

DESIGN AND IMPLEMENTATION OF A SMART AGRIVOLTAIC SYSTEM

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A Final Year Design Project (FYDP) 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
September 2023

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Declaration

It is hereby declared that

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

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Ethics Statement

Our final year design project report contains 15% similarity.

Abstract/ Executive Summary

The aim of our project is to co generate green energy with crops using the same land to ensure bilateral use of land along with automating the process of irrigation to lessen the effort of farmers and to monitor and the parameter of the soil to ensure the maximum crops. In this project we grow yield under solar panels (simulated using tin sheets) to observe the result of shading effect on crops and while comparing we get a little less yield under the shaded region whose amount was satisfactory. We created this project to help the nation become self-sufficient in the production of electricity and sought to switch to clean energy in order to reduce harmful emissions. The challenge of acquiring this project is the high initial cost. Smart Agrivoltaic systems are a promising technology with the potential to provide many benefits. However, more research and development is needed to overcome some of the challenges associated with this technology.

Keywords: Agrivoltaic System, Green Energy, PV panel, Agriculture.

Dedication

To our parents because without their support it would not be possible for us to complete our graduation.

Acknowledgement

- We would like to thank our supervisor Professor Dr. Md. Mosaddequr Rahman whose excellence and perfection helped us a lot throughout the work. Also, we want to thank Mr. Mohaimenul Islam for guiding us throughout the whole project.
- Special thanks to Soil Science Department Sher-E-Bangla Agricultural University for helping us to validate our sensor data.

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List of Acronyms

IEEE-	Institute of Electrical and Electronics Engineers
IoT-	Internet of things
PCB-	Printed Circuit Board
LCD-	Liquid Crystal Display
LED-	Light Emitting Diode
OLED-	Organic Light Emitting Diode
PV Panel-	Photovoltaic Panel

Chapter 1: Introduction

1.1 Introduction

Agrivoltaic system is an innovative and revolutionary approach to combine solar panel-based renewable energy production and agricultural production simultaneously on the same land. This particular approach is very important for densely overpopulated developing and developed countries where the maximum electricity demand is fulfilled using non-renewable fossil fuels and the government has no other choice but to expend its foreign reserve to buy fossil fuels so that country's electricity demand can be fulfilled. Because of this fossil fuel-based non-renewable electricity production, we are getting harmful byproducts like CO₂ released into the environment which is responsible for excess amounts of heat that leads to changing weather patterns like floods, severe drought, less rainfall, and excess rainfall making the whole planet more inhabitable. Here most popular renewable energies like solar, and wind can be used to reduce both of our dependency on non-renewable energy sources and our carbon footprint but that can lead us to food insecurity by creating pressure on agricultural land. Here Agrivoltaic system steps in which is superior compared to conventional and renewable PV panel-based electricity production and conventional farming because the farmer/landlord doesn't have to depend only on agricultural income where he may face bad weather or declining sales also he can generate additional income by selling excess energy and this will make a significant contribution reducing the carbon footprint.

1.1.1 Problem Statement

Solar energy is one of the important clean & green sources of energy that is gaining increased attention in recent years. Due to the global food and energy crisis caused by harsh weather and war. In recent years, it has gained tremendous attention Nowadays almost every country is facing an electricity crisis due to the interruption of the supply of natural resources like oil, gas, and diesel because of war and many other factors. Moreover, global warming is causing droughts and other natural calamities, hampering food production and making food costly. It is found that to produce 1 kWh of electricity about 475g of CO₂ is released into the air whereas using the irradiation of the sun PV system can produce 1 kw/h of electricity emitting 15 g of CO₂. Electricity generated through coal, oil, and gas contributes 38% of the total CO₂ emissions in the environment whereas considering the overall installed PV system around the whole world prevents around 590 million tons of CO₂ emissions[1]. Despite global efforts to decarbonize the power sector, electricity, and heat generation account for more than 40% of global CO₂ emissions from fuel combustion, with coal plants accounting for more than 70% of these emissions.CO₂ emissions from electricity generating are caused by the interaction of the following factors: electrical output, generation efficiency, fossil portion of total generation, and carbon intensity of fossil generation thus affecting the environment in a serious manner due to which the world has seen one of the worst droughts, especially European countries and according to the online news portals it will be a new normal[2][3].In this case, solar energy is the best solution in terms of health and environmental risks. But from the perspective of our country, it is quite impossible to set up large-scale solar parks as our country is densely populated. Moreover, we don't have huge open spaces for this & all we have is farmlands which are also decreasing day by day because of population pressure. Here Agrivoltaic system comes

in which the combined production of solar power and agricultural crops simultaneously in the same field. In this context, the Agrivoltaic system is the optimum/best solution to solve this problem where growing plants and generation of electricity is done at the same time on the same land and this system provides mutual benefits between the food–energy–water consumption in drylands[4].The Agrivoltaic system will inevitably cause changes in microclimatic conditions under the panel. As a result of the decrease in solar radiation under the PV panel, the water consumption balance will change and water savings will be achieved [5].

