperature Sensor	LM35	10
Water Level Sensor	Liquid Level Sensor for Arduino (5) / 52mm pp liquid water level sensor (6)	10
PH Sensor	Digital pH Sensor module	5
Arduino Uno	ATmega328P-b bit	2
LCD Module	2x16 LCD display and 6 momentary push buttons	1
Relay Module	5V 1-Channel Relay interface board	1
Bore hole	Shallow 6 Inch pipe, 120 feet depth	
Static water level	30 feet	
Suction Pipe Size & Delivery Pipe	1.5’’,2’’&3’’	
Total Water Lifting	1.2 -1.72 million / day	

Table 8: parameters and required quantity of design 2

4.2.4. Economic Analysis

Name	**Quantity**	**Total Approximate Price (BDT)**	**Source**
Mounting Structure & Setup cost	-	1,20,000	Local Solar System Solution
PV Cells	11 Panels	1,10,000	https://www.loomsolar.com/collections/sola r-panels/products/loom-solar-panel-190watt-mono-crystalline https://www.loomsolar.com/products/loomsolar-panel-shark-super-high-efficiency-module?fbclid=IwAR2HvckYDKZzaFW4lS wkBhGi8kNV4snXg40rcc8W5NvwzpUpiP6lycbOwk

Solar DC Circuit Breaker	2	1200	https://www.daraz.com.bd/products/2p-63adc400v-mcb-solar-energy-photovoltaic-pvsolar-dc-circuit-breaker-i142942665.html
Battery backup	3	20,000	https://www.daraz.com.bd/products/rahimaf rooz-tall-tubular-ips-battery-rtb-200i170320534.html
Series motor	3	32176	
DC Water Pump for Irrigation 3HP	3	16088	
Soil moisture Sensor	10	1650	https://techshopbd.com/detail/3712/Soil_Mo isture_Sensor_Module_techshop_banglades h
LM35 Temperature Sensor Waterproof	10	3200	https://store.roboticsbd.com/sensors/1179lm35-temperature-sensor-waterproofrobotics-bangladesh.html
Water Level Sensor Depth of Detection (Water Sensor RBD683)	10	2500	https://store.roboticsbd.com/sensors/683water-level-sensor-depth-of-detectionwater-sensor-for-arduinoroboticsbangladesh.html
Humidity Sensor DHT11	10	1800	https://store.roboticsbd.com/sensors/667dht11-temperature-and-relative-humiditysensor-module-for-arduino-roboticsbangladesh.html
Digital pH Sensor module	5	11500	https://www.daraz.com.bd/products/1setliquid-ph-0-14-value-detection-regulatorsensor-module-control-meter-tester-bnc-phelectrode-probe-for-arduinoi160924919.html
Arduino Uno ATmega328P-b bit	2	1300	https://store.roboticsbd.com/arduinobangladesh/94-8-arduino-unobangladesh.html
Relay Module	1	90	https://store.roboticsbd.com/roboticsparts/702-1-channel-5v-relay-board-modulerobotics-bangladesh.html
Total in BDT = 321504			

Table 9: Required budget of design 2

Payback Analysis:

We have shown the yearly total amount of irrigated land by the project and total cash inflow of the project in previous design. Now we have calculated the payback period as follows:

$$Simple\ payback\ period = (Initial\ Investment)/(Yearly\ Cash\ inflow)\ )$$
$$= (321504(BDT))/(29\ 760(BDT)) = 10\ years \text{ 8 months}$$

Disadvantages:

Even If this system has the storage system to run at night time,

1. The system is complex to implement
2. 12v DC pump has low efficiency
3. DC 3HP pump are highly efficient but unavailable in Bangladesh
4. The system requires high maintenance

2.4.3 Analysis of Design 3: Stand-alone Agri-voltaic System with Inverter

Load Analysis:

To sum up all the loads that are going to draw power, it can be narrowed down to microcontrollers and sensors, and the water pump, The water pump used, AC. Agm.6B (surface pump), needs a power of 1.5kW. All the sensors and microcontroller can be assumed to use 5W.

Battery Capacity:

Daytime load (10 hrs.):
Wh (day) = 1500×3+ 5×10 = 1550Wh Night
time load (14 hrs.):
Wh(night) = 5×14= 70Wh

Peak Load= 1500+ 50 = 1550
Maximum current may be drawn = 6.8+0.2= 7A
So,
Voltage (Battery) = 12 V
DoD= 0.8 (80%)
Battery Efficiency = 0.7 (70%)

Wh (load) = Wh(peak) ÷ Efficiency = 2215 Wh

Battery Ah needed = 72÷ (0.8×12) = 190 Ah

Average Current drawn = (6.8+0.2) ÷2 = 3.5A

Therefore, we need to select a battery that can provide 200 Ah.

Thus, we have chosen, SAIF POWER IPS SPECIAL BATTERY 200AH 12V

Approximation of array size

Daytime load (10 hrs.):

Wh (day) = 1500×3+ 5×10 = 1550Wh Nighttime load (14 hrs.):

Wh(night) = 5×14= 70Wh

PV Wh needed = Wh (day) + (Wh(night)/ Battery Efficiency) + ((Wh (day)+Wh(night))/ Battery Efficiency) x0.5

= 2678 Wh

Array peak watt, Pm > Wh (PV)/ Daily solar radiation at Netrokona

= 2678 ÷ 4.64

= 578 W

So, number of panels needed = 4

We are using a monocrystalline PV cell, which has an efficiency of 16%. So, area of PV cells needed = 1633 ÷ (0.16 × 1000) = 10 square meters.

Solar Panels

LOOM SOLAR

Maximum power (pmax)	190 Wp
Maximum power voltage (Vmp)	20 V
Maximum power current (Imp)	9.50 A
Short circuit current (Isc)	9.80 A
Open circuit voltage (Voc)	25 V
Maximum system voltage	1000 V

Specifications are at STC:
1000w/m² irradiance AM 1.5. Cell Temp 25°C

LOOM SOLAR

Maximum power (pmax)	440 Wp
Maximum power voltage (Vmp)	42 V
Maximum power current (Imp)	10.5 A
Short circuit current (Isc)	11 A
Open circuit voltage (Voc)	45 V
Maximum system voltage	1500 V

Specifications are at STC:
1000w/m² irradiance AM 1.5. Cell Temp 25°C

Fig 15: Loom solar configurations

Parameters:

Name	Specification	Quantity
PV Cells	Mono Crystalline 4 panels of Dimensions-1.5x0.665x0.035 m, Mass-11kg 1 panel Dimensions-2.063x1.026x0.035 m, Mass-24kg	10 + 1 = 11 panels
Battery backup	Lead–acid batteries Tubular batteries 200Ah	1
Inverter	Sine Wave Inverter Capacity 2.5 KVA, Rated Power 2100 W Supports three batteries	1
Water Pump for Irrigation THF-6A(ECO)	2.24kW (3hp) Max flow rate $42m^3/h$ (100m depth)	1
Soil moisture Sensor	YL-69 Soil Hydrometer Module / Soil Moisture Sensor	10
Humidity Sensor	DHT11	10
Temperature Sensor	LM35	10
Water Level Sensor	Liquid Level Sensor for Arduino (5) / 52mm pp liquid water level sensor (6)	10
PH Sensor	Digital pH Sensor module	5
Arduino Uno	ATmega328P-b bit	2
LCD Module	2x16 LCD display and 6 momentary push buttons	1
Relay Module	5V 1-Channel Relay interface board	1
Bore hole	Shallow 6 Inch pipe, 120 feet depth	
Static water level	30 feet	
Suction Pipe Size & Delivery Pipe	1.5’’,2’’&3’’	
Total Water Lifting	1.2 -1.72 million / day	

Table 10: parameters and required quantity of design 3

Economic Analysis:

Name	Quantity	Total Approximate Price (BDT)	Source
Mounting Structure & Setup cost	-	1,20,000	Local Solar System Solution
PV Cells	11 Panels	1,10,000	https://www.loomsolar.com/collections/solarpanels/products/loom-solar-panel-190-wattmono-crystalline https://www.loomsolar.com/products/loomsolar-panel-shark-super-high-efficiency-module?fbclid=IwAR2HvckYDKZzaFW4lS wkBhGi8kNV4snXg40rcc8W5NvwzpUpiP6lycbOwk
Solar DC Circuit Breaker	2	1200	https://www.daraz.com.bd/products/2p-63adc400v-mcb-solar-energy-photovoltaic-pvsolar-dc-circuit-breaker-i142942665.html
Battery backup	1	20,000	https://www.daraz.com.bd/products/rahimafro oz-tall-tubular-ips-battery-rtb-200i170320534.html
Water Pump for Irrigation 3HP	1	12,000	https://esmart.com.bd/product/gazi-ecoirrigation-water-pump/
Inverter 2.2kVA	1	35,000	https://www.youtube.com/watch?v=IHO5SO FoZkE https://www.luminousindia.com/cruze-2-5kva.html
AC Surge Protection Device	1	3,200	https://new.abb.com/lowvoltage/products/system-pro-m/surgeprotective-devices-ovr/spd-class-3
Soil moisture Sensor	10	1650	https://techshopbd.com/detail/3712/Soil_Mois ture_Sensor_Module_techshop_bangladesh

LM35 Temperature Sensor Waterproof	10	3200	https://store.roboticsbd.com/sensors/1179lm35-temperature-sensor-waterproofrobotics-bangladesh.html
Water Level Sensor Depth of Detection (Water Sensor RBD683)	10	2500	https://store.roboticsbd.com/sensors/683water-level-sensor-depth-of-detection-watersensor-for-arduinoroboticsbangladesh.html
Humidity Sensor DHT11	10	1800	https://store.roboticsbd.com/sensors/667dht11-temperature-and-relative-humiditysensor-module-for-arduino-roboticsbangladesh.html
Digital pH Sensor module	5	11500	https://www.daraz.com.bd/products/1setliquid-ph-0-14-value-detection-regulatorsensor-module-control-meter-tester-bnc-phelectrode-probe-for-arduino-i160924919.html
Arduino Uno ATmega328P-b bit	2	1300	https://store.roboticsbd.com/arduinobangladesh/94-8-arduino-unobangladesh.html
Relay Module	1	90	https://store.roboticsbd.com/roboticsparts/702-1-channel-5v-relay-board-modulerobotics-bangladesh.html
Total in USD = 3800			
Total in BDT = 3,24,000			

Table 11: Required budget of design 3

Payback Analysis:

IDCOL (Infrastructure Development Company) Bangladesh and donor agencies give 40% of total cost as grant to encourage solar irrigation. So, setting up a solar irrigation system would cost less than the costing shown here for this project. Table above shows the related cost for the set up in BDT and the total amount is 3, 24,000 BDT. To calculate a simple payback period, we need to know the cost of irrigation per area of land to calculate yearly cash inflow of the project. From an above Table, we have taken the average cost of irrigation per hectare of land. In Table, we have shown the yearly total amount of irrigated land by the project and total cash inflow of the project. Now we have calculated the payback period as follows:

$$Simple\ payback\ period = (Initial\ Investment)/(Yearly\ Cash\ inflow)\ )$$
$$= (324000(BDT)/(29\ 760(BD0T = 11\ years$$

Advantages/Disadvantages:

Advantages	**Disadvantages**
• readily available • cost approx. 12000 BDT • pump 10-58 liter of water per min • Operate at 180 – 220V(ac) • 1-2 years warranty • Run 5-6 years • reliability • farmers can install and do the maintenance • safety	• efficiency losses • System will not recover from low battery if there is no backup generator • Potential clock and timer issues

Table 12: Advantages and disadvantages of design 3.

2.5 Conclusion

The different analysis of each design helped us to determine which design is more optimal, user friendly and co related with our aim. Since, we know which design is the most efficient to work on using smart photovoltaic systems for irrigation.

Chapter 3: Use of Modern Engineering and IT Tool

3.1 Introduction:

As a technique for improving or investigating process performance, simulation modeling and analysis is becoming increasingly popular. In today's world, simulation has a wide range of applications, including health care, computer and communication systems, manufacturing and material handling systems, the automobile industry, logistics and transportation systems, service systems, military operations, and scheduling. Because simulation is a key tool for modeling and analysis, progress is being made in this subject. Simulation has become one of the most extensively utilized and recognized methods in system analysis and operation research due to recent breakthroughs in simulation methodologies, software availability, and technical developments. As a result, there is an ever-increasing number of simulation software solutions on the market. Because software is getting more affordable and contains easy-to-learn languages, simulation has expanded its scope. As a result, specific simulation software for a certain task is available on the market.[15] If one is designing a stand-alone PV system in the field of solar energy, there will be different simulation software for matching activities based on the needs of the users. (Lalwani and Kothari)

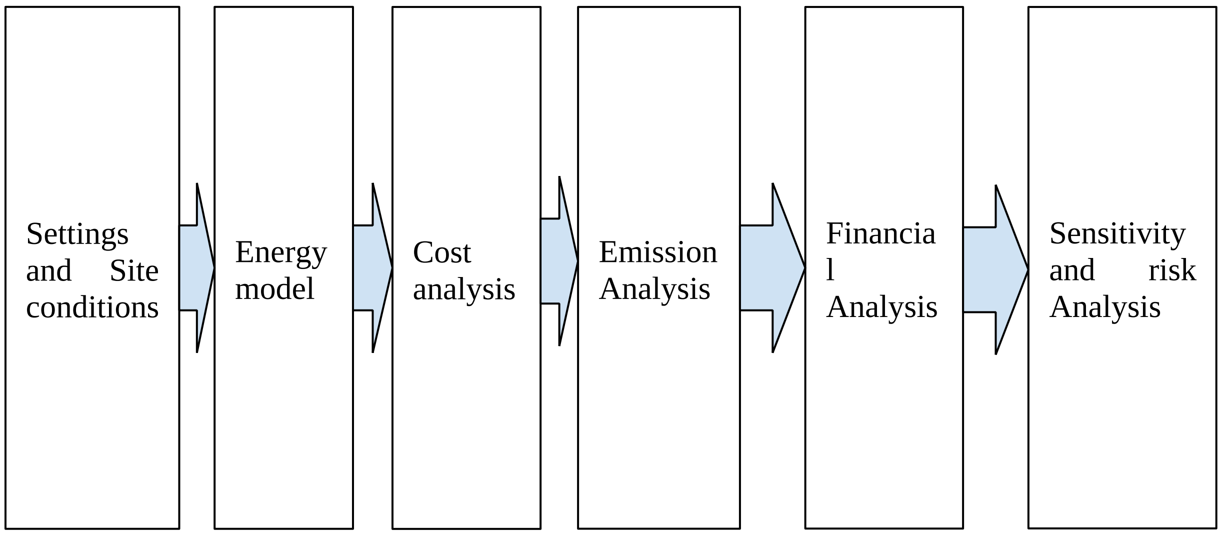
Table 13: Major Software's for PV Simulation in the world market

Software Name	**Manufacturer/Developing Institution**	**Cost/ License**	**Website**
RET Screen	Natural Resources Canada	Free of Charge	www.retscreen.net
HOMER	National Renewable Energy Laboratory, USA	Free of Charge	www.nrel.gov/homer
NREL Solar Advisor Model (SAM)	National Renewable Energy Laboratory, Washington	Free	https://www.nrel.gov/a analysis/Sam/background d.html

PVsyst	Institute Environmental Sciences (ISE), University of Geneva, Switzerland	900 CHF for one machine license; 150 CHF for additional machines	http://www.pvsyst.com
ESP-r 11.5	University of Strathclyde, Scotland	Free	http://www.esru.strath. ac.uk/Programs/ESP- r.htm

RET Screen is the outcome of a collaboration between members of the Canadian government, industry, and academics. It's a decision-making aid. The software is used to evaluate energy production and savings, prices, pollution reductions, financial viability, and risk for a variety of renewable and energy-efficient technologies (RETs). Engineers, architects, and financial planners can use it to simulate and analyze any sustainable energy project. That is why RET Screen is the best product in its category. For decision-makers, it includes a five-step standard study that includes energy analysis, cost analysis, emission analysis, financial analysis, and sensitivity/risk analysis. As a result, we've chosen to use it to compare our three primary designs. Fig16

Fig 16: RET Screen platform for renewable project analysis



3.2 Select appropriate engineering and IT tools

The main available software to perform quantitative and qualitative analysis is HOMER and RET Screen. HOMER (Hybrid Optimization Model for Electric Renewables) is a computer based micro power system optimization model which allows the user to simulate, optimize and also has the ability to do sensitivity analysis on a system consisting of multiple energy sources like wind, PV, diesel generator, battery bank etc. and various loads like AC, DC and thermal loads along with converters and the grid. It is generally used for the design and analysis of hybrid power systems. Since HOMER software was only available for a trial period of 1 week so we decided to use RET Screen for analysis.

RET Screen software is used to determine if a renewable energy project makes financial sense with an analysis capable of covering an entire project life cycle. It has three major analysis tools include Benchmark analysis, Feasibility analysis, and Performance analysis

1. Technical Analysis:

In financial languages, technical analysis is a security analysis procedure of 106 noticing the modifications in previous prices with the aim of predicting upcoming price and volume. However, in engineering standings, technical analysis deals with parameters of the product upon which the efficiency and efficient application depends. For standalone PV system's technical analysis, number of PV units needed for achieving 100% power capacity and resultant total power carried to load are examined

2. Economic Analysis:

Economics deals with manufacture of goods, their delivery and customer's reaction. Economics of a certain project can be evaluated on the foundation of economic factors like NPV, IRR, equity and simple payback periods.

3. Emissions Analysis:

GHG emissions are a key drive of global warming that is initiating severe health problems and even deaths of thousands of thousands of individuals consistently. Main source behind GHG emissions is inadequate ignition of high carbon content fossil fuels. That is the reason the entire world is searching for clean and environment friendly energy sources and in this point of view numerous etiquettes have also been set to control emissions. The price and life-span of the apparatus are taken from the reliable sources of internet and published papers for the models and the Energy consumption calculation has been done for a basic rural need.