1.1.2 Background Study

According to Bangladesh Power Development Board (BPDB) , the country's power generation capacity is around 25000 MW [6] and an average of 100% of the country is electrified. Besides, more fossil-based power plants are being built in various places in order to fulfill electricity demand. Previously Bangladesh’s power sector has seen various problems like high system loss, delay in power plant completion, electricity theft, low maintenance, etc. Now, these problems have been reduced to a significant level. Here the main problem with countries with 100% electrification is our power plants are mainly fossil fuel-based.

TABLE 1: Total energy Supply from sources (Bangladesh) [7]

Year	Coal	Natural gas	Hydro	Biofuels and waste	Oil	Wind, solar, etc.	Units
1990	11781	156049	3182	287395	75533		TJ
1995	13434	230015	1339	302220	114135		TJ
2000	3620	309020	2761	319391	130781		TJ
2005	17682	452583	2761	345409	149351		TJ
2010	33942	694175	2779	356687	158001		TJ
2015	58450	895545	2160	351714	265813	778	TJ
2020	95916	1097613	3161	334897	325833	1465	TJ

From Table 1, it's clearly visible that about 44% of the country’s electricity needs are fulfilled through natural gas, then oil, coal, and other substances and the amount has increased as the years progressed. As the population rate is increasing the demand for electricity will also increase proportionally and supplying electricity generated through fossil fuels to such a large population is not an easy task. Moreover, dependence on fossil fuel-based electricity production will push the nation towards energy insecurity and this also creates a huge impact on the country’s foreign reserve to handle it Government has allotted time for load-shedding which is not a permanent solution at all. Moreover, we have to face load-shedding for natural calamities also. Furthermore, green energy like solar power is a source of electricity. Because of its availability, lack of pollution, and renewability, solar power has emerged as a viable alternative source. The advantages of using solar energy using a solar panel include the solar

panel's longer lifetime than any other energy source and it can be installed anywhere. But here our aim is to plot solar panels in agricultural areas which will simultaneously ensure cultivation and sustainable green electricity generation.

1.1.3 Literature Gap

However more study is needed to know the full potential of Agrivoltaic systems. PV greenhouses, for example, have yet to be researched, as previous farm trials focused mostly on Agrivoltaic systems consisting of stilt-mounted PV modules above crops. Additional research on stilt-mounted PV systems is required, especially for their use to shade-intolerant crops.

Shade-tolerant plants such as Asian greens, arugula, chard, collard greens, parsley, sorrel, spinach, scallions, broccoli, kohlrabi, cabbage, hog bean, alfalfa, yam, taro, cassava, and sweet potato benefit from Agrivoltaic system [8] because these are shade-tolerant crops. The system's use for shade-intolerant crops, which are expected to grow under low light conditions are not determined yet and there is no research on popular crops like wheat, maize, potato, pulses, and oil seeds etc which are grown in our country. Many important commercial crops, such as corn, watermelon, tomato, cucumber, pumpkin, cabbage, turnip, and rice, are shade-intolerant and requires a lot of sunlight. If an Agrivoltaic system is used for economically less lucrative and shade-tolerant crops, the system would be unable to supply expanding global demand for food and clean power.

However, it is worth investing to check the feasibility of combining Agrivoltaic systems with shade-intolerant crops. It is important to determine whether an improvement in total area productivity is also possible for crops that require a lot of sunlight. Shade tolerance refers to a plant's ability to withstand low light. There are few screening studies on shade tolerance of plants [9][10].Corn, watermelon, tomatoes, and taro are known to have high saturation points, meaning they need plenty of light to thrive. Cucumbers, beets, squash, cabbage, and green peppers are examples of plants that like moderate light. Mushrooms tend to grow in slightly dark areas. Moreover, there is no clear mention in those papers of how much electricity is being produced from the Agrivoltaic system per area.

1.1.4 Relevance to Current and Future Industry

According to SREDA 44% of the Country's electricity is generated using Natural gas[11]and the pressure on Natural gas is increasing. On the other hand, the price of fuels is increasing at an alarming rate. Due to these reasons, our electricity production cost is increasing and creating additional pressure on people's income. But still, energy security remains a question and as a densely populated and developing country, we cannot switch to renewable energy-based electricity production systems overnight. That's the reason There is an alarming need for a sustainable plan for the production of electricity and food keeping in mind the rising population and climate change. There is a significant demand for renewable resources of energy and solar energy is one of the most common forms of renewable energy. According to the International Energy Agency, solar PV accounted for 3.1% of global electricity generation, and it remained the third-largest renewable electricity technology behind hydropower and onshore wind after overtaking bioenergy in 2019[12].Hence, due to climate concerns, the COP26 held in Glasgow in 2021 pledged to provide \$100 billion per year to developing nations [13].These financial

resources will give developing nations to get them equipped with new sustainable and green energy sources which will also drive down energy costs[14][15].