3.3 Use of modern engineering and IT tools

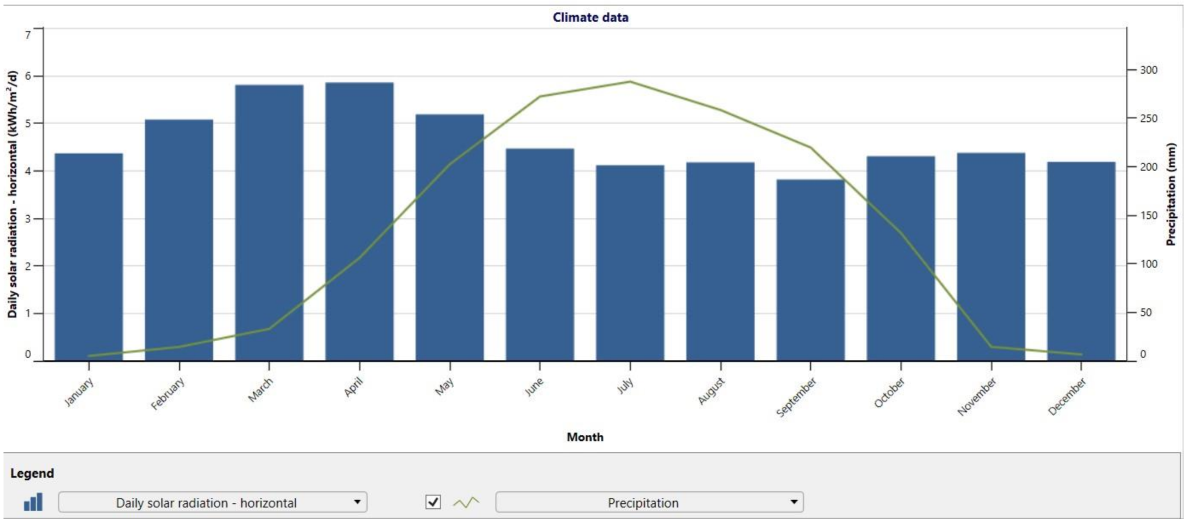
Fig 17: Climate Data:

RETScreen - Climate database

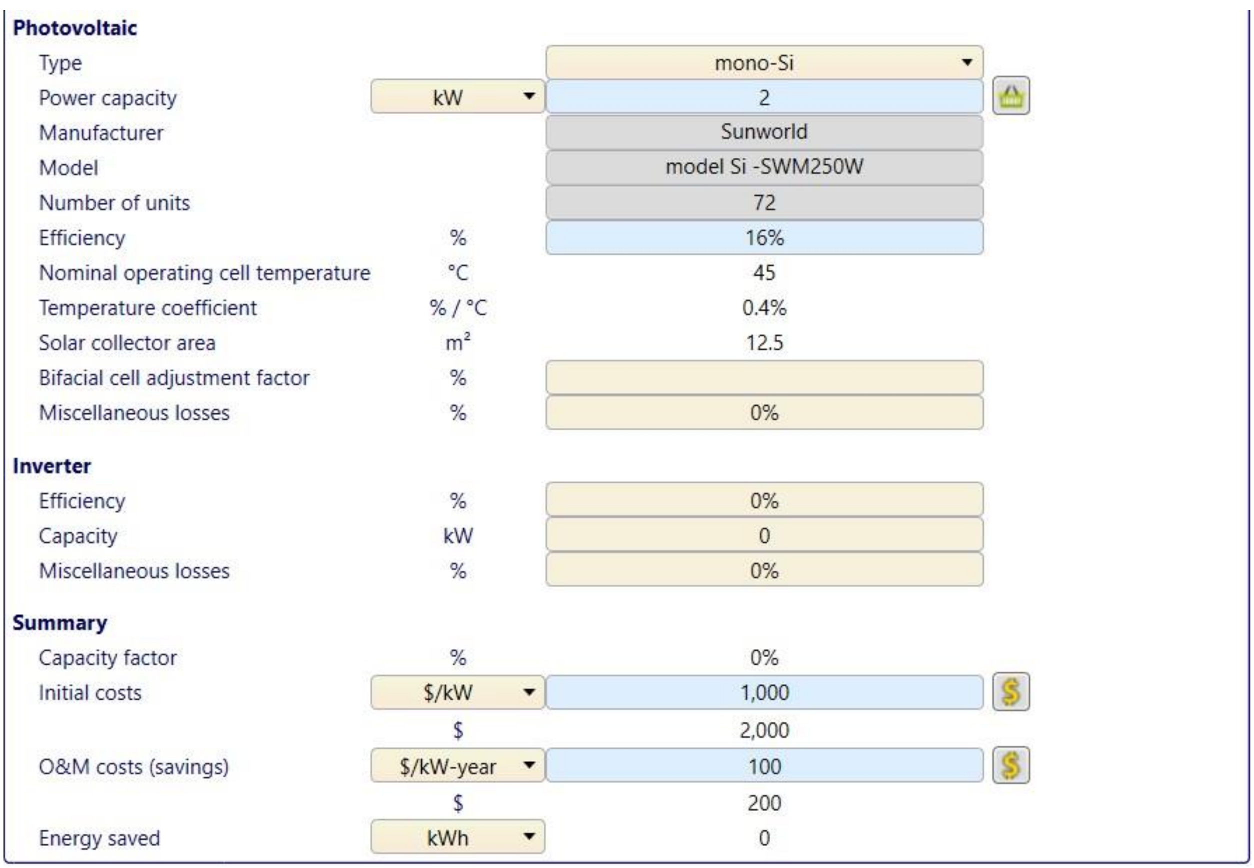
Map
Search
Data

Country			Bangladesh	
Province/State				
Climate data location	See map		Maimansingh	
Latitude		°N	24.8	
Longitude		°E	90.4	**Source**
Climate zone		1A	Very hot - Humid	NASA
Elevation		m	27.2	NASA
Heating design temperature		°C	13.7	NASA
Cooling design temperature		°C	31.4	NASA
Earth temperature amplitude		°C	14.1	NASA

Month	Air temperature	Relative humidity	Precipitation	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days 18 °C	Cooling degree-days 10 °C
	°C	%	mm	kWh/m²/d	kPa	m/s	°C	°C-d	°C-d
January	17.8	52.5%	5.27	4.37	101.2	2.1	17.3	6	242
February	21.4	41.8%	14.56	5.08	101.0	2.4	21.2	0	319
March	26.5	36.9%	33.17	5.81	100.6	2.7	26.8	0	512
April	30.1	48.8%	106.20	5.86	100.3	3.0	31.0	0	603
May	30.5	63.9%	202.43	5.19	100.0	3.3	31.4	0	636
June	29.6	78.5%	272.10	4.47	99.7	3.8	30.1	0	588
July	28.8	84.7%	287.37	4.12	99.7	3.8	29.0	0	583
August	28.6	84.9%	258.23	4.18	99.9	3.3	28.8	0	577
September	27.8	84.8%	219.60	3.82	100.2	2.6	27.9	0	534
October	26.1	77.8%	131.75	4.31	100.6	1.9	26.1	0	499
November	22.5	69.6%	14.70	4.38	101.0	1.9	22.2	0	375
December	18.9	63.3%	6.82	4.19	101.2	1.9	18.4	0	276
Annual	**25.7**	**65.8%**	**1,552.20**	**4.64**	**100.5**	**2.7**	**25.9**	**6**	**5,742**
Source	NASA	NASA	NASA	NASA	NASA	NASA	NASA	NASA	NASA
Measured at					m	10	0		



3.3.1 Use of RET Screen for Design 1(Directly coupled water pumping System):



Photovoltaic		
Type		mono-Si
Power capacity	kW	2
Manufacturer		Sunworld
Model		model Si -SWM250W
Number of units		72
Efficiency	%	16%
Nominal operating cell temperature	°C	45
Temperature coefficient	% / °C	0.4%
Solar collector area	m²	12.5
Bifacial cell adjustment factor	%	
Miscellaneous losses	%	0%
Inverter		
Efficiency	%	0%
Capacity	kW	0
Miscellaneous losses	%	0%
Summary		
Capacity factor	%	0%
Initial costs	$/kW	1,000
	$	2,000
O&M costs (savings)	$/kW-year	100
	$	200
Energy saved	kWh	0

Fig18: RET screen PV specification

PV Panel: Here, we have chosen photovoltaic type mono-si and no. of units of 72 W PV panel to design our 2kW photovoltaic power capacity. To get better solar radiation we have taken a slope equal to 25 degrees for summer season and azimuth equal to 0 (Recommended by Homer). Moreover, to keep our result more accurate, we have considered miscellaneous loss of inverter equal to 0.

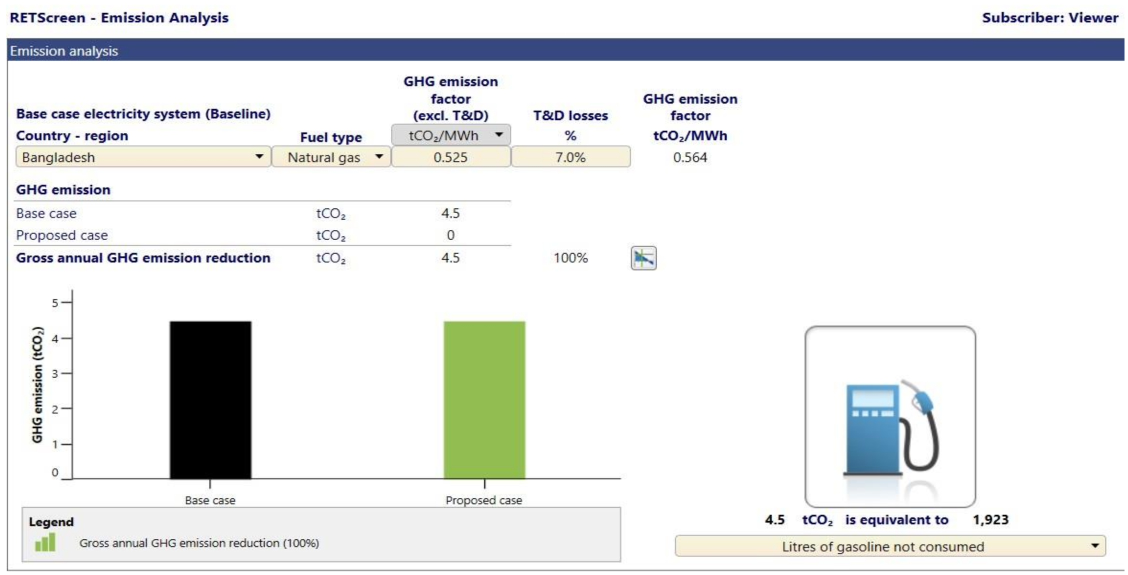


Fig 19: Emission Analysis

Initial costs (credits)	Unit	Quantity	Unit cost	Amount	
Incremental initial costs				$ 2,563	
Show data					
Motors					
Pump and Motors			$ 563		*Update cost*
Power system					
Photovoltaic			$ 2,000		*Update cost*
Boring Well	cost	1	$ 1,250	$ 1,250	
Panel Structure	cost	1	$ 500	$ 500	
Electrical Wiring and Misc Cost	cost	1	$ 625	$ 625	
Installation Charge	cost	1	$ 125	$ 125	
Total initial costs				**$ 5,063**	
Annual costs (credits)	Unit	Quantity	Unit cost	Amount	
O&M costs (savings)	project			$ 200	
Show data					
Motors					
Pump and Motors			$ 0		*Update cost*
Power system					
Photovoltaic			$ 200		*Update cost*
incremental O&M costs	cost			$ -	
	cost			$ -	
Total annual costs				**$ 200**	
Annual savings	Unit	Quantity	Unit cost	Amount	
Fuel cost - base case				$ 793	
Fuel cost	cost			$ -	
Cash Inflow from Crops	cost	1	$ 372	$ 372	
Total annual savings				**$ 1,165**	

Fig 20: Cost Analysis

Financial viability

Financial parameters

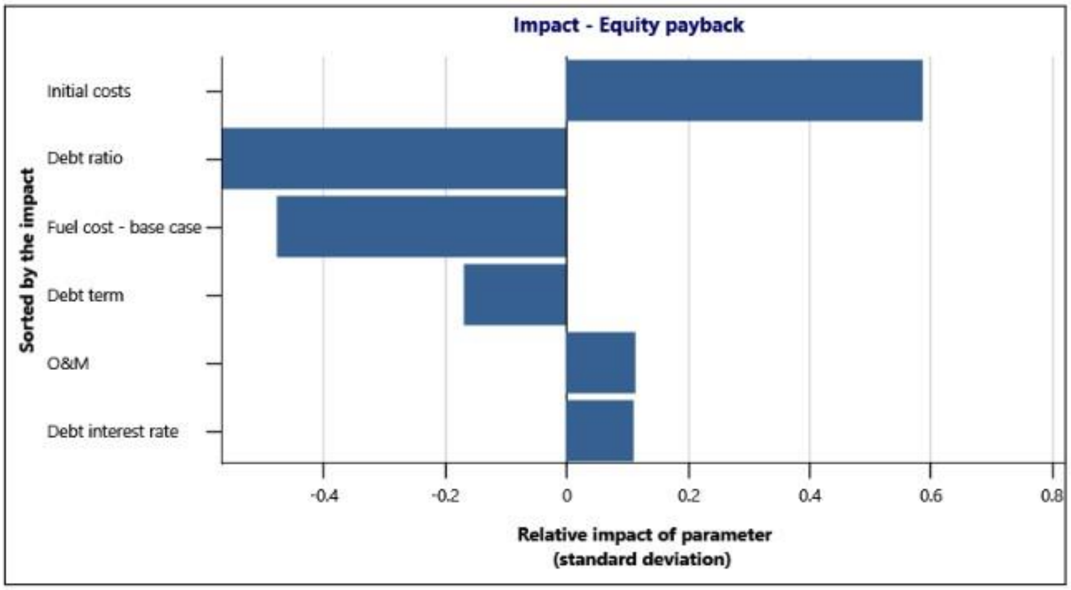
Inflation rate	%	2%
Project life	yr	20
Debt ratio	%	70%
Debt interest rate	%	7%
Debt term	yr	15

Costs | Savings | Revenue

Initial costs			
Incremental initial costs	50.6%	$	2,563
Boring Well	24.7%	$	1,250
Panel Structure	9.9%	$	500
Electrical Wiring and Misc Cost	12.3%	$	625
Installation Charge	2.5%	$	125
Total initial costs	**100%**	**$**	**5,063**
Yearly cash flows - Year 1			
Annual costs and debt payments			
O&M costs (savings)		$	200
Debt payments - 15 yrs		$	389
Total annual costs		**$**	**589**
Annual savings and revenue			
Fuel cost - base case		$	793
Cash Inflow from Crops		$	372
GHG reduction revenue		$	0
Other revenue (cost)		$	0
Total annual savings and revenue		**$**	**1,165**
Net yearly cash flow - Year 1		**$**	**576**

Fig 21: Cost and financial Viability

Impact



Distribution

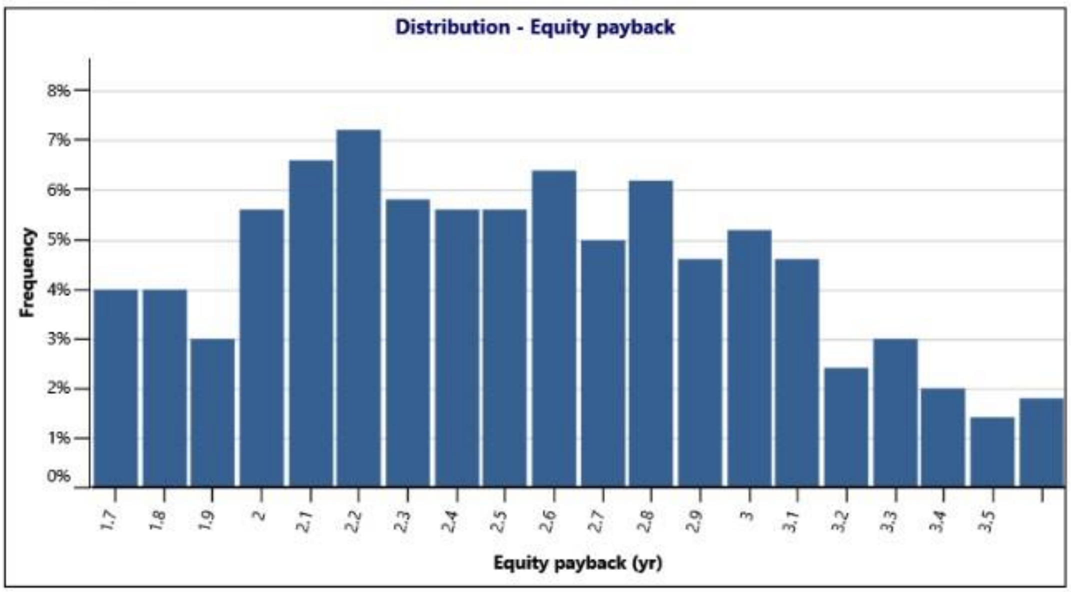


Fig 22: Risk and Impact analysis

3.3.2 Use of RET Screen for Design 2(Agri voltaic system with Power storage Capacity):

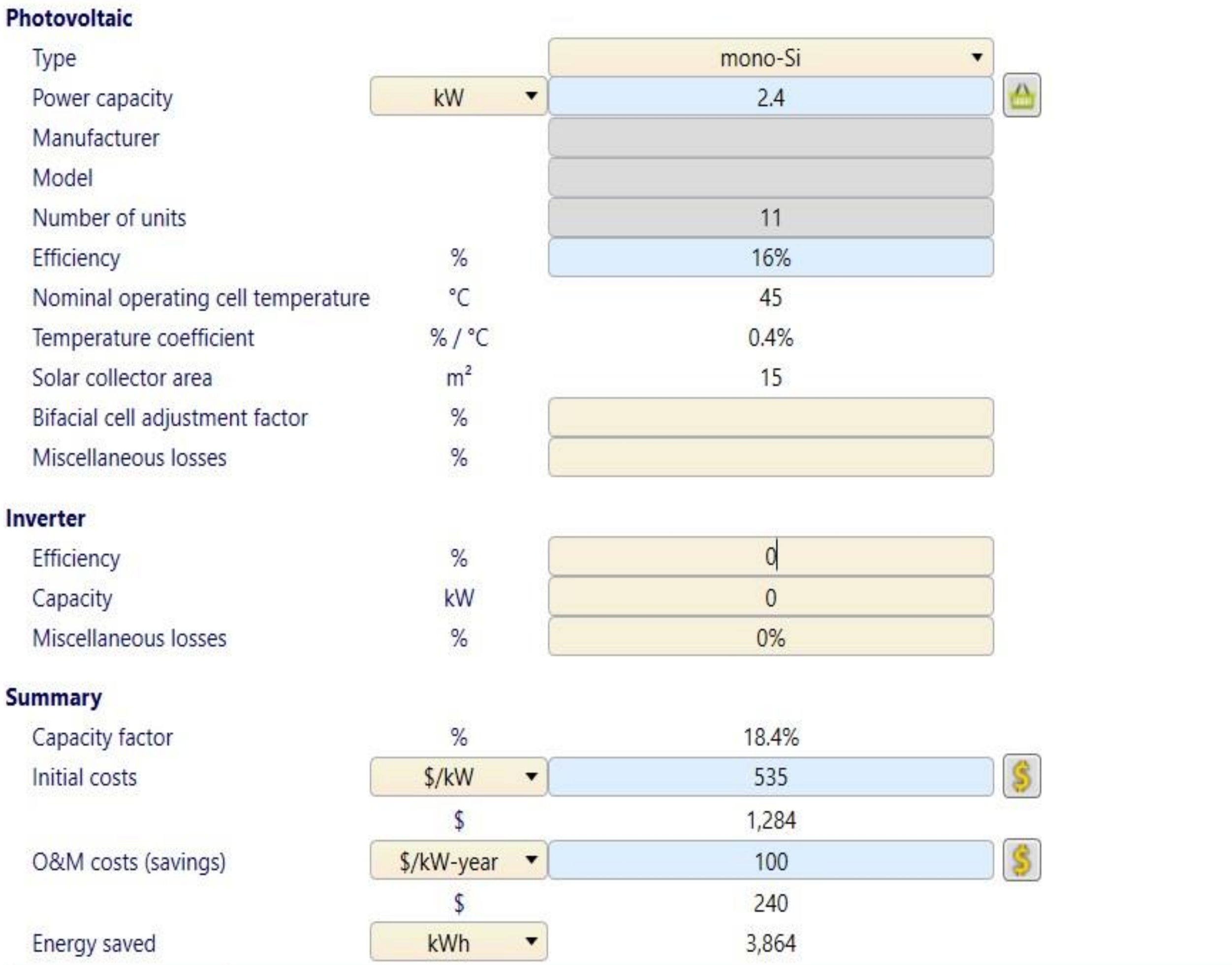


Fig 23: RET screen PV specification

Financial viability

Financial parameters

General		
Fuel cost escalation rate	%	2%
Inflation rate	%	2%
Discount rate	%	9%
Reinvestment rate	%	9%
Project life	yr	20
Finance		
Debt ratio	%	70%
Debt	$	2,910
Equity	$	1,247
Debt interest rate	%	7%
Debt term	yr	15
Debt payments	$/yr	319