According to IEA, Renewables are the only electricity generation source whose share is expected to grow, with declining shares for coal, natural gas, nuclear and oil generation. Worldwide Solar PV's installed power capacity is poised to surpass that of coal by 2027, becoming the largest in the world. Despite current higher investment costs due to elevated commodity prices, utility-scale solar PV is the least costly option for new electricity generation in a significant majority of countries worldwide. Distributed solar PV, such as rooftop solar on buildings, is also set for faster growth as a result of higher retail electricity prices and growing policy support to help consumers save money on their energy bills[16]In this context Farming under solar panels (Agrivoltaic) is the best solution to reduce the Electricity problem and this will maximize the utilization of land and increase crop productivity. Because of Agrivoltaic system crops will require less amount of irrigation[17][18] which will result in lower production costs. In one of the studies, it is mentioned that the production efficiency has increased by 60%–70% by this method [19].Moreover, farmers can use electricity generated from Agrivoltaic for their own use/agricultural purposes and can profit financially by selling the remaining extra electricity.

1.2 Objectives, Requirements, Specification and constraint

1.2.1. Objectives

Agrivoltaic systems are still in the early stages of development, therefore there is still room for technical advancements and more application areas. There is a scope that the energy produced from the Agrivoltaic system might be used to improve the farm's other operational processes, such as the processing of harvested goods or lighting system of the farm. The electrification of farm equipment or all vehicles is another option. At the farm level, the energy might be used directly for irrigation and water-pumping devices or saved by pumping water into a reservoir to be used later for irrigation.

Another scope for Agrivoltaic system is that farmers can also sell the produced energy to the grid system. It will help them to earn extra money. This will encourage other farmers to go for an Agrivoltaic system.

So, Our objective of this project is to Design a Smart Agri Voltaic system to co-generate green energy and crops with less amount of irrigation along with Implementing an automated monitoring solution for increased solar and agricultural yield considering different factors i.e. environment, soil parameters, etc.

1.2.2 Functional and Nonfunctional Requirements

The functional and non-functional requirements of our project is as follows:

Functional Requirement

- As this is an Agrivolatic system, photovoltaic modules will be used for energy generation considering optimum tilt angle and shadow calculation.
- The Irrigation needs to be done based on the data of the soil moisture sensor.

- Soil sensors are needed to measure the fertility (presence of Nitrogen, Potassium, and Phosphorus) and pH level of the soil.
- The sensor's output data (soil sensor, moisture sensor, humidity sensor), and crop data
- should be sent to the user timely.

Non-Functional Requirement

- Around 0.25 acres of land where **paddy** is cultivated will be cultivated.
- Shadow less agricultural land is required.
- The PV panels need to be at a height so that it does not interrupt the works of farmers and other cultivation equipment.
- The land owner needs to follow the cloud data

System level Requirements

TABLE 2: System level Requirements

System level Requirements	Component Level Specification
The panels will move after every 24 hour so that in alternative days all the crops get sunlight	PV panel, Axis movable Frame for solar panel, Linear Actuator
To irrigate the farmland	Water pump, Pipe,
Measuring and monitoring the humidity of soil and nutrition level by analyzing the presence of Nitrogen, Potassium, Phosphorus in the soil	Soil monitor sensor, Water sensor
Energy storage device so that the user can able to use electricity when there is no sunlight or at night hour	Here we will use a lead acid battery to store the surplus energy.
Control & processing unit for controlling the components	To control the components we will use a microcontroller and to turn on-off the components like a water pump, we will use a relay module. We will also be able to control the system manually via wireless medium using mobile phone applications.
A communication unit for relaying data from the sensors to the application.	We will use a GSM GPRS module for communication which works in all countries with GSM (2G) networks.

1.2.3 Specifications

Technical Specifications

TABLE 3 : System Specifications

Subsystem	Component (Major)	Specification	Specification (Prototype)
Energy source	PV panel	Capacity - 540W, 24V ; Vmax – 41.92V;Voc – 49.40V; imax– 12.89A; isc – 13.72A Dimension:227.9*113.4*3.5 CM	Capacity- 30W,12V; Vmax-27.05; Dimension- 420*670*30MM
Energy storage	Lead-acid Battery	Voltage 12v Ampere 150 amp	Voltage 12v Ampere 30 amp
Sensor	Soil sensor, moisture sensor	Measuring Range: 0-1999 mg/kg ;Accuracy: ±2%F.s Working Humidity: 5 to 95% (relative humidity) Response Time (T90, seconds): less than 10 Communication Port: RS485++XH2.54 2P Working Temperature: 5 to 45 ° C Power Supply: 12V-24V DC++DC 3.3-12V Nitrogen, Potassium, Phosphorus, Humidity	Measuring Range: 0-1999 mg/kg ;Accuracy: ±2%F.s Working Humidity: 5 to 95% (relative humidity) Response Time (T90, seconds): less than 10 Communication Port: RS485++XH2.54 2P Working Temperature: 5 to 45 ° C Power Supply: 12V-24V DC++DC 3.3-12V Nitrogen, Potassium, Phosphorus, Humidity
Irrigation	AC water pump	Power: HP: 1, KW: 0.75, Capacity: H/m: 13~7;Q-I/m: 50~400;Sn. inch: 2;Dn. inch: 2 ¹¹	Power:8W, Capacity: H/feet: 5Q-I/m: 10;
	Pump for spraying pesticide	Power: HP: 0.5, Start up Pressure: 1.5 Bar	Power:8W, Capacity: H/feet: 5Q-I/m: 10;
Automatic monitoring system	Microcontroller	Operating Voltage 5V; Digital I/O Pins 20 PWM Channels 7; Analog Input Channel 12 DC Current per I/O Pin 40 mA; Clock Speed 16 MHz;	Operating Voltage 5V; Digital I/O Pins 20 PWM Channels 7; Analog Input Channel 12 DC Current per I/O Pin 40 mA; Clock Speed 16 MHz;