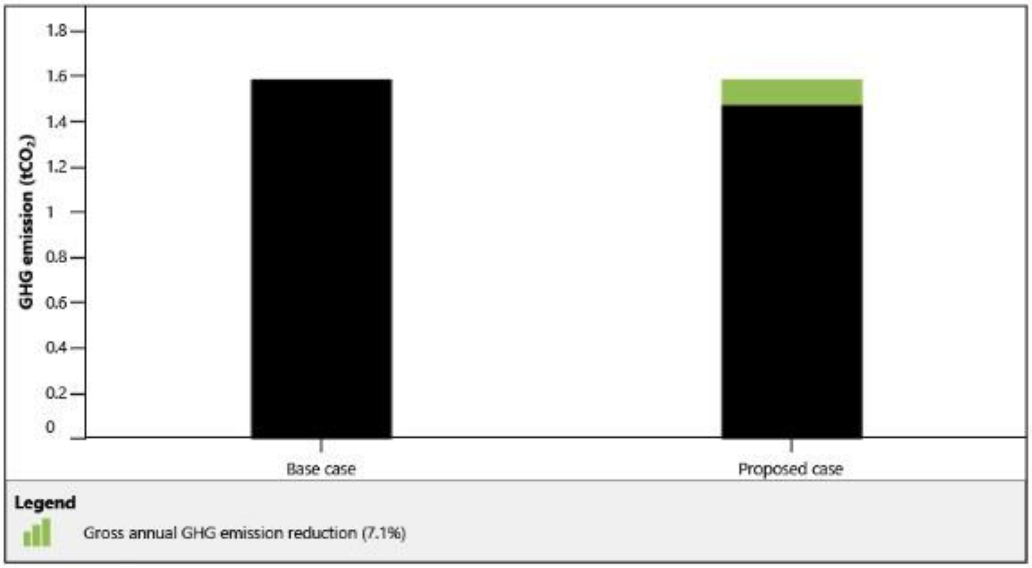
Costs | Savings | Revenue

Initial costs			
Incremental initial costs	100%	$	4,157
Total initial costs	**100%**	**$**	**4,157**
Yearly cash flows - Year 1			
Annual costs and debt payments			
Fuel cost - proposed case		$	262
O&M costs (savings)		$	140
Debt payments - 15 yrs		$	319
Total annual costs		**$**	**722**
Annual savings and revenue			
Fuel cost - base case		$	282
Cash inflow from crops		$	372
GHG reduction revenue		$	0
Other revenue (cost)		$	0
Total annual savings and revenue		**$**	**654**
Net yearly cash flow - Year 1		**$**	**-68**

Fig 24: Cost and financial Viability

GHG emission

GHG emission



GHG equivalence

0.1 tCO_2 is equivalent to 48.4
Litres of gasoline not consumed

GHG emission		
Base case	1.6	tCO_2
Proposed case	1.5	tCO_2
Gross annual GHG emission reduction	**0.1**	**tCO_2**

Fig 25: Emission Analysis

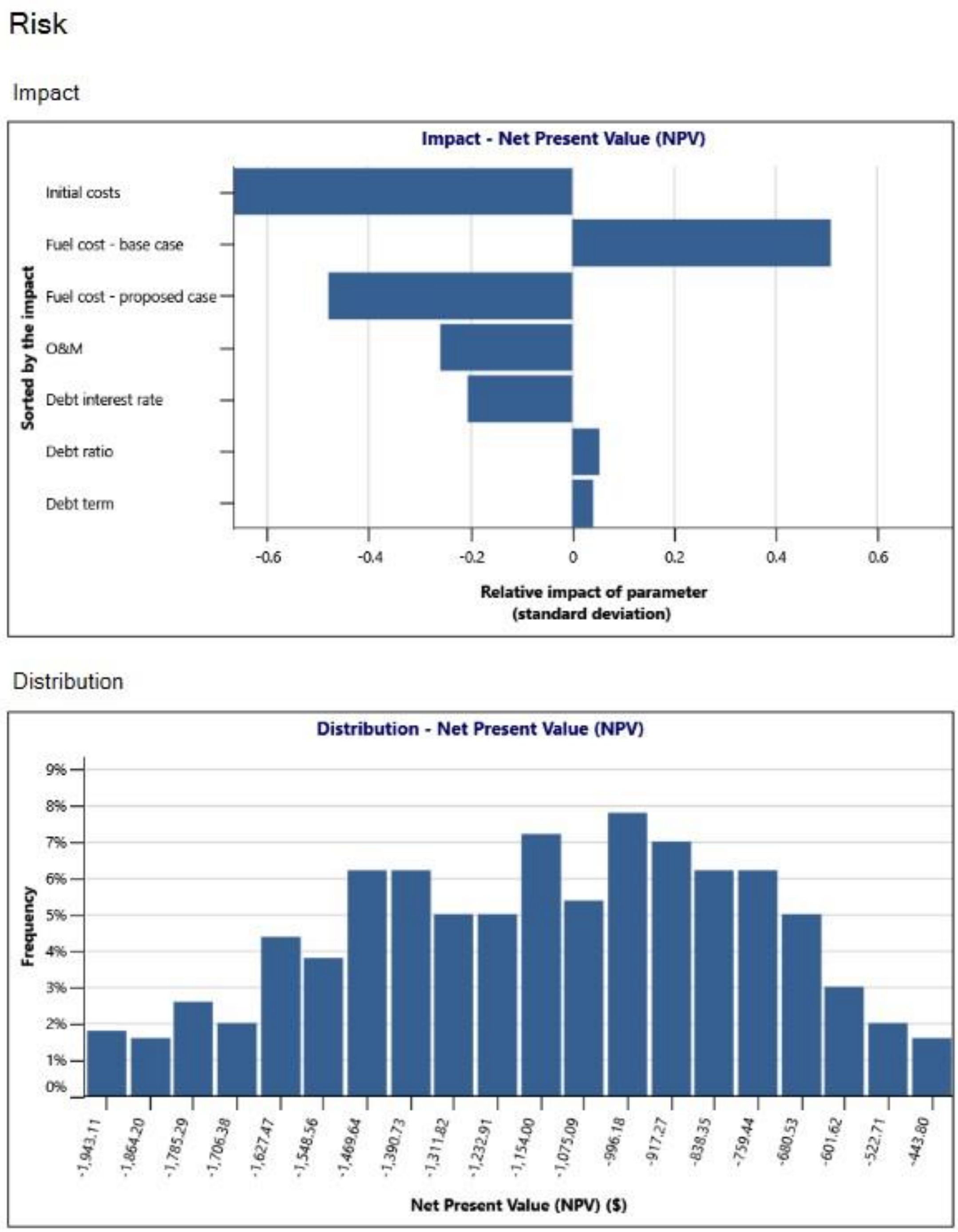
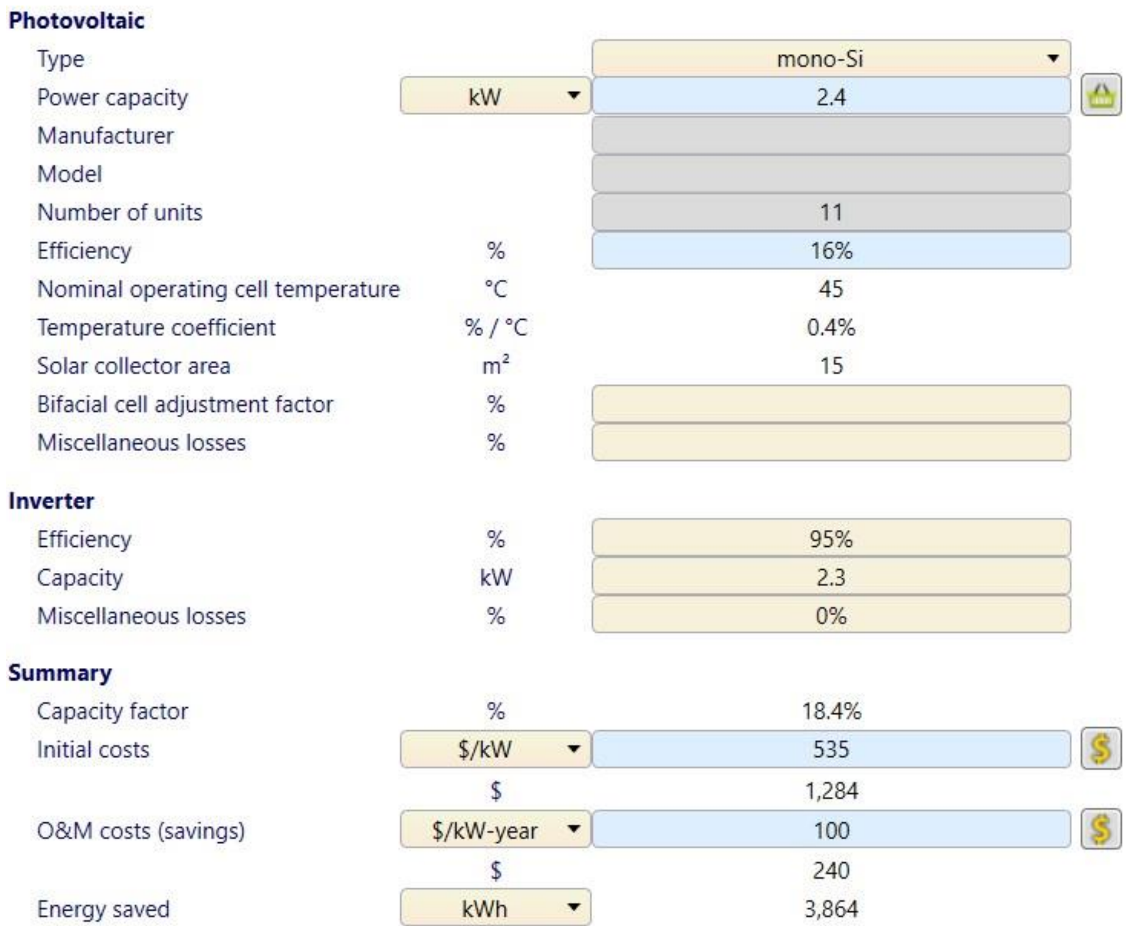


Fig 26: Risk and Impact analysis

3.3.3 Use of RET Screen for Design 3(Smart Standalone system with inverter and battery):



Photovoltaic		
Type		mono-Si
Power capacity	kW	2.4
Manufacturer		
Model		
Number of units		11
Efficiency	%	16%
Nominal operating cell temperature	°C	45
Temperature coefficient	% / °C	0.4%
Solar collector area	m^2	15
Bifacial cell adjustment factor	%	
Miscellaneous losses	%	
Inverter		
Efficiency	%	95%
Capacity	kW	2.3
Miscellaneous losses	%	0%
Summary		
Capacity factor	%	18.4%
Initial costs	$/kW	535
	$	1,284
O&M costs (savings)	$/kW-year	100
	$	240
Energy saved	kWh	3,864

Fig 27: RET screen PV specification

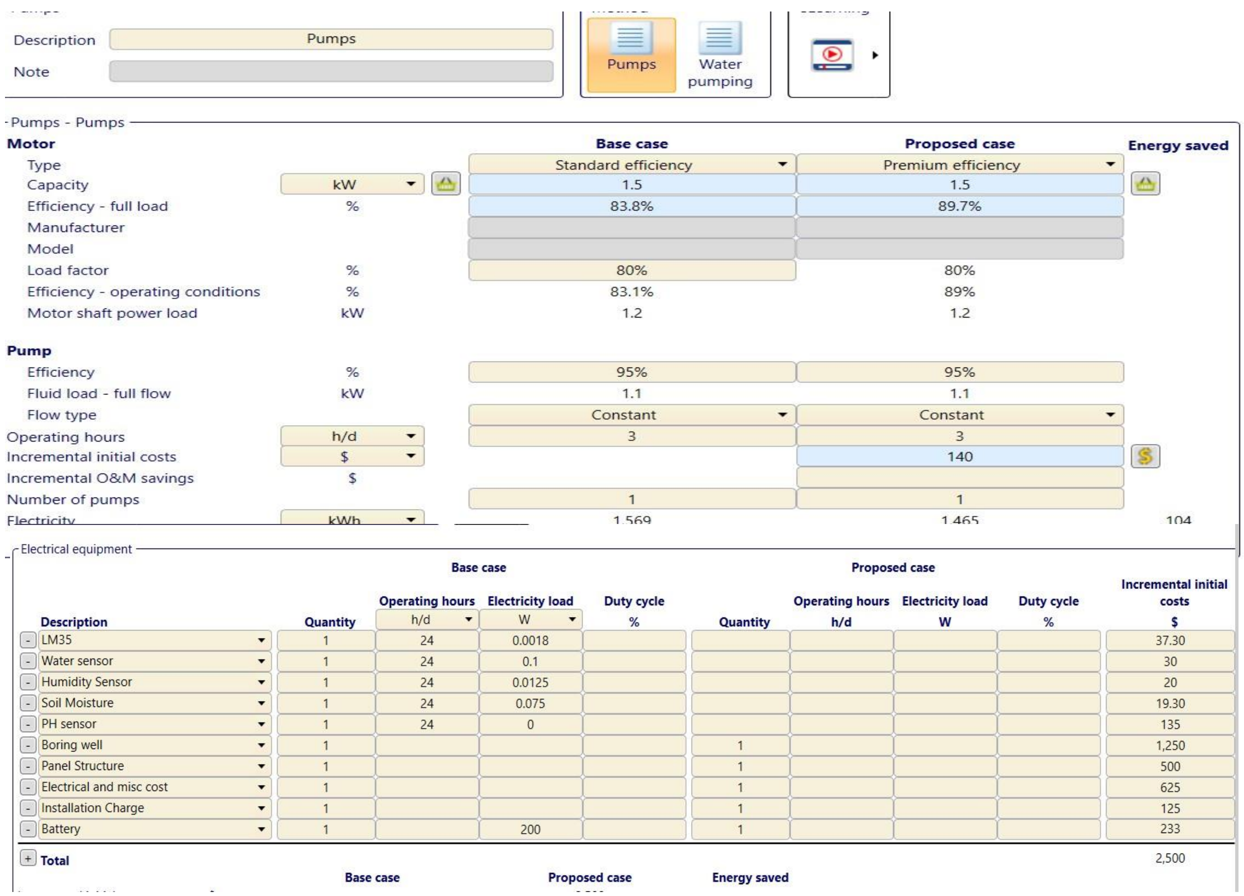


Fig 28: Cost Analysis

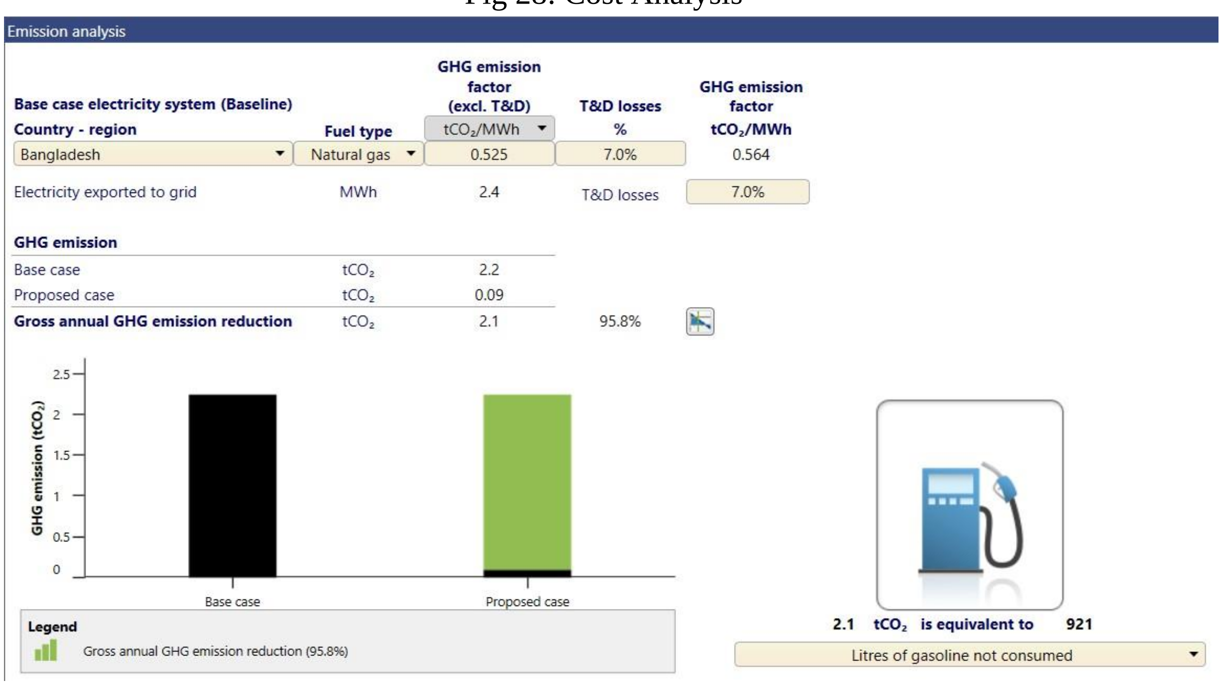


Fig 29: Emission analysis

Financial viability

Financial parameters

General		
Fuel cost escalation rate	%	2%
Inflation rate	%	2%
Discount rate	%	9%
Reinvestment rate	%	9%
Project life	yr	20
Finance		
Debt ratio	%	70%
Debt	$	2,910
Equity	$	1,247
Debt interest rate	%	7%
Debt term	yr	15
Debt payments	$/yr	319

Costs | Savings | Revenue

Initial costs			
Incremental initial costs	100%	$	4,157
Total initial costs	**100%**	**$**	**4,157**
Yearly cash flows - Year 1			
Annual costs and debt payments			
Fuel cost - proposed case		$	-239
O&M costs (savings)		$	140
Debt payments - 15 yrs		$	319
Total annual costs		**$**	**220**
Annual savings and revenue			
Fuel cost - base case		$	158
Cash inflow from crops		$	372
GHG reduction revenue		$	0
Other revenue (cost)		$	0
CE production revenue		$	0
Total annual savings and revenue		**$**	**530**
Net yearly cash flow - Year 1		**$**	**309**

Fig 30: Cost and financial Viability

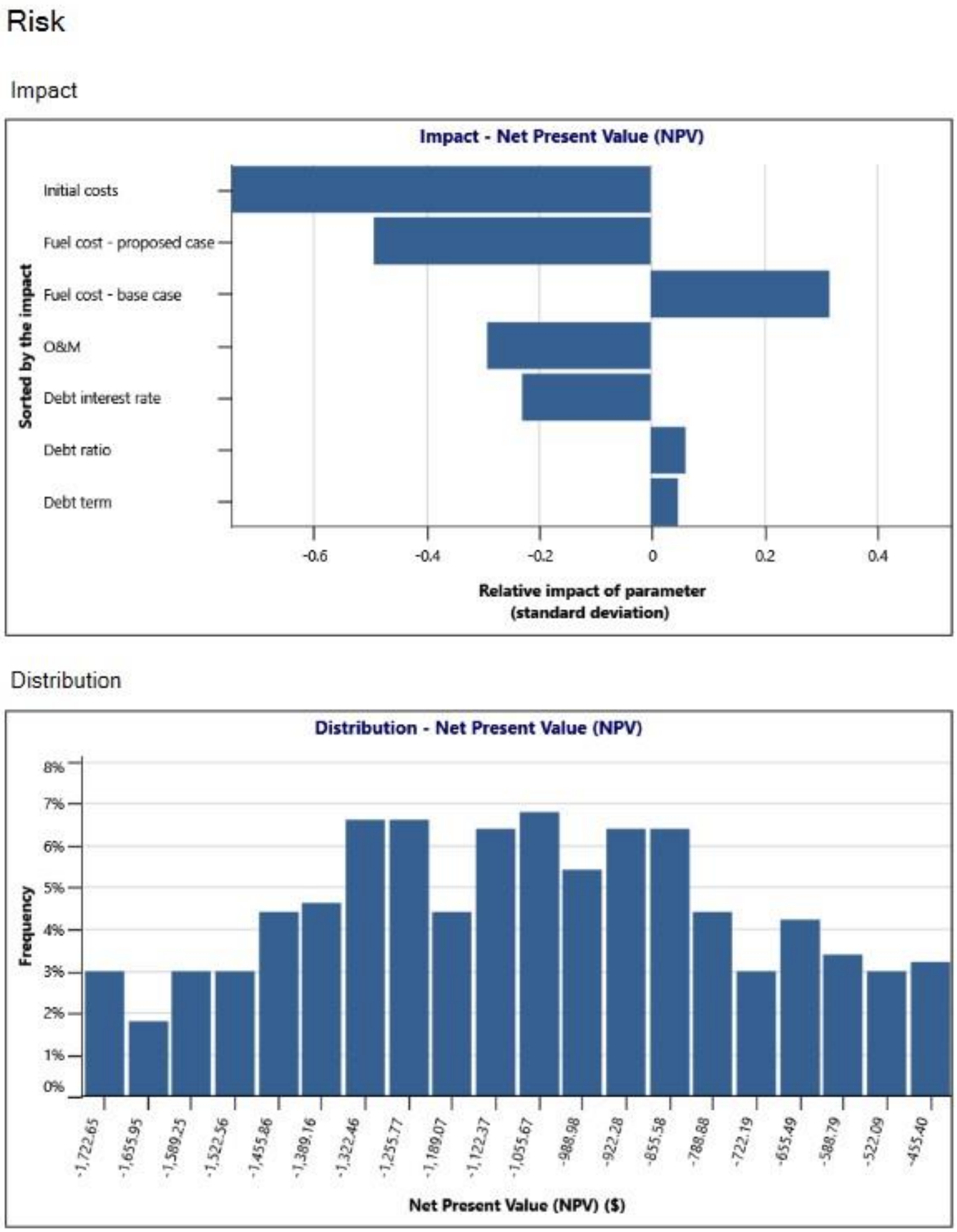


Fig 31: Risk and Impact analysis

3.4 Conclusion

Using Modern engineering and its tools basically helped us for functional verification. By using RET Screen, we determined the technical, economic and emission analysis which shows more accurate results to compare the designs and select the most efficient and optimal solution.

Chapter 4: Optimization of Multiple Design and Finding the Optimal Solution.

4.1 Introduction

After analyzing the efficiency of 3 design approaches, it shows the comparison between those design approaches. Now, analyzing the result and comparison, we need to select one design which meets our requirements very closely. The most optimal solution will be our finalized design approach.

4.2 Optimization of multiple design approach

We selected design 3 as the most optimized solution and described how design 3 meets our every requirement**.**

Water requirement fulfillment

In all three designs, we made sure that it delivers the required amount of water to the field. Although different kinds of motors are used in the designs for effectiveness, the load ratings of the water pumps are different, yet they meet the main agenda, which is to fulfill the required amount of water to the crops.

If we look at the RET screen data provided on the above, we see that from the financial viability design 1 is the most optimum, from eliminating carbon emission design 1 is the optimum even from risk and impact analysis design 1 is the most optimum. However, design 1 misses out one of the key points of our projects, which is the impact of IOT, thus not making the system standalone. Furthermore, it runs on a DC motor, which cannot be locally fixed or found easily. Nonetheless, there is no future scope to even earn from the project by supplying electricity to the power grid. Although, the initial cost of the design 3 is higher than the design 1, the sustainability and maintainability is better of the design 3, due to the use of available and known products. Therefore, the optimum design is the Design 3

Risk Analysis of the design Solutions Methodology

The poor risk-mitigating strategies has led to the prime reason for the deficiencies in overcoming the renewable energy targets. The successful mitigation of the project-associated risks is a key factor to complete the projects on time and is well within the control. An approach proposed by Rodney is to model, simulate and to evaluate project risks in term of quality, delay and cost; which aims to reproduce the behavior of the project, evaluate its performance and anticipate its probable drifts while valuing the following specifications applicable to the entire process of risk management with dynamic and multi-views which consider all aspects of the project and represent different levels in detail.

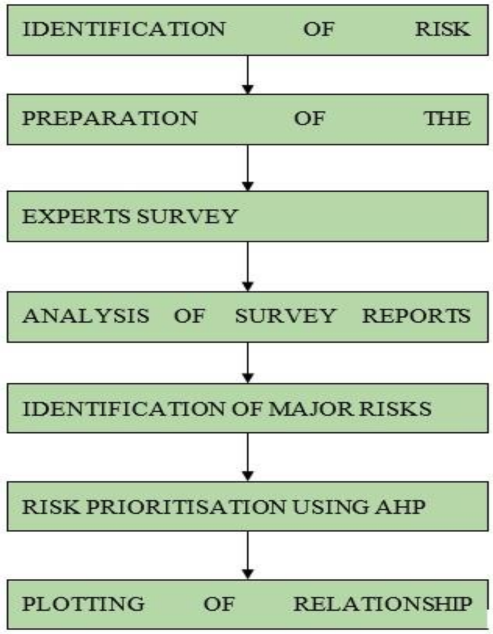


Figure.32: Methodology framework

Risks Associated with Solar projects

Classification of Risks	Risks/Barriers Description
Policy Risk	• High costs and unfavorable power pricing rules • Environmental externalities • Institutional and regulatory barriers • High rate for consumers • Frequent changes in government policy
Environment	• Forthcoming environmental legislation that may affect the project • Biodiversity protection issues • Workers Health and Safety issues
Financial and equity risk	• Difficult to fund working capital because a) banks are hesitant to lend to rural entrepreneurs

	b) banks are reluctant to approve consent raw materials as collateral ● Unpredictable rates in borrowing, lending and returns. ● Skewed financial incentives ● Inadequate funding in long –term basis ● Loss in capital is high
Technology	
Operation & Maintenance	Difficulty in finding suitable skilled and unskilled employees to work in this field
Land feasibility	● Selection of appropriate site ● Land acquisition issues
Transparency risk	Prevalent corruption in administrative, bureaucratic and business circles.

Table 13: Associated risks and description

From the above-mentioned risks, about 50 questions are formulated for identifying the risks. Survey is conducted in three stages that are
1. Before Installation 2. During Installation 3. After Installation

Questionnaire preparation

Questionnaire is prepared on the basis such that for each question ratings from 1-5 is given and for each question there are PRIORITY & IMPACT columns. PRIORITY - priority of each question towards the solar projects IMPACT - impact of each question towards the solar projects .5-5 rating means High priority & High Impact

Experts Survey

The following are the experts & selected organizations where the questionnaire-based survey is carried out.

- Solar Electro Bangladesh Ltd
- Rahimafrooz Renewable Energy Ltd.
- Evergreen Power P/L
- G-TECH SOLUTION LTD
- Akash Solar

Analysis of survey reports using risk matrix

The survey results are then analyzed using a matrix to find out the main risks specified by all the experts and then all the survey reports are merged together for Political/Policy risk, Financial Risk, Technical Risk, Environmental Risk. The Weightage is given for each question and then from this collective result, the Weightage above 40 are taken as the most important Risk for the technical risk. There are 19 questions. For each question the survey results from each expert are different, in the table for each question relevant scores given by the experts are noted and the total Weightage is calculated.

A.H.P (Analytic hierarchy process) Analytic Hierarchy Process, AHP belongs to the multicriteria decision-making methods (MCDM). In AHP, inputs like price, weight, or area, or even subjective opinions such as feelings, preferences, or satisfaction, can be translated into measurable numeric relations.

The basic steps in the formulation of a solution for decision problems with the aid of AHP are not tedious: 1. Define the decision goals 2. Hierarchy structure formulation for the decision problem regarding the categories and criteria those figures into the decision 3. Comparison of pair criteria in each category 4. Calculate the priorities and a consistency index in reference with logical comparisons and consistency 5. Evaluation of alternatives according to the identified priorities.

We couldn't perform our poll with the intended experts due to pandemic effects, but we talked it among ourselves after reviewing some papers and various sources on the internet and figured the severity, likelihood, and detectability on a scale of 1-10. The failure mode analysis for our system design 1 is shown in the table.

Failure Mode	Severity (110) S	Likelihood (1-10) L	Detectability (1-10) D	Risk Priority Number RPN = S*L*D
Unavailability of equipment, if there is any failure	4	3	6	72
Theft of equipment	2	2	8	32
Technical and Engineering Design mistakes	8	5	7	280
Worker accidents	5	7	5	175
Unexpected Instability Maintenance and Repair	6	3	4	72
Business Costs are Higher than Expected	4	8	7	224

Fire and Explosion	8	4	7	224
Fluctuation of Solar Irradiance	9	9	5	405
Damage by the Third Party	6	5	5	150
Local Peoples over reaction	4	3	3	36

Table 14: The failure mode analysis of design 1

Some of the failure events which are different for each design are compared in the Risk matrix bar chart below show below

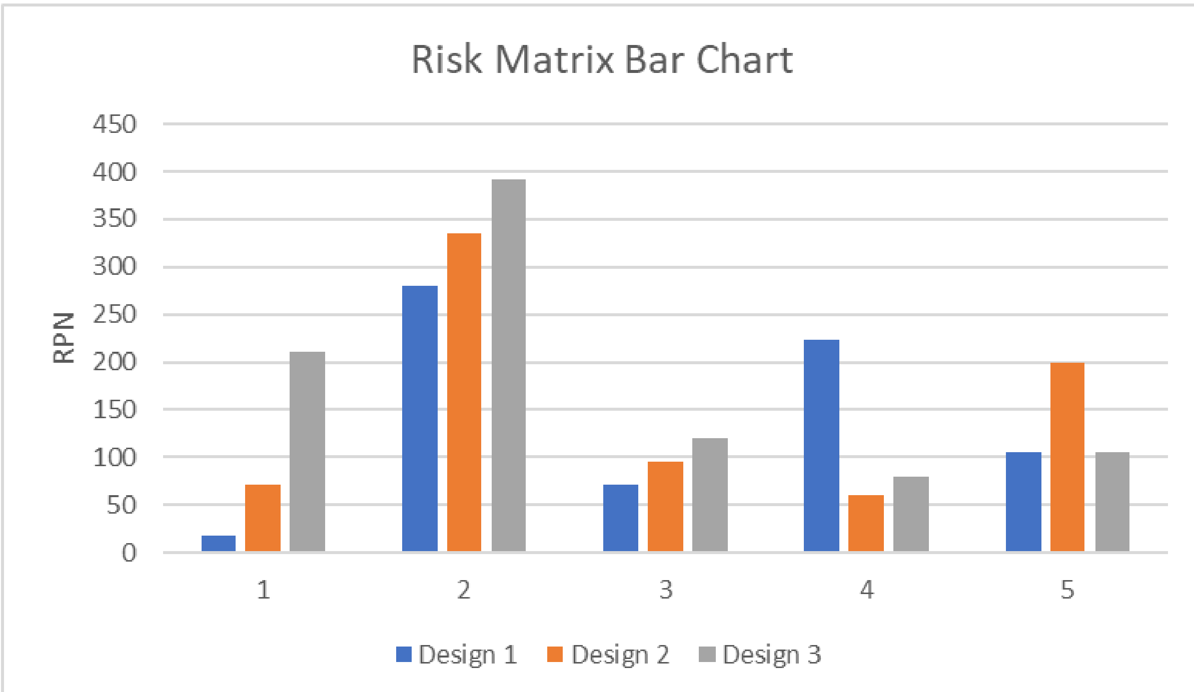


Fig 33: Risk matrix bar chart

1 Unavailability of equipment, if there is any failure
2 Technical and Engineering Design mistakes
3 Unexpected Instability Maintenance and Repair
4 Business Costs are Higher than Expected
5 Fire and Explosion

4.3 Identify optimal design approach

Designs	**Greenhouse Gas Emission [Out of 10]**	**Cost effectivity [Out of 10]**	**Usability [Out of 10]**	**Maintenance [Out of 10]**	**Availability [Out of 10]**	**Efficiency (%) [Out of 10]**
Design1: Directly coupled pump	4.5tC02	**Exceeded**	**Inconvenient**	**Simple**	**Pump not easily available**	**7.4**
	5	**7**	**7**	**10**	**8**	
Design 2: DC System with Power Storage Capacity	1.5tC02	**Satisfied**	**Convenient**	**Simple**	**Pump not easily available**	**8.6**
	7	**9**	**9**	**10**	**8**	
Design 3: Stand-alone Agri-voltaic System with Inverter	2.1tco2	**Satisfied**	**Convenient**	**Complex**	**Easily available components**	**9**
	9	**9**	**9**	**8**	**10**	

Table 15: Optimization of design approaches

After going through a staggering number of research papers and data, we could narrow down our designs for the project. But to advance, we had to decide the optimal solutions to the multiple designs. For this, we did several kinds of calculations and data analysis, via different software tools on the internet. And to our end result, taking all the factors discussed above into account we have chosen the design- A smart standalone PV system with inverter and battery. We hope to finish the project within due time and make an impact to the prosperity of the society.