Here 13~7;Q-I/m: 50~400 indicates the flow rate. For 13 meter distance (depth + height) it can flow 50 liter water per minute and for 7 meter it can flow 400 liter per minute

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

Non-technical Constraints:

The project was chosen with numerous non-technical restrictions keeping in mind so that it may help consumers in their daily lives. Otherwise, it may cause issues for the stakeholders. So it must be cost effective.

- **Budget:** As we have designed a Smart Agrivoltaic system we will need huge amount of solar panel, wires, structure to complete the project. In that instance, failing to execute the project inside a budget will make the stakeholders unable to fund it.
- **Space:** As the system will be implemented on a agricultural land so the structure will be used there may reduce the area of farming due to the structure setup.
- **Security:** As the components will remain in the open agricultural field there is a high chance of the components getting stolen.
- **Regular Maintenance:** Since there PV panels will be used so there is a high possibility of the panels being dusty so it will require regular maintenance otherwise it wont produce sufficient/desired amount of electricity which will result a huge loss to the farmer/stakeholders.

Technical Constraints:

As the project is IoT-based, the safety of the components as well as the people in the neighborhood is critical. Our project's technological restrictions were as follows:

- **Weather issue:** In gloomy and winter days it may fail to produce electricity. Moreover, the structure may get rusted.
- **Battery life:** The life span is too short in contrast to solar panels and backup may not last all night.
- **Crops Data collection:** Manual data collection might not be possible on time moreover there is a chance of data manipulation.
- **Malfunction of Components:** In case of software bugs, the relay may malfunction which may lead to less or excessive irrigation unexpectedly and this can be a reason for poor crop production

1.2.5 Applicable compliance, standards, and codes

The following table represents the Codes and Standards relevant to this project.

TABLE 4 : Applicable Codes

SL	Product Name	Name of Standards
	Solar Module/Panel	(i) BDS IEC 61215-1:2019 Terrestrial photovoltaic (PV) modules – Design qualification and type approval – Part 1: Test requirements (ii) BDS IEC 61215-2:2019 Terrestrial photovoltaic (PV) modules – Design qualification and type approval – Part 2: Test procedures (iii) BDS IEC 61730 (Part 1):2019 Photovoltaic (PV) module safety qualification – Part 1: Requirements for construction (iv) BDS IEC 61730 (Part 2):2019 Photovoltaic (PV) module safety qualification – Part 2: Requirements for testing (v) BDS IEC 60891:2020 Procedures for temperature and irradiance corrections to measured I-V characteristics of crystalline silicon photovoltaic devices
	Solar Charge Controller	BDS IEC 62509:2016 Battery charge controllers for photovoltaic systems – Performance and functioning
	Inverter	(i) BDS IEC 62109 (Part 1):2016 Safety of power converters for use in photovoltaic power systems Part 1: General requirements. (ii) BDS IEC 62109 (Part 1):2016 Safety of power converters for use in photovoltaic power systems Part 1: General requirements.
	Battery	(i) BDS IEC 61427-1:2016 Secondary cells and batteries for renewable energy storage - General requirements and methods of test - Part 1: Photovoltaic off-grid application (ii) BDS IEC 60086-4:2005 Primary batteries - Part 4: Safety of lithium batteries.

1.3 Systematic Overview/summary of the proposed project

In this Smart Agrivoltaic system we have integrated agriculture and electricity production in the same land along with smart irrigation. Which will reduce our dependency on fossil fuel based electricity generation and will also ensure automatic equitable distribution of water in the agricultural land considering the sensor data. As pv panels are used above the agricultural land it will eliminate the need of grid electricity for agricultural purpose. Moreover there will be huge amount of surplus electricity remaining which can be sold to the neighbors or can be supplied to the micro grid. This will reduce farmers dependency on agricultural income and will also open up a new source of income to the farmer by selling the surplus energy. Moreover through the various sensors used here, the farmer can also monitor his land and the soil nutrient condition of the land sitting at home.

1.4 Conclusion

As the world is getting civilized day by day the requirements of energy is increasing in proportional with them but the production of electricity produce so much toxic emission that harm the life of biodiversity along with the increase in the price of fuel make the production of electricity costly as a result the underdeveloped or developing country face difficulties to keep up with the demand of power. The alternate way we can go is to shift to renewable energy sources but for this approach the main barrier is windy areas if we thought for wind turbine energy, upstream rivers if we thought for hydro energy and vast land to go to solar. But what we have is huge fertile land where our farmers grow rice paddy and so on. Here, in our design, we use the same land for solar energy generation where our farmers grow crops in short we cogenerate electricity with crops and make the bilateral use of land thus we will be able to get electricity without any extra land use or any fossil fuel. The proposed design can be installed on any kind of agricultural land whose crops are shade tolerable. We can monitor the soil nutrients using mobile and web applications. In summary the development of smart Agrivoltaic system will reduce the manual labor of farmers in prospect of irrigation and will help then nation to get clean energy.