Chapter 5: Completion of Final Design and Validation

5.1 Introduction

After finding the most optimized solution for the project by examining through various analyses, we finally finalized our Design for a smart Agri Voltic system for irrigation. The design needs a sensor devices and other hardware components which the described below,

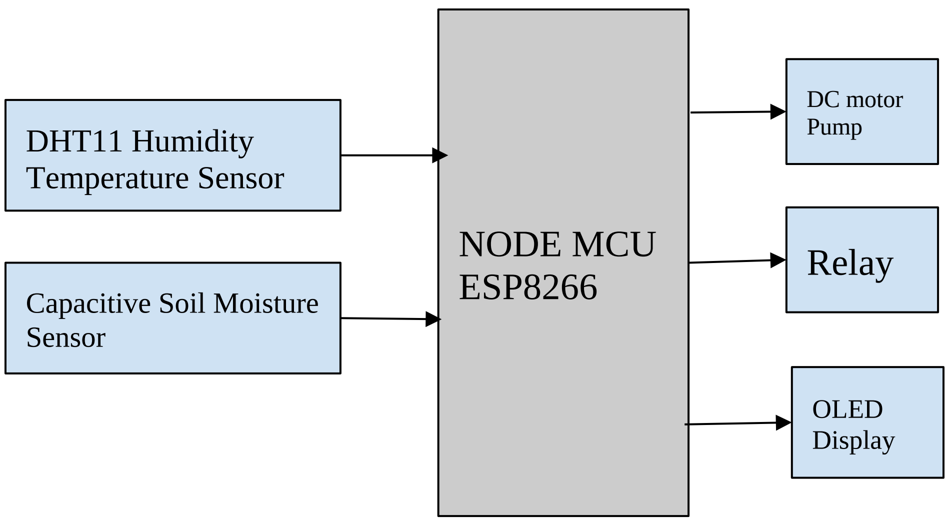


Fig 34: Block diagram

Schematic Diagram Device 1

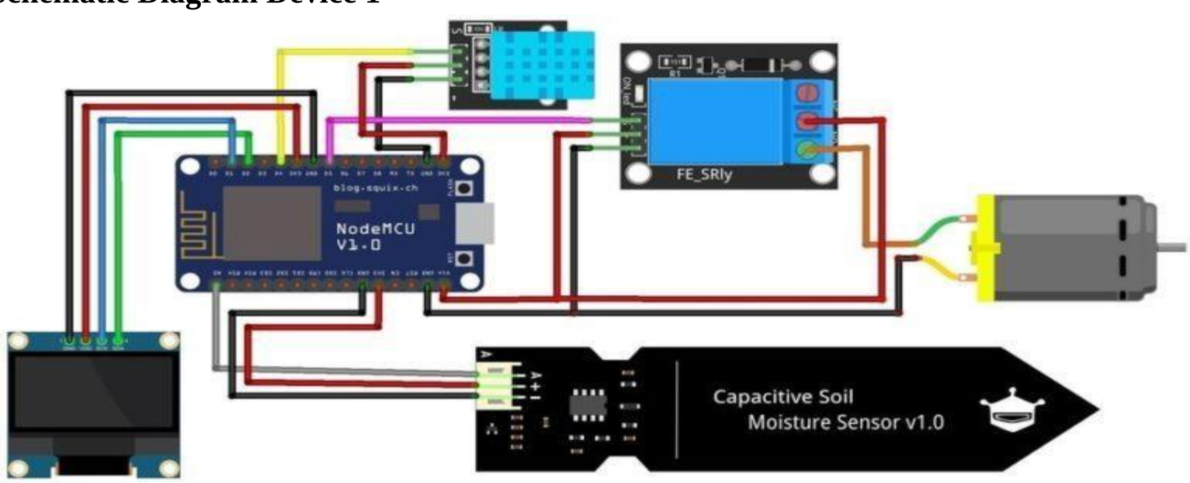


Fig 35: Schematic diagram of device 1

The major pin connections are provided beneath:

1. Soil moisture sensor DATA pin - NodeMCU ESP8266 Analog pin A0
2. DHT11 sensor DATA pin - NodeMCU ESP8266 Digital pin D3
3. Relay module- NodeMCU ESP8266 Digital pin D5
4. Water Flow sensor DATA pin - NodeMCU ESP8266 Digital pin D4

Prototype System Picture Device 1

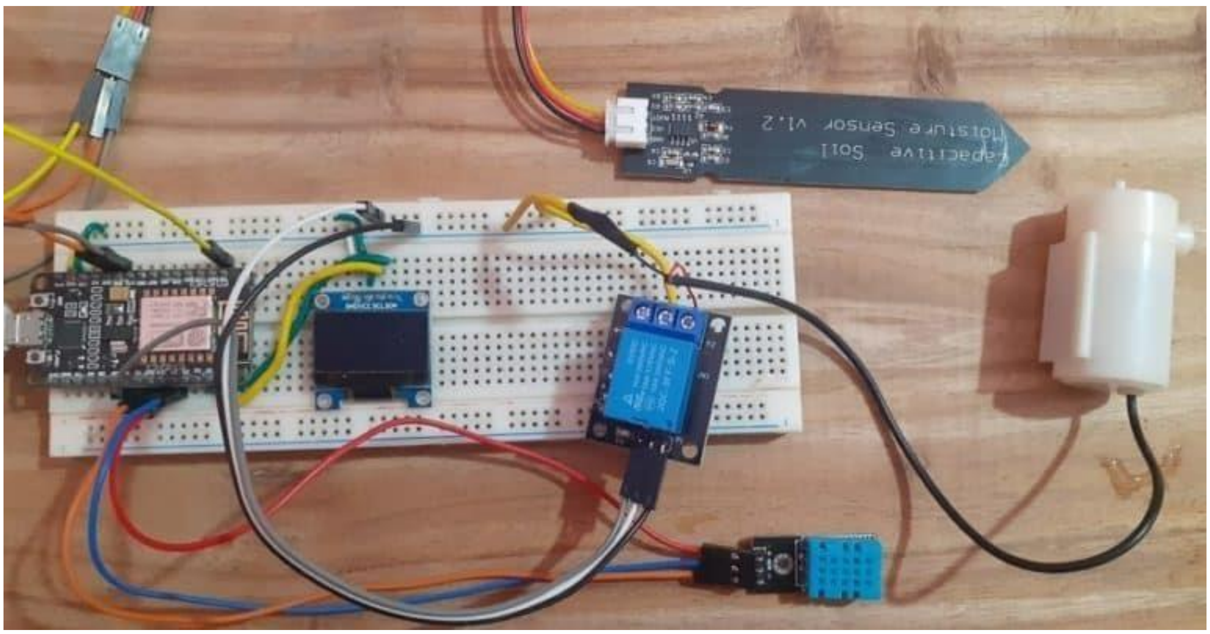


Fig 36: Prototype system setup of device 1

IoT & ThingSpeak setup

The IoT and ThingSpeak setup utilized in this project is a thorough system architecture in which all of the sensors are integrated into one. As a result, the necessity to perform the same method for each sensor is reduced. We also need to communicate this sensor data to the ThingSpeak server, which is why all of the sensors were placed on one Arduino from which it was transferred to the server.

The data is displayed on the serial monitor before being sent to the server, and this data is saved as a CSV file, which allows us to view the real-time data of the specified sensors in a tabular format. Also, we need to send this sensor data together in the ThingSpeak server, so that is why it was needed to put the sensors all under one Arduino from where it is sent to the server. This data is sent to the ThingSpeak server via Wi-Fi module ESP8266 where this data is being plotted to make a graph in every real-time and from there, we can observe the trend or the change in the data. The graphs shown are for different sensors and for each graph we needed to create a different field under a certain channel. There is an API key for the specified channel we have created for the sensor fields. This API code of the channel is copied and pasted in the code where required along with the Wi-Fi username and password. The sensors connected with the. The sensor data which we are sending to ThingSpeak are temperature and humidity The data obtained in ThingSpeak is accessible to anyone who is concerned, e.g.,

Hardware Description

NodeMCU is an open-source Lua based firmware and development board specially targeted for IoT based Applications. It includes firmware that runs on the ESP8266 Wi-Fi SoC from Espressif Systems, and hardware which is based on the ESP-12 module.

Fig 38

This soil moisture sensor module is used to detect the moisture of the soil. It measures the volumetric content of water inside the soil and gives us the moisture level as output. The module has both digital and analog outputs and a potentiometer to adjust the threshold level.

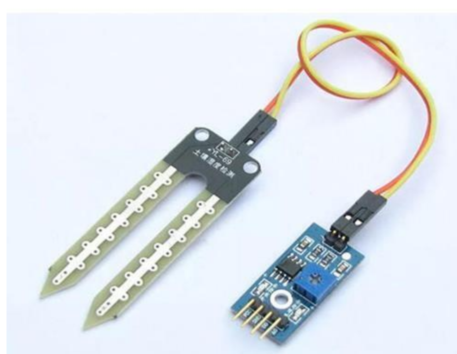


Fig 39

The relay module is an electrically operated switch that can be turned on or off deciding to let current flow through or not. They are designed to be controlled with low voltages like 3.3V like the ESP8266 or 5V like Arduino.

Fig 40

DHT11 is a low-cost digital sensor for sensing temperature and humidity. This sensor can be easily interfaced with any micro-controller such as Arduino, Raspberry Pi etc. It uses a capacitive humidity sensor and a thermistor to measure the surrounding air, and spits out a digital signal on the data pin

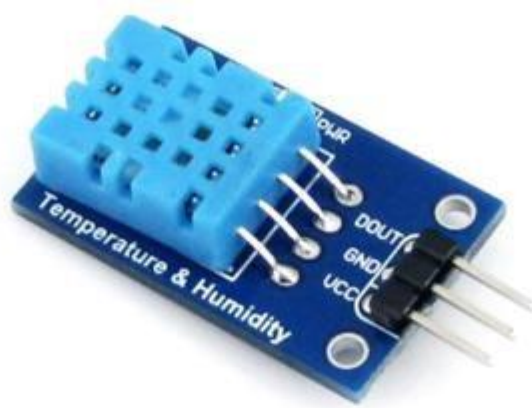


Fig 41

Software

Proteus 13 is one of the best simulation software for various circuit designs of microcontrollers. It has almost all microcontrollers and electronic components readily available in it and hence it is a widely used simulator. It can be used to test programs and embedded designs for electronics before actual hardware testing. The simulation of programming of microcontrollers can also be done in Proteus. Simulation avoids the risk of damaging hardware due to wrong design

5.2 Completion of final design and Simulation

Prototype *Scaled to 1/10th of the proposed project*

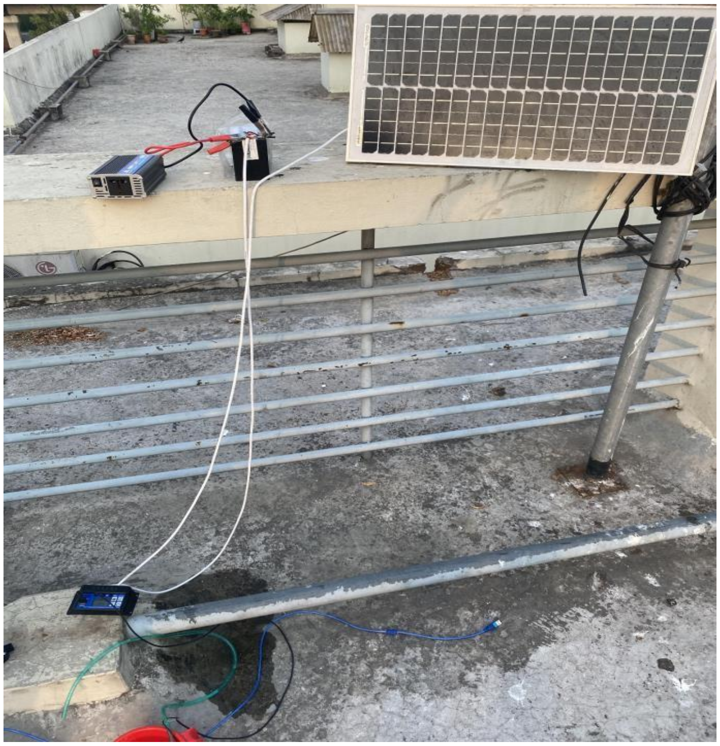


Fig 43: Set up of the prototype

Time of the day	PV OC Voltage Day-1	PV OC Voltage Day-2	PV OC Voltage Day-3	Mean PV OC Voltage
9	17.25	18.08	17.79	17.71
10	17.52	18.25	18.21	17.99
11	18.89	19.78	19.08	19.25
12	19.63	20.57	21.43	20.54
13	20.38	21..02	20.78	20.58
14	21.67	20.82	20.19	20.89
15	20.87	20.15	18.78	19.93
16	20.06	19.87	19.54	19.82
17	19.52	18.16	18.77	18.82
18	18.72	17.56	16.93	17.74

Table 16: Data collected from prototype.

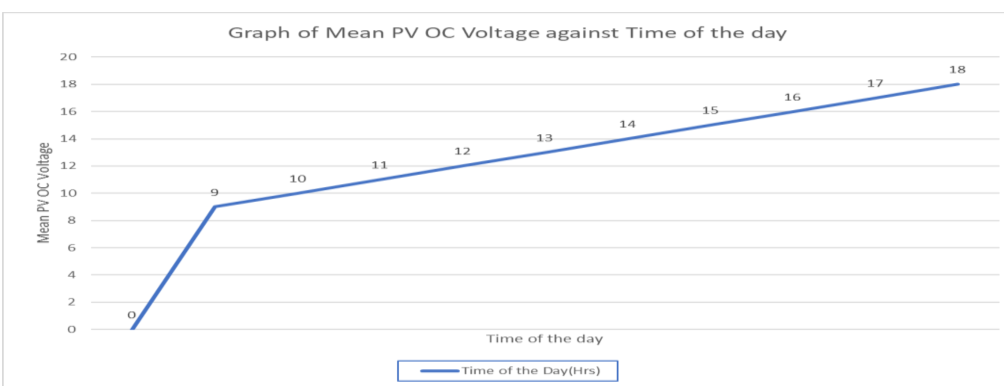


Fig 44: Graph of mean PV OC voltage against Time of the day

During the whole Day our Battery Charge Controller Showed “Charging” Status of battery since our maximum Vbat = 14V was set. Using a 500W Inverter we were able to easily run our 6W DC Motor pump with the help of an AC to DC converter

Simulation *scaled to 1/3rd of the proposed project*

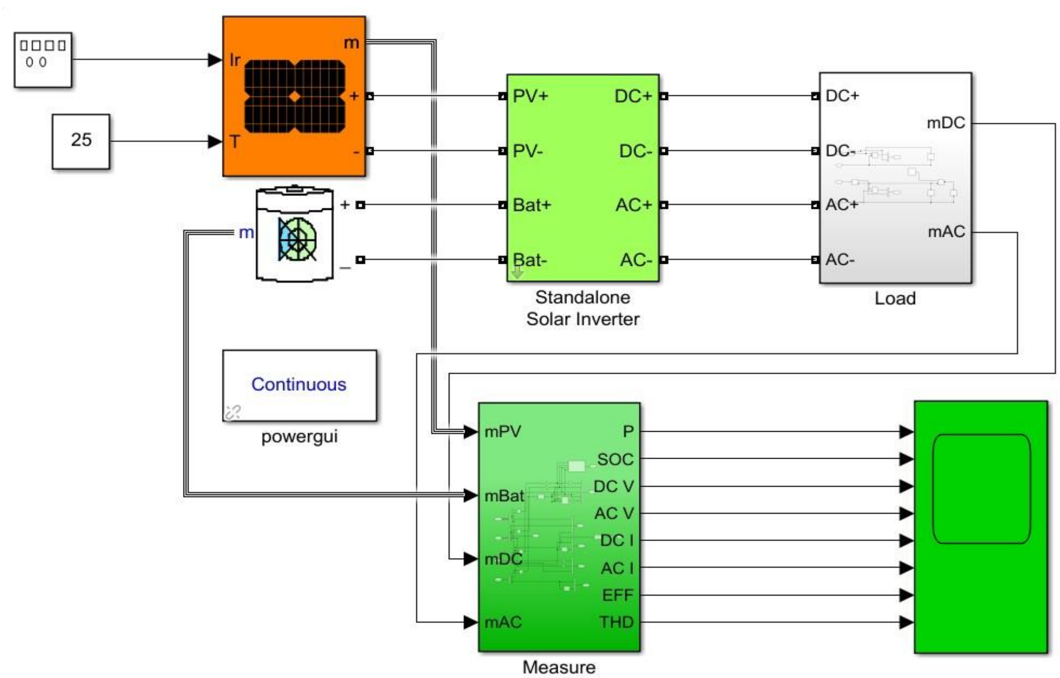


Fig 45: Circuit for Simulation Here for the irradiance, we have given a signal (sine) of 1000W/m2 and given a frequency of ⅛ Hz since we needed the irradiance for our simulation time of 4s. This signal helped us achieve an increasing and decreasing irradiance which is a model irradiance of Sun's Irradiance

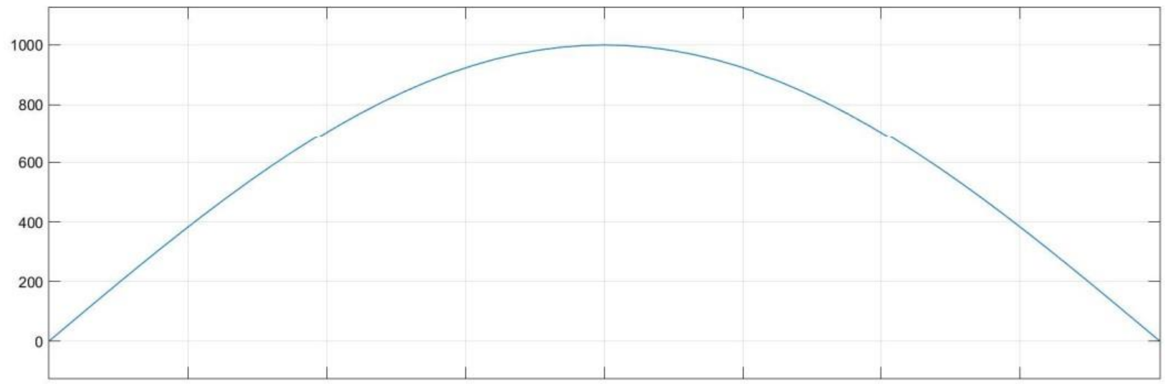


Fig 46

Our 4 PV Panel Array is expected to produce a maximum of 1589Wp. So, from our simulation we have obtained 1344Wp PV Power (Fig) at 25 C.

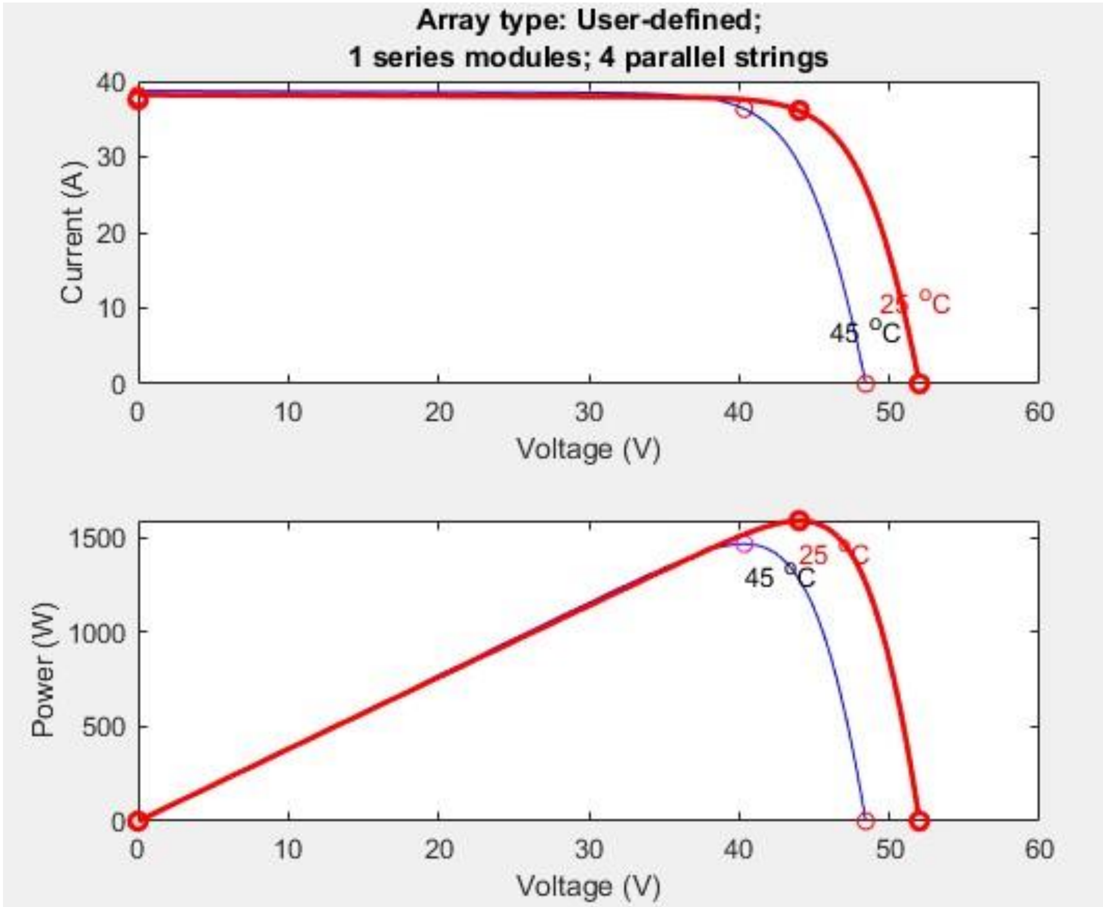


Fig 47

Our load model which includes our smart IoT device (Sensors, Microcontrollers etc.) as DC Load and a constant AC load.

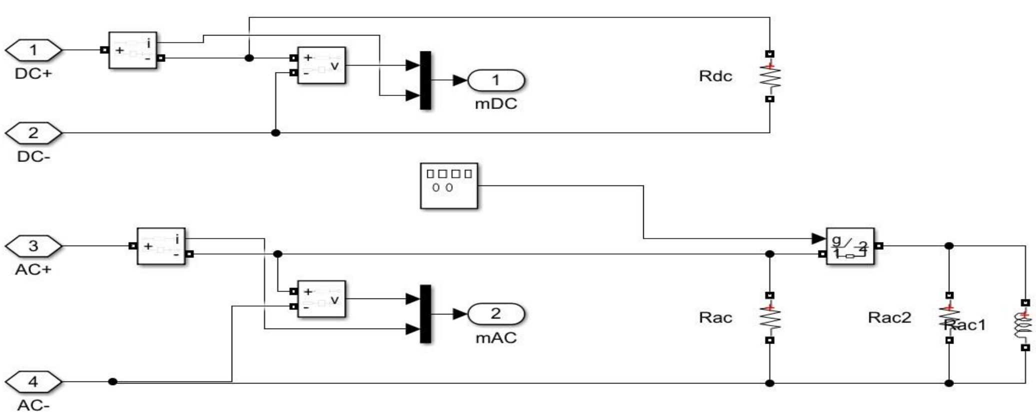


Fig 48

A signal generator is used to demonstrate how a relay can turn on the AC Load (motor Pump throughout 50% of the simulation time.

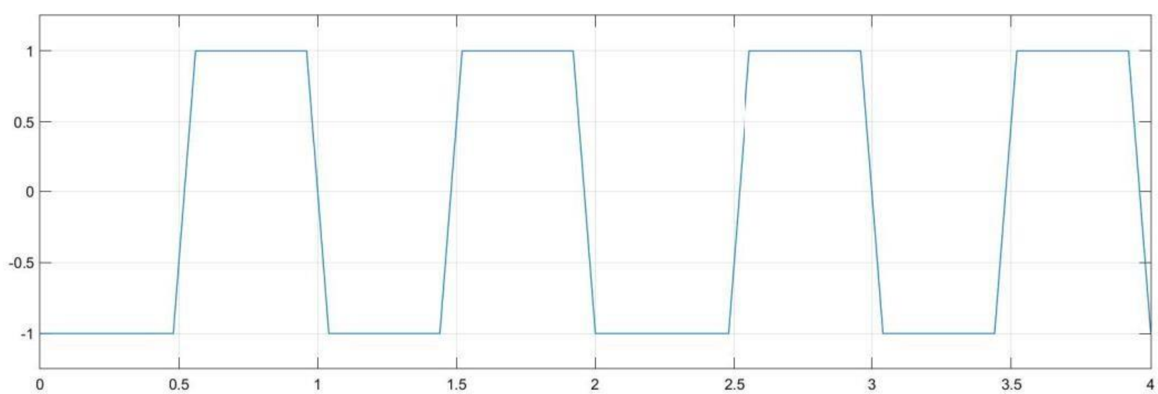


Fig 49: Output graphs of Simulation

The Simulation Report of the whole system is given below which shows the PV Power generation, the AC power Consumption and the DC Power Consumption. The efficiency of the system and the State of Charge of the Battery and the Total Harmonic Distortion is also shown.

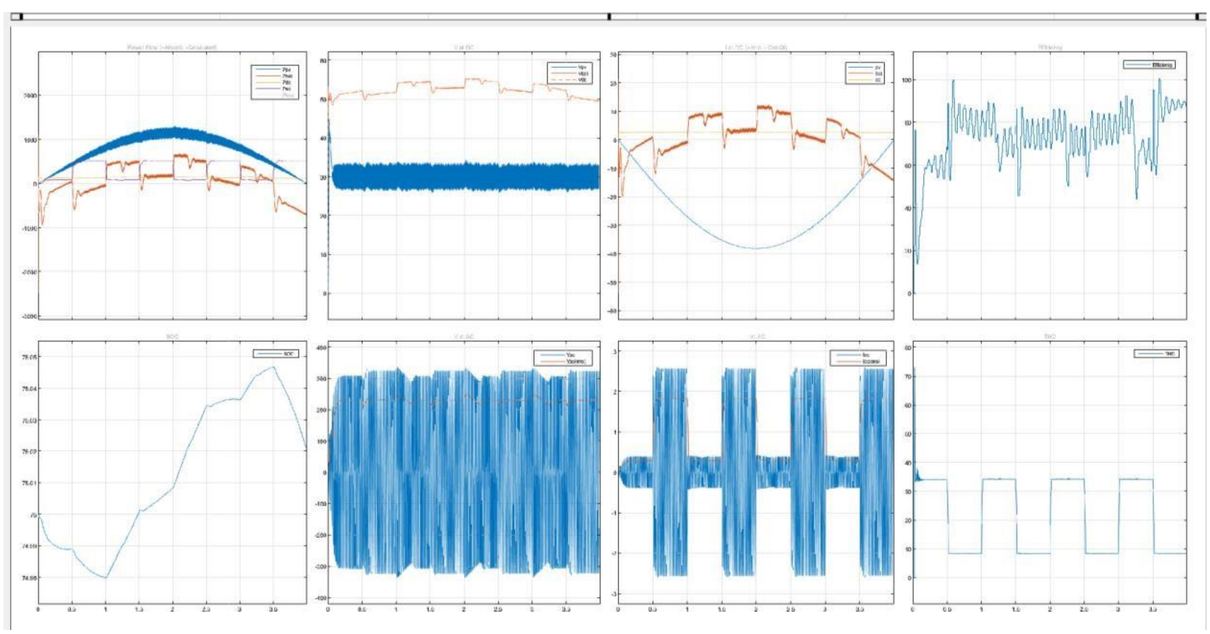


Fig 50: Output graphs of Simulation

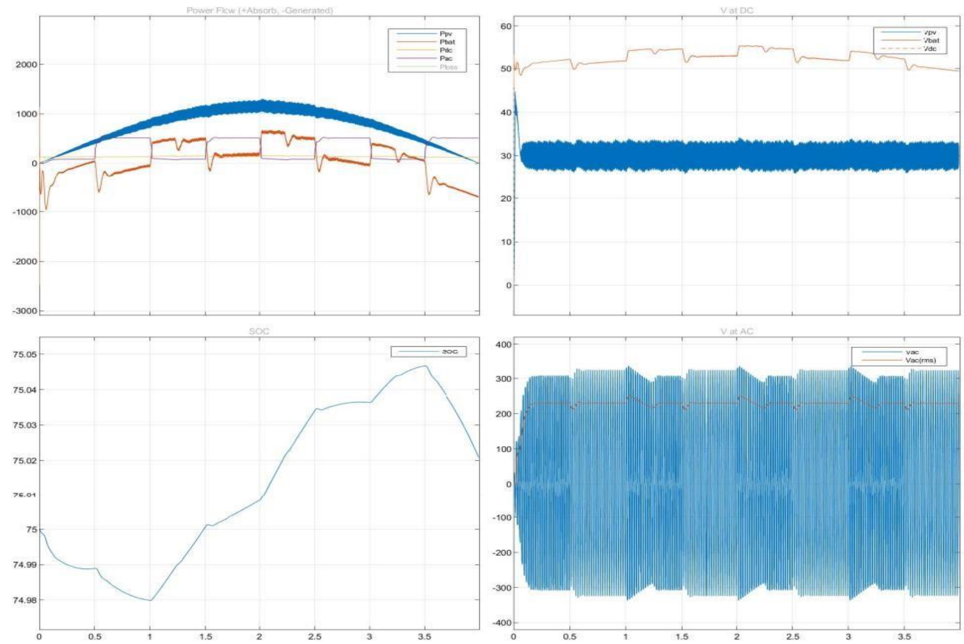


Fig51: Output graphs of Simulation

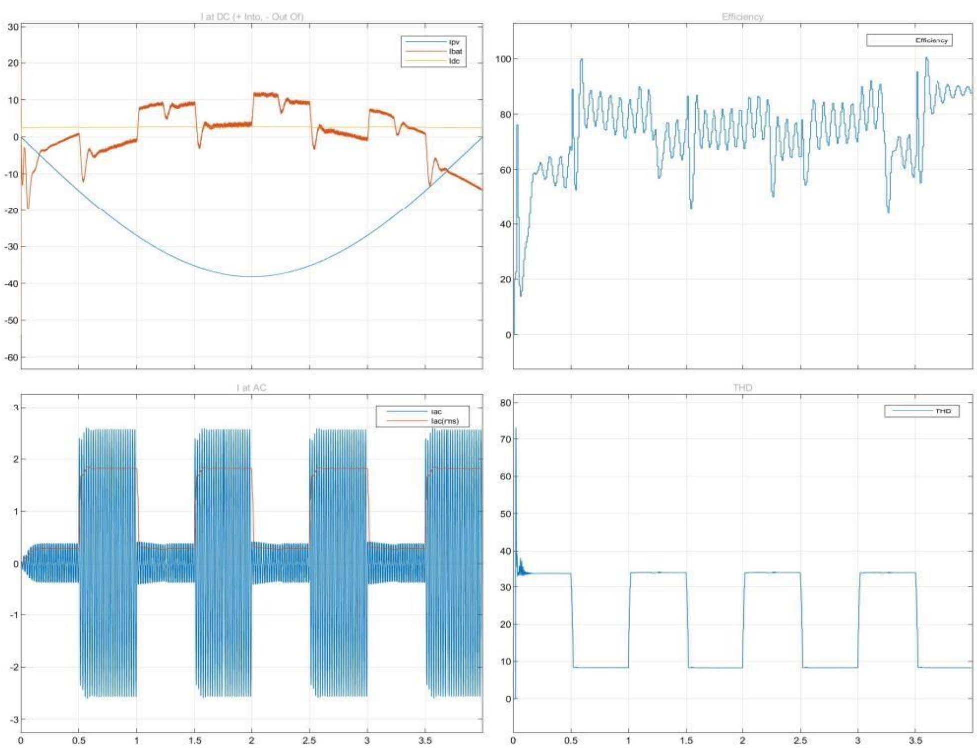


Fig52: Output graphs of Simulation

The Increase in Iac is due to the running state of the AC motor model at unity power factor state.

5.3 Evaluate the solution to meet desired need

This chapter focuses on the data collection of the parameters from a small plant at a specific time of the day using the devices. These data are observed carefully to see the trend that they have created and find out the possible reasons behind certain types of data trends. There are also some anomalies in the data reading which is also justified with reason in this chapter. These data are also used to generate graphs with the help of 'Origin' software.

Analysis on lemon tree plant at a roof

To confirm the functionality of our device, we took readings from a pot of lemon plant which was growing from a seed for 4 months. We have tabulated the temperature, humidity, readings in the table below. The table contains 32 sets of data.

time	dry1	wett1	sensor1	sensor2	average precent	moisturestartprocent	start hour	endhour	temperature	watering duration	Valve Status
11:29:38	795	435	84	88	0	30	9	21	23	60	0
11:29:39	795	435	84	86	86	30	9	21	23	60	0
11:29:40	795	435	83	85	85	30	9	21	23	60	0
11:29:41	795	435	83	84	84	30	9	21	23	60	0
11:29:42	795	435	83	84	83	30	9	21	23	60	0
11:29:43	795	435	83	84	83	30	9	21	23	60	0
11:29:44	795	435	83	84	83	30	9	21	23	60	0
11:29:45	795	435	41	43	83	30	9	21	23	60	0
11:29:46	795	435	19	21	42	30	9	21	23	60	0
11:29:47	795	435	15	17	20	30	9	21	23	60	1
11:29:48	795	435	13	15	16	30	9	21	23	60	1
11:29:49	795	435	81	83	14	30	9	21	23	60	1
11:29:50	795	435	81	83	82	30	9	21	23	60	1
11:29:51	795	435	81	83	82	30	9	21	23	60	1
11:29:52	795	435	81	83	82	30	9	21	23	60	1

11:29:53	795	435	81	83	82	30	9	21	23	60	1
11:29:54	795	435	81	83	82	30	9	21	23	60	1
11:29:55	795	435	81	83	82	30	9	21	23	60	1
11:29:56	795	435	81	83	82	30	9	21	23.25	60	1
11:29:57	795	435	81	83	82	30	9	21	23	60	1
11:29:58	795	435	81	83	82	30	9	21	23	60	1
11:29:59	795	435	81	83	82	30	9	21	23	60	1
11:30:00	795	435	81	83	82	30	9	21	23	60	1
11:30:01	795	435	81	83	82	30	9	21	23	60	1
11:30:02	795	435	81	83	82	30	9	21	23	60	1
11:30:03	795	435	83	85	82	30	9	21	23	60	1
11:30:04	795	435	83	86	84	30	9	21	23	60	1
11:30:05	795	435	82	84	84	30	9	21	23	60	1
11:30:06	795	435	95	96	83	30	9	21	23	60	1
11:30:07	795	435	95	96	95	30	9	21	23	60	1
11:30:08	795	435	81	83	95	30	9	21	23	60	1
11:30:09	795	435	82	83	82	30	9	21	23	60	1
11:30:10	795	435	81	83	82	30	9	21	23	60	1

Table: spreadsheet data

The data we have collected from all sensors are shown in the above tables with graphical representation. But we cannot determine the overall water and energy saving requirements of a 1hectare area of land condition directly from the data or graphs. To be able to do that, we have to analyze a large amount of data and add more sensors and conduct a real experiment from a major crop field.

For future developments it can be enhanced by developing this system for large acres of land. Also, the system can be integrated to check the quality of the soil and the growth of crop in each soil and at different stages. The sensors and microcontroller are successfully interfaced and wireless communication is achieved between various nodes. All observations and experimental tests prove that this project is a complete solution to field activities and irrigation problems. Implementation of such a system in the field can definitely help to improve the yield of the crops and overall production.

Implementation of ThingSpeak & ESP8266

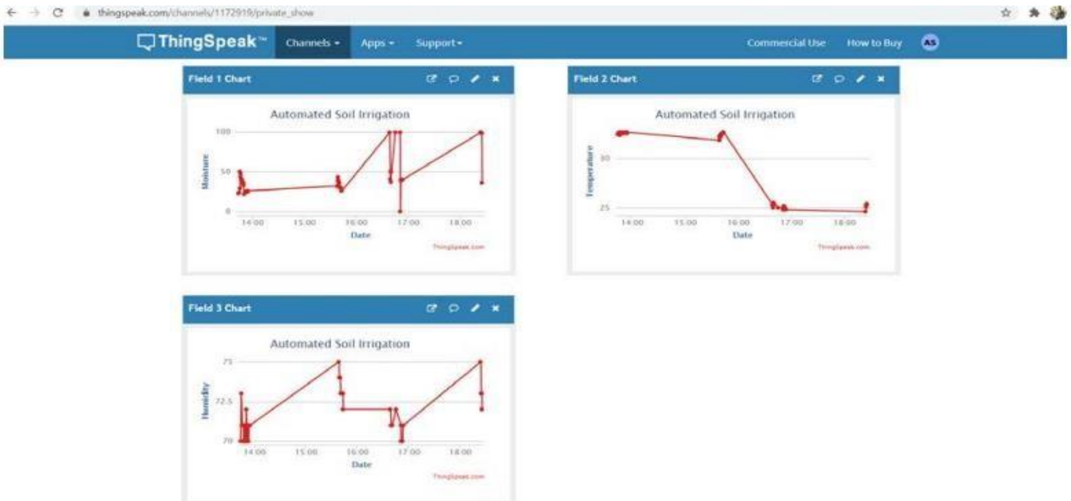


Fig : Screenshot of ThingSpeak

Limitations

The thingspeak free version that we are using has certain limitations:

- Only four channels can be created at a time.
- Data is updated at a 15 seconds interval so we could not send data every second.
- Private channel sharing is limited to only 3 shares.
- The channels will not be able to receive any data if its storage limit is exceeded

During the experiment, it was observed that the relay was not working with node-mcu, so for actuation for sending the ambient condition to server, it was verified that the data gets to server at every 10 s and the same has been checked in serial monitor. Also, it was found that sometimes the DHT 11 was unable to read the temperature and humidity condition, due to its internal problem, so we are taking the data after some periodic interval and since the ambient condition doesn't change drastically in a short span, it works well with the situation.