Chapter 2: Project Design Approach

2.1 Introduction

A smart Agrivoltaic system is a solution to the lack of space for solar power plants and the current energy crisis of our country. But as Bangladesh is an agricultural country, most of our land is being used for agricultural purposes. Here the smart Agrivoltaic system comes in. In this system we can use the same land to co-generate electricity and crops simultaneously.

This project requires some system level requirements. The requirements has been met through different subsystems. These subsystems are an automated irrigation system, energy generation, crops production soil fertilizer monitoring system and smart phone application to show real time data.

These subsystems has been combined in our project in three different design approaches. Furthermore, these design approaches has been compared in terms of considering the requirements and constraints. Finally, a design approach is selected based on the number of positive outcomes and which later proceeds to go for implementation.

2.2 Identify multiple design approach

Design approach 1:

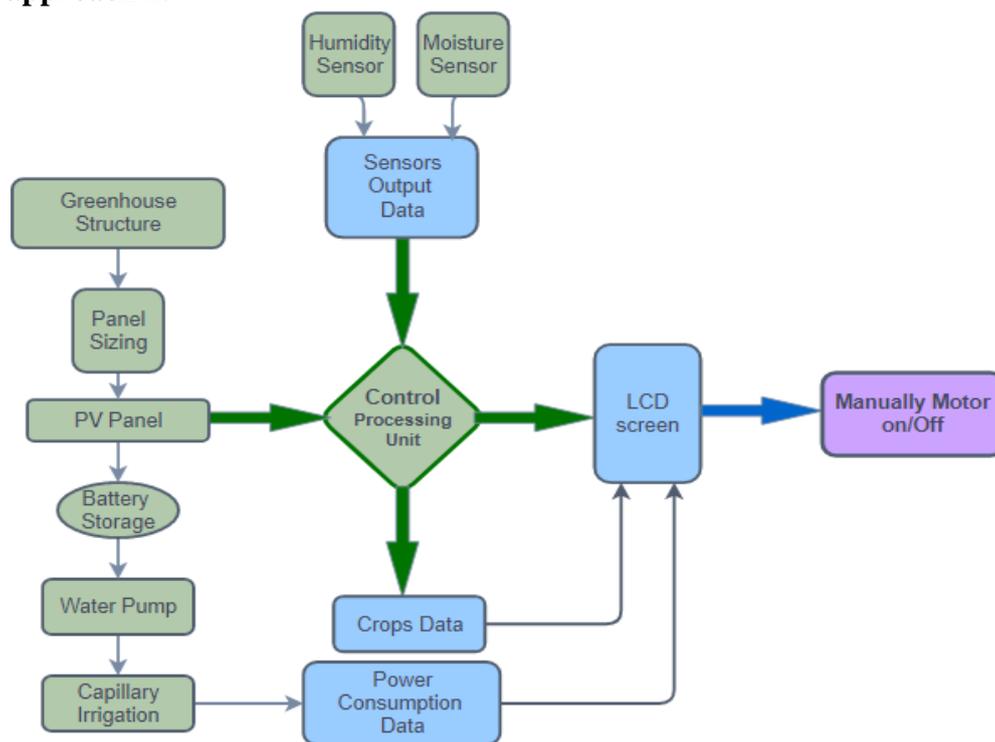


Fig. 1. Block Diagram of Design approach 1

In our above block diagram, for approach one there will be two sensors. Humidity sensor and the moisture sensor. These sensors are directly connected to our Microcontroller. Crops will be cultivated under the greenhouse structure. We will place the PV panels on the top of our PV module. The energy which will produce by the PV panels, will be stored in the battery and from the battery it will give power to the water pump and other sensors. Our moisture sensor

data and the crops data will be shown in the LCD screen. With this approach Farmer have to turn On/Off the Motor manually. He can On/Off it from the Web server.

Pros-

- Stakeholders can get real-time data regarding soil, crops, and irrigation online.
- No fuel will be needed for the irrigation water pump.

Cons-

- No optimal sizing of the PV panels will be done
- No battery backup for the produced electricity to be used at night or on gloomy days.