5.4 Conclusion

ThingSpeak is chosen as the cloud as it is a hassle-free open-source IoT platform service for building IoT prototypes rapidly. Apart from the restrictions arising because of its free version, it has several key features which makes it user-friendly like we do not need to set up servers or develop web software and we can visualize our sensor data in real-time. In the next chapter, we will be covering our data collection mechanism and its analysis.

Chapter 6: Impact Analysis and Project Sustainability

6.1 Introduction

Every implemented project has positive and negative impacts. Even if a project with various advantages might not be accepted by the consumers. Thus, we have to consider all impacts and build a project which includes all advantages along with consumer satisfaction. Furthermore, to make a project sustainable, we need to consider some factors such as, Societal, Technology, Environment, Ethics, Political, Legal, and Economic etc.

6.2 Assess the impact of solution

A SWOT analysis is performed to assess the strengths (S), weaknesses (W), opportunities (O) and threats (T) of the impact of Agri voltaic systems

Strengths 1. Maximize the land use 2. Adaptation of crops against climate change and natural disaster 3. Diversification of farmer’s income	Weakness 1. Non mature technology 2. Less efficiency for crop yield and energy production 3.Shading positively influences the protein content worsens the taste of the ice as a high protein content increases the viscosity of cooked rice, affecting its texture
Opportunities 1. A new market 2. Compatible with various crops 3. Increase the communication about renewables in rural world	Threats 1. Lack of acceptability from farmers 2. Technological breakthrough

Table 19: SWOT analysis

Strengths

Land utilization is maximized by combining solar panels and food crops on the same plot of land. The Land Equivalent Ratio (LER) is applied to this new idea to quantify land production and compare the Agri voltaic system with separating solar farm and agriculture.

Shade and protection for the crops are provided by panels suspended above the agricultural ground. Climate change brings increased hail storms, heat waves, and other natural disasters, all of which can be devastating to crops. The shade offered by the panel keeps the above-ground crop from

burning and lowers water stress. The shadow reduces plant transpiration and hence their water requirements. Furthermore, Agri voltaic systems do not cause soil artificialization, which is a major concern to agriculture today.
The agricultural sector is experiencing a severe economic downturn. Farmers' earnings are low, and government assistance is becoming scarce.

Weaknesses

Agri voltaic systems are still in their infancy. When compared to basic solar projects, the cost of this type of project is higher. It's also problematic because nothing is known about the installation's true impact on agriculture. There is still a lot of ambiguity regarding how the Agri voltaic system will affect the crops above it.
A reduction in agricultural and electricity output per hectare has occurred. This can be a barrier for farmers and solar developers, as well as a significant loss for the operator, as combining the two sectors is challenging (agriculture and energy).
The farmer is constrained by the structure that supports the panels. He won't be able to adjust the proportions of his agricultural machinery once it's installed because the PV plant's design is based on the measurements of the machines. It's more difficult to farm around metal poles. The irrigation system must also be modified. Some chemical agents must be used with caution to avoid causing damage to the metal structure or the panels. The solar farm's operation and maintenance are further hampered by the elevation panels. The ability to work at heights must be granted to maintenance employees.

Opportunities

The market is expanding and opportunities are various. Competition is weak.
The impossibility of building a solar power plant on agricultural land is currently the main obstacle to the development of large-scale solar power plants. The possibility to implement PV plants on agricultural land is huge. Increase the communication about renewable energy in rural world

Threats

Farmers must support Agri voltaic efforts for them to be effective. To illustrate the potential synergy between agriculture and solar power, crops against the panels must be maintained. Farmers' knowledge is crucial to the project's success. Farmers, on the other hand, may be wary about participating in such initiatives. To begin with, this imposes certain restrictions on them. In 2018, sociological research was undertaken to see if renewable energy projects in rural regions were acceptable. Farmers' interviews bring out the most important points of dispute. Farmers are suspicious about the technological aspects of the projects.
The disparity between the rural and urban worlds is another source of conflict. Farmers are unconcerned about renewable energy initiatives spearheaded by urban residents, feeling that the programs are being imposed on them. Improved communication and increased farmer engagement in initiatives might help to reduce this hazard. Floating panels may potentially be a viable option

for achieving the solar plan's goals. Wind turbines are becoming increasingly powerful yet occupying a little amount of space. Onshore wind turbine development is exploding. [16].

Steeple Analysis

The steeple analysis is a method that considers seven elements to assist you make the best decision possible (Societal, Technology, Environment, Ethics, Political, Legal, and Economic). These factors indicate the advantages and disadvantages of the products or businesses. This phase is critical for identifying your goods' risks as well as highlighting their strengths and benefits. As a result, we will utilize this approach to examine various macro-environmental factors in this project.

Social	The agriculture field is nowadays one of the most important fields especially in Bangladesh, and farmers are all seeking new devices and technologies for better production.
Technology	•IoT technology aids in the progress of various sectors by simplifying the functionality of numerous systems. This cutting-edge and cutting-edge technology aids in the development of several real-world initiatives, many of which are in the agricultural area.
Environment	The smart farming and AGV system promote the use of renewable energy sources, making it ecologically benign and contributing to environmental protection.
Ethics	The smart farming project adheres to the code of ethics; it is completely safe and secure for farmers, as well as the data acquired.
Political	Increases job opportunities in Agri voltaic system fabrication and installation
Legal	Introduction of new laws to maintain agricultural function and monitoring.
Economic	The use of IoT technology affects the economy because of lowering the cost of the product, this later will itself help in the increase of production and incomes.

Fig 53: steeple analysis

Safety Consideration:

In any project the safety of the used equipment and gadgets should be maintained in the proper way. If the safety maintenance cannot be ensured by the team, the whole project can be demolished in any second. On the other hand, if a high-cost technology that is used in the project crashes due to any reason, it will be very difficult to repair it in a short time. In our Smart stand-alone Agri Voltic project the high-cost equipment we are using is the solar system, solar batteries and pump which are the major and main equipment to properly run the system. If any of this fails working the whole project will shut down and replacing them will take time. So, we need to secure the safety of this high-cost equipment by hiring experienced maintenance management to monitor over the whole project 24 hours. By doing this the employees can regularly maintain the equipment and if any damage occurs, we can take steps beforehand. Moreover, in rural areas, natural calamities occur very often. we need to take precaution about which natural calamity is hit seasonally in the target location and which possible preparation we can take which can protect our external system from any hinderence.in our project as we are using the structure for solar panel, the accurate strength of the mounting structure should be implemented so that any calamity can hinder the panels. Furthermore, we are implementing the project in a rural area. The locals have less knowledge about technology and without knowing they can get hurt by wrongly using equipment. To ensure their safety we can give them a guideline or put an eye-catching Caution sign in dangerous areas. By taking these safety considerations we can ensure a strong, effective and sustainable project without facing major difficulties in the long term.

6.3 Evaluate the sustainability

Sustainability in the project profession is an approach to business that balances the environmental, social, economic aspects of project-based working to meet the current needs of stakeholders without compromising or overburdening future generations.

- **Economics sustainability:**

1. To maintain economic sustainability we cannot use low-cost equipment or components which may fail operating in a short time or have low efficiency. We need to ensure high quality of every product and before implementing or buying the product by testifying each product.

2. Also we need to do routine maintenance for every component like batteries, motor, sensors etc. We can be aware, if a component is running smoothly or not and we can change or repair those if needed before the damage. It will also make our project more sustainable.[17]

• Environmental sustainability:

1. Water level: In our project we are using soil moisture sensors so that we can irrigate a minimum amount of water. Also, our water level sensor can warn us about the low level of water so that we can take precautions. In such a way, the land will not be dried up and environmental sustainability of the project will be maintained.

2. Less Disposal: Normally diesel or electric pumps or motors dispose of toxic elements like oil etc. in the soil which can harm the production capacity of a land and also emits more carbon in the air. But in our submersible solar pumps there will be no fuel disposals and the carbon emission are very less with long operating life. In the case of batteries, we are using lead acid batteries which run longer and more durability than the other batteries so there will be no disposal from the battery for a long period by this environmental sustainability will be maintained. [18]

• Social sustainability:

1. As our project will be new the local people might not have faith in the project. To gain their trust we need to have evidence of the standard of the project. For that we need to get permission from the government. Offices with legal papers. On the other hand, it will also save our project from false accusations and help us to run the project for a long period of time without any argument with local or outsiders.

2. Also, in the case of social sustainability we can Aware the farmers by providing a guideline of proper use of the machinery. It will help them to gain knowledge about the used machinery and they can easily benefit by utilizing the project.

3. The theft issue is really concerning in rural areas. Such incidents can cause a great loss in this project as the components we are using can be expensive. To protect the project from any kind of theft issues, we need to hire a strong security management or install CCTV cameras to look after the overall project. [19]

6.4 Conclusion

Considering the impacts and sustainability might help us to generate the project for a long run. Predicting the impact beforehand and taking an initiative to satisfy the consumer expectations, will help the project gain popularity. Moreover, taking safety measures can ensure the project's longevity and better future aspects.

Chapter 7: Engineering Project Management

7.1 Introduction

For implementing a project, making a plan of project progression with estimated dates should be the first prior. It not only helps to manage the project easily but also predicts the risk factors. A properly organized project plan helps us to cross check if the progression is going in the right direction or not. All the plans might not be done by the estimated schedule because of the occurrence of natural disaster, component dysfunction or unavailability of components but these risk factors can be predictable if we can design a plan with estimated time durations. Also, the project team should assign works individually and sync the work with each other to overcome the difficulties and run the project steadily.

7.2 Define, plan and manage engineering project

Initial Project Plan:

Project Plan			
400P			
Work Progress	**Start Date**	**End Date**	**Duration**
Problem Identification	17/6/2021	1/7/2021	14
Topic Review and Finalization	1/7/2021	15/7/2021	14
Concept Note Preparation	8/7/2021	26/8/2021	49
Project Proposal	12/8/2021	16/9/2021	35
400D			
Work Progress	**Start Date**	**End Date**	**Duration**
Simulate the design	1/10/2021	30/10/2021	29
Gathering Required Components	30/10/2021	7/11/2021	8
Starting to work on sensors modules and IOT hardware	8/11/2021	30/11/2021	22
Algorithm Development	30/11/2021	31/12/2021	31
400C			
Work Progress	**Start Date**	**End Date**	**Duration**
Building Cloud Database	15/1/2022	5/2/2022	21
Prototype Testing	20/1/2022	10/2/2022	21
Prototype Demonstration Preparation	8/2/2022	28/2/2022	20
Project Final Report Presentation	15/2/2022	15/3/2022	28

Table 20: Estimated project plan

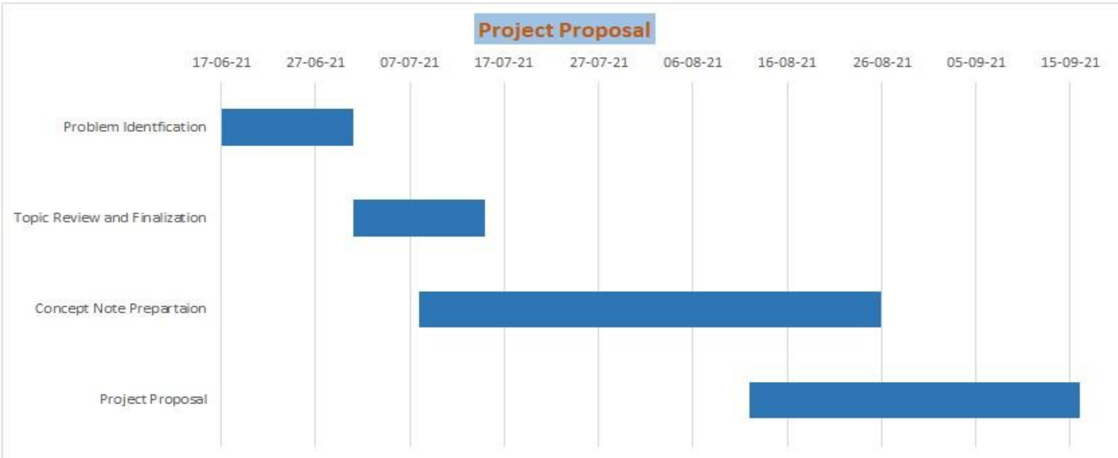


Fig 54: Estimated project Proposal plan

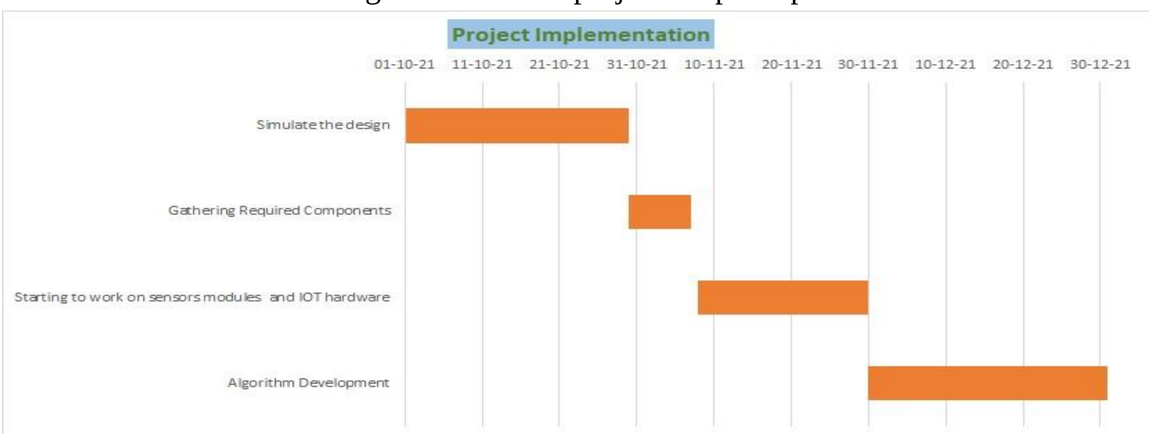


Fig 55: Estimated project implementation plan

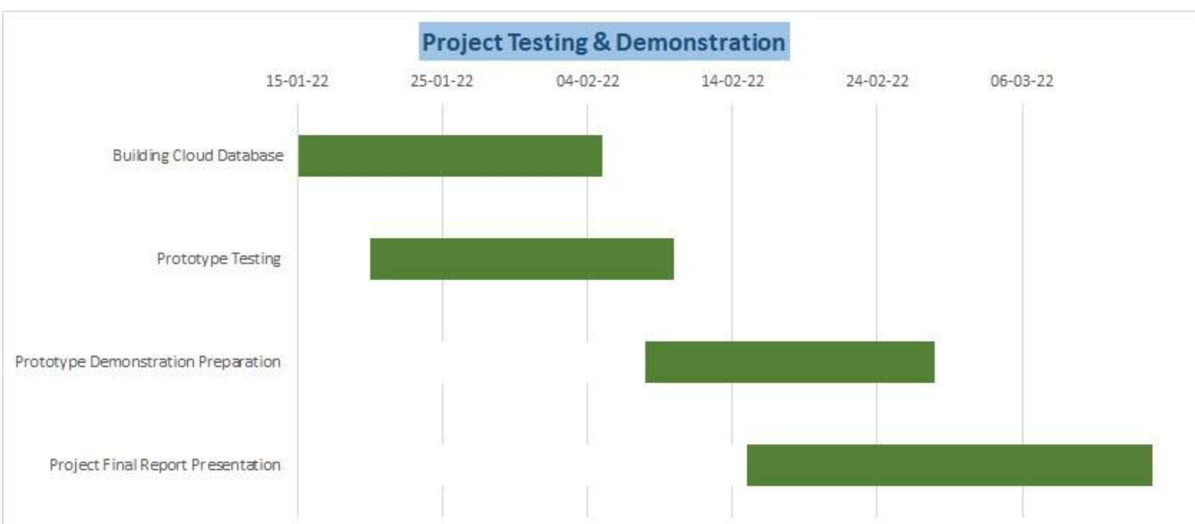


Fig 56: Gantt Chart

Revised Project Plan:

400C			
Work Progress	**Start Date**	**End Date**	**Duration**
Simulate the design	15-01-22	05-02-22	21
Gathering Required Components	20-01-22	28-01-22	8
Starting to work on sensors modules and IOT hardware	01-02-22	14-02-22	13
Building Cloud Database	10-02-22	10-03-22	28
Prototype Testing	24-02-22	10-03-22	14
Prototype Demonstration Preparation	06-03-22	20-03-22	14
Project Final Report Presentation	30-03-22	15-04-22	16

Table 21: Revised project plan

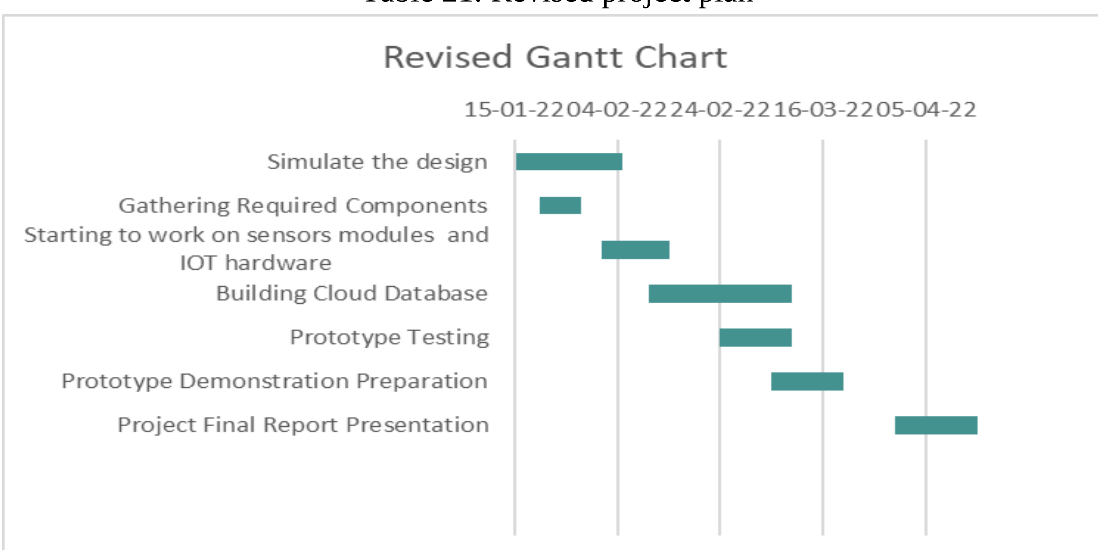


Fig 57: Revised Gantt Chart

Risk Management and Contingency Plan:

As our whole project is designed with electrical components both hardware and software, we might face some problems like component damage. Excessive current flow can destroy important components which can shut down the whole system. To prevent this failure, we can use a circuit breaker or fuse. As, if an over flow of current goes through a circuit breaker the circuit will automatically shut down so we can avoid accidents or failure of components.