Design approach 2:

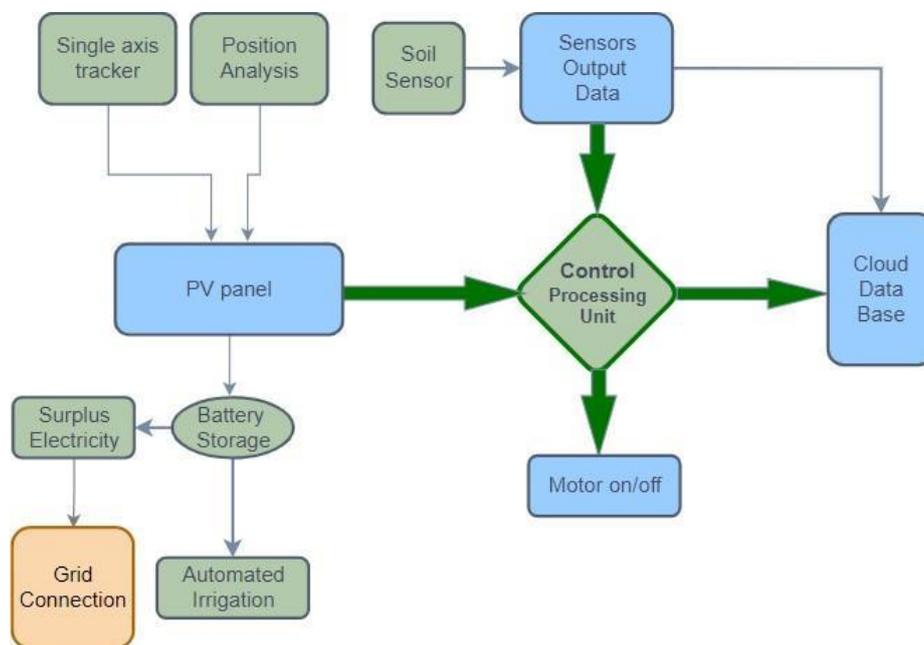


Fig. 2 . Block Diagram of Design approach 2

Like the previous approach here also the soil sensor will be directly connected with our microcontroller. But in this approach there will be no greenhouse structure. Instead of a greenhouse there will be a Single Axis Solar Tracker. The PV panel will track the sun and will be rotated accordingly. From the solar panel the energy will be stored in the battery & from the battery the sensors and the motors will be powered up. It will be a grid connected system so the surplus energy will go to the grid. In this approach we are automating the irrigation process. Based on the soil sensor data motor will turn on/off. The sensor data will be shown in the cloud.

Pros-

- Stakeholders can get real-time data regarding soil, crops, and irrigation online.
- Irrigation will run automatically based on sensors data which will minimize the water consumption
- Surplus energy will be stored in battery which can be used at night or on gloomy days.

Cons-

- This system is restricted only for greenhouse system.
- As PV panels will be set over the greenhouse structure, the tilt angle can not be set according to latitude of the place.

Design approach 3:

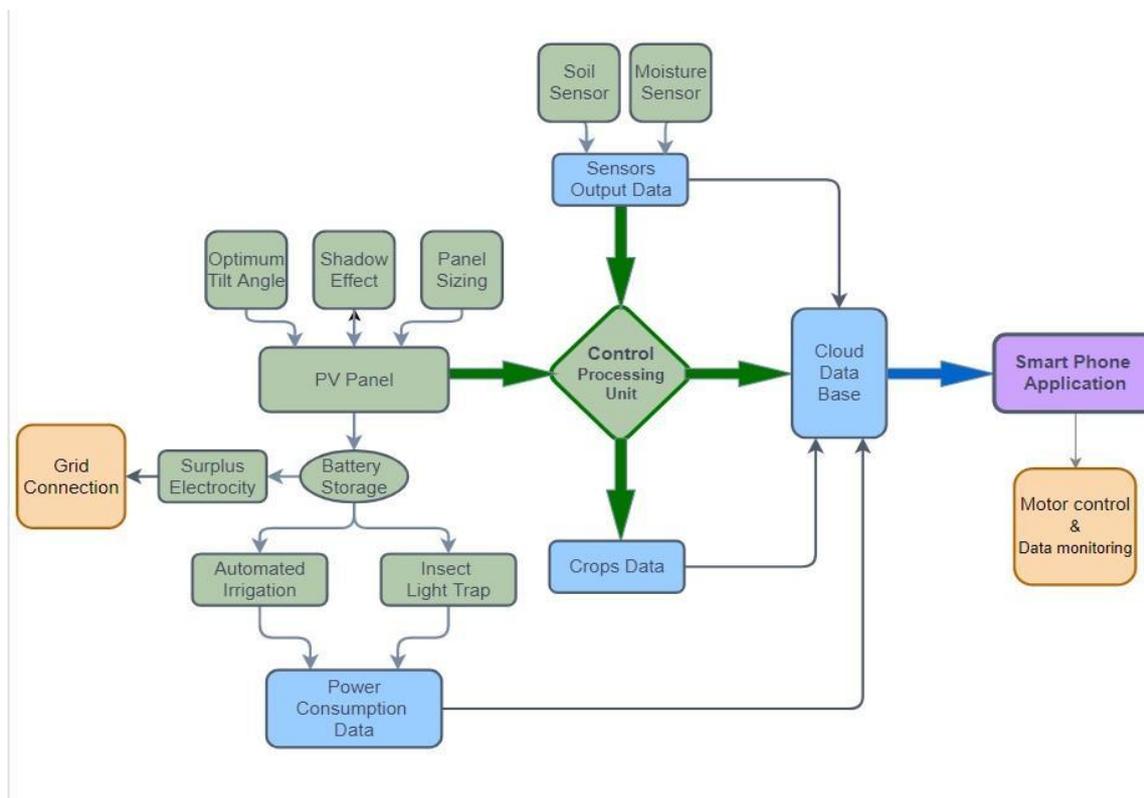


Fig. 3. Block Diagram of Design approach 3

This is the final design approach. Here 3 sensors will be there. DHT11 sensor, NPK sensor, Soil moisture sensor. Every sensor will be connected with the main Microcontroller. Here before setting up the PV panel, we will do the panel sizing & calculate the optimum tilt angle. Then we will do the shadow analysis of those panels. Based on these analysis we will set up the PV panels. Same as before there will be a battery to store the energy. Surplus energy will go to the Grid. From the battery all the sensors, motor and insect light trap will be powered up. Here also based on the soil moisture sensor data motor will be automated. Farmer will be able to control the motor from their web dashboard and mobile application as well. All the sensor data will go to the cloud database & farmers will be able to monitor all these data from the cloud.

Pros-

- Stakeholders can get real-time data regarding soil, crops, and irrigation online.
- Irrigation will run automatically based on sensors data which will minimize the water consumption

- PV panels will be set in such a way that can maximize the crops and electricity generation.
- Surplus energy will go to the national grid which can increase the revenue of landowners.

Cons-

- This system will be a bit complex to implement as it has lots of subsystems.

2.3 Describe multiple design approach

Existing design approach 1:

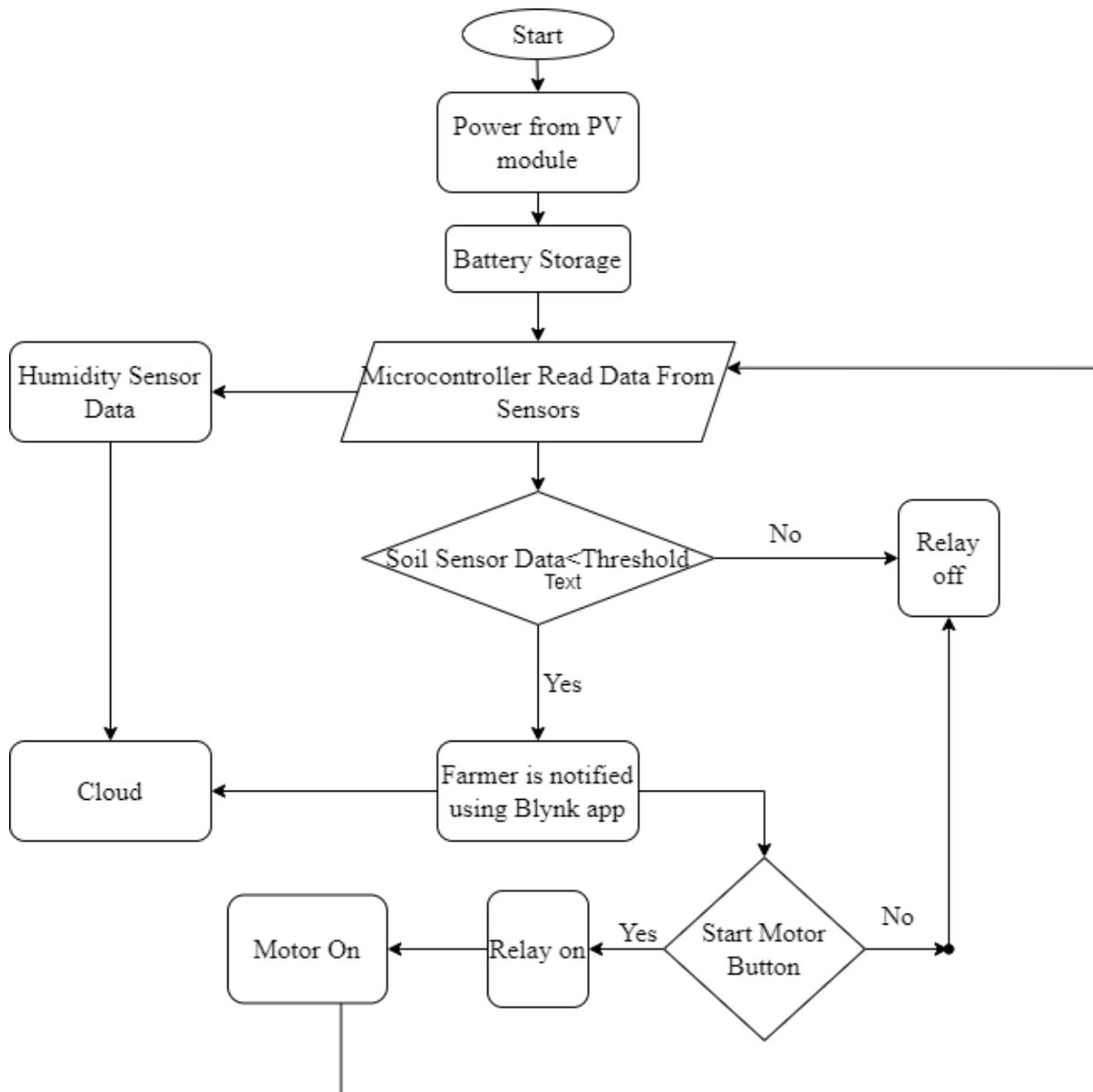


Fig. 4. Flow chart of Design approach 1

The PV module will generate energy and will be stored in the battery, then the battery will power the microcontroller which will read the value of the attached sensor and store the values

in cloud. After reading the value of sensors it will compare the value of soil sensor data to threshold value and if value is less than threshold value then it will notify the user and the user will be able to turn of the water pump motor manually using mobile blynk application.