Accountabilities, Responsibilities and Risk management:

Name	Roles	Risk Management
Shoheb Abul Hossain	Data analyst and researcher	Hardware Failure
Kasshaf Ahmad	Project Manager	Software Malfunction, Budget creep
Md. Tamzid Hossain	Field inspector and designer of the project	Materials procurement failure
Afia Raidah Ariya	Administration	Poor scheduling and Communication issues

Table 22: Risk management roles and responsibilities

7.3 Evaluate project progress

A project plan is a good option to evaluate the progression of the project. We already saw that there are changes in the revised plan which shows us that not always the project progress will go by the initial plan. There might be occurrences of risk factors or other difficulties which may change the plan. In reality, if any estimated plan did not run, we need to change the progress plan to avoid shutting down the project even for a little period of time. If we evaluate the project management plan continuously, it could help us to predict any hindrance. If any hindrance occurs or predicted to occur, we can instantly divide our works by the decided risk management plan which helps to keep generating the project. On the other hand, we should design a backup plan to safely manage the project from risk. So, evaluating the whole project plan is very important and effective to run a project

7.4 Conclusion

In conclusion, we can say having a project plan should be more prioritized as it is very important to demonstrate or implement a project in an organized way. If the project runs through some difficulties, we can easily change the estimated plan and solve the problem by working according to the risk management plan.

Chapter 8: Economic Analysis.

8.1 Introduction

Economic analysis is a very important factor in implementing a project. By doing economic analysis we can set a budget plan before implementing the project which gives us the prediction of the project is cost effective or not. In multiple design approaches we already saw by doing an economic analysis in each project helped us to select the optimized design easily. Economic analysis also helps to select the most cost-effective components. Moreover, by analyzing the payback amount, we can easily estimate the profit we can gain through the project.

8.2 Economic analysis

Budget of the Prototype:

Components Name	Unit Price in BDT (Tk)	Quantity	Total Price	Store Link
12volt 20watt solar panel	1000	01	1000	https://www.eeeshopbd.com/
24/12V 10A PWM Adjustable Solar Charge Controller	700	01	700	https://www.eeeshopbd.com/
12V 7 AH Rechargeable Battery	800	01	800	https://www.eeeshopbd.com/
Soil moisture Sensor	165	03	495	https://techshopbd.com/detail/3712/Soil_Moisture_Sensor_Module_techshop_bangladesh

LM35 Temperature Sensor Waterproof	320	04	1280	https://store.roboticsbd.com/sensors/1179-lm35-temperaturesensor-waterproof-roboticsbangladesh.html
Water Level Sensor Depth of Detection (Water Sensor RBD-683)	250	02	500	https://store.roboticsbd.com/sensors/683-water-level-sensor-depth-of-detection-water-sensor-for-arduinoroboticsbangladesh.html
Humidity Sensor DHT11	180	03	540	https://store.roboticsbd.com/sensors/667-dht11-temperature-andrelative-humidity-sensormodule-for-arduino-roboticsbangladesh.html
Relay Module	90	01	90	https://store.roboticsbd.com/robotics-parts/702-1-channel-5vrelay-board-module-roboticsbangladesh.html

Table 23: budget of final prototype.

8.3 Cost benefit analysis

In the chapter-2.4.3, we have shown the cost analysis of our project, which is to estimate at BDT 3,24,000, roughly USD 3800, In the table -7 of chapter-2.4.1, we have found that the yearly cash inflow is BDT 29760, USD 372. Therefore, the payback period would be,

$$Simple\ payback\ period = (Initial\ Investment)/(Yearly\ Cash\ inflow)\ )$$

$$= (324000(BDT)/(29\ 760(BD0T = 11\ years$$

Around 40% of the cost can be taken as grants from Infrastructure Development Company and other donor agencies in Bangladesh. thus, decreasing the overall cost of setup for a farmer. As stated earlier, total cost of electricity consumption in the farm is BDT 4000. However, with this large initial investment of BDT 3,24,000, a farmer will never have to think of electricity cost as he is generating his power to run the appliances.

8.4 Evaluate economic and financial aspects

The initial cost is a little steep for someone to invest in farming. In retrospect, the long-term benefit is much bigger. As there will not be any more electricity to run the farm. Every year, a farmer will save approximately BDT 48,000 in just electricity. Furthermore, the payback period is 11 years. Thus, after 11 years this will be an addition to the overall yearly cash inflow.

8.5 Conclusion

To conclude, it can be said the overall income of a farmer will increase with implementation of Agri voltaic system as it is saving electricity cost. Although the system has a high initial cost, it benefits a farmer in the long run.

Chapter 9: Ethics and Professional Responsibilities

9.1 Introduction

Maintaining ethics and professionalism help to achieve popularity of the project as well as user satisfaction. To generate a project, we have to keep selecting the components ethically to cut down the risk. It also helps to maintain the project impression to consumers which is connected to the usage increase of the project.

9.2 Identify ethical issues and professional responsibility

The main ethical and professional responsibility we must consider are:

1. selection of quality components
2. maintaining reasonable cost for consumers 3. safety measures
4. legal documentation of land for the project
5. Signing consent paper with the stakeholders

9.3 Apply ethical issues and professional responsibility

In our project we are using different types of electronics devices and machineries. In this modern world we can find varieties of components in the market but all of them are not properly manufactured. In hope of cutting down the cost, we can easily buy some low-cost products which may have faults even sometimes, some costly products may not run properly. As we are implementing the project in the village area, the farmers are not well aware of this machinery and if we use those low cost or poor efficient products in the project it will be unethical. For example, there are varieties of solar panels in the market without having the ability to absorb the UV rays which can harm crops, environment and surrounding. So, for this ethical consideration we need to test all the devices and machineries before buying and implementing those products and ensure the quality and safety of this project. On the other hand, the village farmers are not familiar with this technology. if we take this opportunity and misuse their resources (e.g., water, land) or sell the project with higher price, it will also be unethical. We need to ensure to avoid all unethical steps and implement an effective project using proper machinery to ensure the quality. The main issue before implementing our project on Netrokona, we have to prepare legal papers of the stakeholders whose land we are using for the project. Also, we have to sign the consent paper with all the stakeholders legally and give them photocopies of their own forms. So that, in future no one can create a false accusation of illegally using land for the project.

9.4 Conclusion

Maintaining ethics will not only be beneficial for the consumers or stakeholders but also for the project management. It can nullify any dangerous situation and false accusation which could hinder the growth of the project

Chapter 10: Conclusion and Future Work

10.1 Project summary/Conclusion

To sum up the whole project, we can say this project is designed for the farmers of rural areas who do not have the electricity facilities for agriculture. The main goal of this project is to improve the farmers production by using smart tools for irrigation. To set up the most optimized project, we run analysis over many design approaches and select the most efficient one which is only user friendly but also cost effective. To give a continuous irrigation service of irrigation, the project has a battery backup system for night and monsoon weather. Moreover, we are using the soil and water flow sensors to decrease the wastage of water through irrigation. To run the project smoothly organized a project plan to evaluate the progression of the project. Furthermore, analyzing the impact and considering ethical and safety issues beforehand, make the project more sustainable.

10.2 Future work

For the betterment of this project in future, we want to add more functions in the prototype model. We already identify some future work we want to include which are:

1. Smart IOT system for applying pesticides on crops
2. Automatic dual axis solar structure with sunlight tracker
3. Increasing the area of PV panel for more energy output
4. Providing consumers with more efficient devices to monitor

References

[1] M. Taheruzzaman and P. Janik, "Electric Energy Access in Bangladesh," *Transactions on Environment and Electrical Engineering*, 14 Sep. 2016. [Online]. Available: https://www.researchgate.net/publication/306047475_Electric_Energy_Access_in_Bangladesh.

[2] C. D. Santos, "Agrivoltaic system: A possible synergy between agriculture and solar energy," 2020. [Online]. Retrieved from https://www.divaportal.org/smash/get/diva2:1427912/FULLTEXT01.pdf.

[3] Gonocruz, R. Nakamura, K. Yoshino, M. Homma, T. Doi, Y. Yoshida and A. Tani, "Analysis of the Rice Yield under an Agrivoltaic System: A Case Study in Japan Environments," 2021, 8, 65. [Online]. Retrieved from https://www.mdpi.com/20763298/8/7/65/pdf.

[4] Chamara, Ruwan & Beneragama, Chalinda, "Agrivoltaic systems and its potential to optimize agricultural land use for energy production in Sri Lanka: A Review,' 5. 417-431,2020, DOI: 10.22059/JSER.2020.302720.1154.

[5] C. N. Kulkarni and A. U. Surwade, "THE FUTURE OF FARMING THROUGH THE IoT PERSPECTIVE," *International Research Journal of Engineering and Technology (IRJET) Volume: 06 Issue: 02*, Feb 2019. [Online]. Retrieved from https://www.irjet.net/archives/V6/i2/IRJET-V6I295.pdf

[6] IEA (2021), Solar PV, IEA, Paris https://www.iea.org/reports/solar-pv]

[7] S. M. Shamim Reza and N. I. Sarkar, "Design and performance analysis of a directly-coupled solar photovoltaic irrigation pump system at Gaibandha, Bangladesh," *2015 3rd International Conference on Green Energy and Technology (ICGET)*, 2015, pp. 1-6, doi: 10.1109/ICGET.2015.7315116.

[8] National Renewable Energy Laboratory, "PV Watts Calculator" Available: https://pvwatts.nrel.gov/pvwatts.php [Accessed: Sep 16, 2021].

[9] B. B. Sharma and N. Kumar, "IoT-Based Intelligent Irrigation System for Paddy Crop Using an Internet-Controlled Water Pump," *International Journal of Agricultural and Environmental Information Systems (IJAEIS)*, *12*(1), 21-36, (2021).[Online].Available:https://econpapers.repec.org/article/iggjaeis0/v_3a12_3ay_3a2021_3ai_3a1_3ap_3a21-36.htm

[10]"Renewable Energy 2021 Bangladesh ICLG”. [Online] Available: https://iclg.com/practiceareas/renewable-energy-laws-and-regulations/bangladesh.

[11,12,13] L. E. Stetson, "Electrical codes and standards in agricultural applications," 1998 Rural Electric Power Conference Presented at 42nd Annual Conference, 1998, pp. d4-1, Doi: 10.1109/REPCON.1998.666965.

[14] “Applied Photovoltaic”- 2nd edition by S.R. Wenham, M.A. Green, M.E. Watt and R. Corkish

[15] Lalwani, Mahendra, and D. P. Kothari. “Investigation of Solar Photovoltaic Simulation Softwares.” INTERNATIONAL JOURNAL OF APPLIED ENGINEERING RESEARCH, DINDIGUL, vol. 1, no. 3, 2010.

……

[16] M. Kumar, “Social, Economic, and Environmental Impacts of Renewable Energy Resources”, *Wind Solar Hybrid Renewable Energy System*, January 21st 2020, DOI: 10.5772/intechopen.89494.

[17,18,19] S. Agrawal and A. Jain, “Sustainability of Solar-based Irrigation in India: Key Determinants, Challenges, and Solutions,” *New Delhi: Council on Energy, Environment and Water*, Dec, 2016. Retrieved from https://www.ceew.in/sites/default/files/CEEW-Sustainabilityof-Solar-Based-Irrigation-in-India-12Dec16.pdf

Appendix

%% PnO MPPT Algorithm PV Operating Point

```
PVOP=PARAMmppt(1);
Dini=PARAMmppt(2);
Dstep=PARAMmppt(3);
Vpwm=PARAMmppt(4);

persistent mem if
isempty(mem)
mem.Vpv=0;
mem.Ppv=0;
mem.Dboost=Dini;
end

Ppv=Vpv*Ipv;
dVpv=Vpv-mem.Vpv;
dPpv=Ppv-mem.Ppv;
dPVpv=dVpv*dPpv; if
dPVpv>0
   Dboost=mem.Dboost-Dstep; else
   Dboost=mem.Dboost%%+Dstep;
end

%% Update Memory
mem.Vpv=Vpv; mem.Ppv=Ppv;
mem.Dboost=Dboost;
end
```

%%Battery Charge Controller Algorithm

```
function [Sbat_Dch,Sbat_Ch] = ChCt(PARAMchct,Vbat)
Vbat_min=PARAMchct(1);
Vbat_max=PARAMchct(2);

%% Overcharge Protection
Sbat_Ch=1; if
Vbat>Vbat_max
Sbat_Ch=0;
```

```
end

%% Overdischarge Protection
Sbat_Dch=1; if
Vbat<Vbat_min
Sbat_Dch=0; end
```

NodeMCU ESP8266 Code :

Including the libraries for the components. LiquidCrystal.h is for the LCD display and dht.h is for temperature and humidity sensor.

```
#include <dht.h> //library for DHT
#include <ESP8266WiFi.h>
#include <SPI.h>
#include <Wire.h>
#include <Adafruit_GFX.h>
#include <Adafruit_SSD1306.h>
#include <DHT.h>  // Including library for dht

#define SCREEN_WIDTH 128 // OLED display width, in pixels
#define SCREEN_HEIGHT 64 // OLED display height, in pixels
#define OLED_RESET -1 // Reset pin # (or -1 if sharing Arduino reset pin)

#define DHTPIN D4          //pin where the dht11 is connected
DHT dht(DHTPIN, DHT11);

String apiKey = "C25ICK6FHOR7PST4"; // Enter your Write API key from ThingSpeak
const char *ssid = "MySmartHome";     // replace with your wifi ssid and wpa2 key const
char *pass = "nRF52840";
const char* server = "api.thingspeak.com";

Adafruit_SSD1306 display(SCREEN_WIDTH, SCREEN_HEIGHT, &Wire, OLED_RESET);

const int AirValue = 790;   //you need to replace this value with Value_1
const int WaterValue = 390;  //you need to replace this value with Value_2
const int SensorPin = A0; int soilMoistureValue = 0; int
soilmoisturepercent=0; int relaypin = D5;
```

```
WiFiClient client;


void setup() {
  Serial.begin(115200); // open serial port, set the baud rate to 9600 bps
  display.begin(SSD1306_SWITCHCAPVCC, 0x3C); //initialize with the I2C addr 0x3C
(128x64)
  display.clearDisplay();
  pinMode(relaypin, OUTPUT);

  dht.begin();

  WiFi.begin(ssid, pass);

  while (WiFi.status() != WL_CONNECTED)
  {
    delay(500);
Serial.print(".");
  }
    Serial.println("");
    Serial.println("WiFi                    connected");
delay(4000);
}


void loop()
{                  float      h      =
dht.readHumidity();
  float t = dht.readTemperature();

  Serial.print("Humidity: ");
  Serial.println(h);
  Serial.print("Temperature: ");
  Serial.println(t);

  soilMoistureValue     =     analogRead(SensorPin);        //put     Sensor     insert     into     soil
  Serial.println(soilMoistureValue);

  soilmoisturepercent = map(soilMoistureValue, AirValue, WaterValue, 0, 100);
```

```
 if(soilmoisturepercent > 100) {
 Serial.println("100 %");

 display.setCursor(0,0);  //oled display
display.setTextSize(2);
display.setTextColor(WHITE);
display.print("Soil RH:");
display.setTextSize(1);
display.print("100");
 display.println(" %");
display.setCursor(0,20);  //oled display
display.setTextSize(2);
display.print("Air RH:");
display.setTextSize(1);
display.print(h);
 display.println(" %");
display.setCursor(0,40);  //oled display
display.setTextSize(2);
display.print("Temp:");
display.setTextSize(1);
display.print(t);
 display.println(" C");
 display.display();

 delay(250);
display.clearDisplay();
}


else if(soilmoisturepercent <0)
 {
 Serial.println("0 %");

  display.setCursor(0,0);  //oled display
  display.setTextSize(2);
  display.setTextColor(WHITE);
  display.print("Soil RH:");
```

```
  display.setTextSize(1);
  display.print("0");
    display.println(" %");
  display.setCursor(0,20);  //oled
  display
  display.setTextSize(2);
  display.print("Air RH:");
  display.setTextSize(1);
  display.print(h);
   display.println(" %");
  display.setCursor(0,40);  //oled
  display
  display.setTextSize(2);
  display.print("Temp:");
  display.setTextSize(1);
  display.print(t);
   display.println(" C");
  display.display();

  delay(250);
display.clearDisplay();
}


else if(soilmoisturepercent >=0 && soilmoisturepercent <= 100)
{
  Serial.print(soilmoisturepercent);
  Serial.println("%");

  display.setCursor(0,0);  //oled display
display.setTextSize(2);
display.setTextColor(WHITE);
display.print("Soil RH:");
display.setTextSize(1);
display.print(soilmoisturepercent);
display.println(" %");
display.setCursor(0,20);  //oled display
display.setTextSize(2);
display.print("Air RH:");
display.setTextSize(1); display.print(h);
display.println(" %");
```

```
display.setCursor(0,40);  //oled display
display.setTextSize(2);
display.print("Temp:");
display.setTextSize(1);
display.print(t);   display.println(" C");
display.display();

  delay(250);
display.clearDisplay();
}

  if(soilmoisturepercent >=0 && soilmoisturepercent <= 30)
  {
    digitalWrite(relaypin,                              HIGH);
Serial.println("Motor is ON");
  }
  else if (soilmoisturepercent >30 && soilmoisturepercent <= 100)
  {
    digitalWrite(relaypin,                              LOW);
Serial.println("Motor is OFF");
  }

  if (client.connect(server, 80)) // "184.106.153.149" or api.thingspeak.com
  {
    String postStr = apiKey;
       postStr += "&field1=";
       postStr +=String(soilmoisturepercent);
       postStr += "&field2=";
       postStr += String(h);
       postStr += "&field3=";
      postStr += String(t);
       postStr += "&field4=";
      postStr += String(relaypin);
       postStr += "\r\n\r\n\r\n\r\n";

    client.print("POST /update HTTP/1.1\n");
client.print("Host: api.thingspeak.com\n");
    client.print("Connection: close\n");
    client.print("X-THINGSPEAKAPIKEY: " + apiKey + "\n");
```

```
    client.print("Content-Type: application/x-www-form-urlencoded\n");
    client.print("Content-Length: ");
client.print(postStr.length());     client.print("\n\n");
    client.print(postStr);

}
    client.stop();
```