Existing design approach 2:

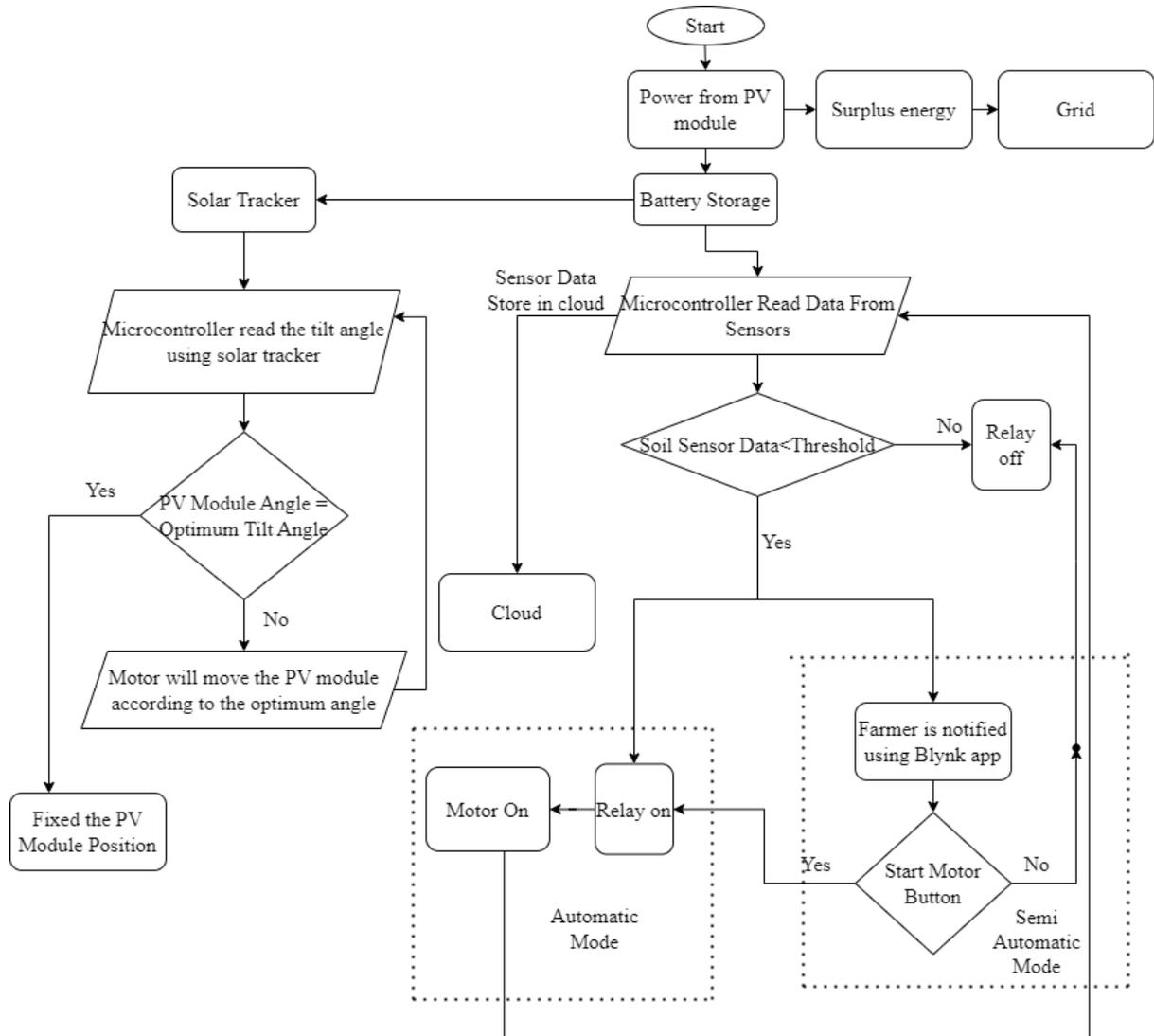


Fig. 5. Flow chart of Design approach 2

The pv module will generate energy and will be stored in the battery, then the battery will power the solar tracker which will send the data of tilt angle to the microcontroller and microcontroller will send the signal to motor to adjust the panel tilt angle according the optimum tilt angle and fixed it and power the microcontroller which will read the value of the attached sensor storing the values in cloud. After reading the value of sensors it will compare the value of soil sensor data to threshold value and if value is less than threshold value then it will notify the user and will automatically start the water pump and when the value will be greater than threshold value the pump will automatically shut off. The user will also be able to turn of the water pump motor manually using mobile blynk application.

Existing design approach 3:

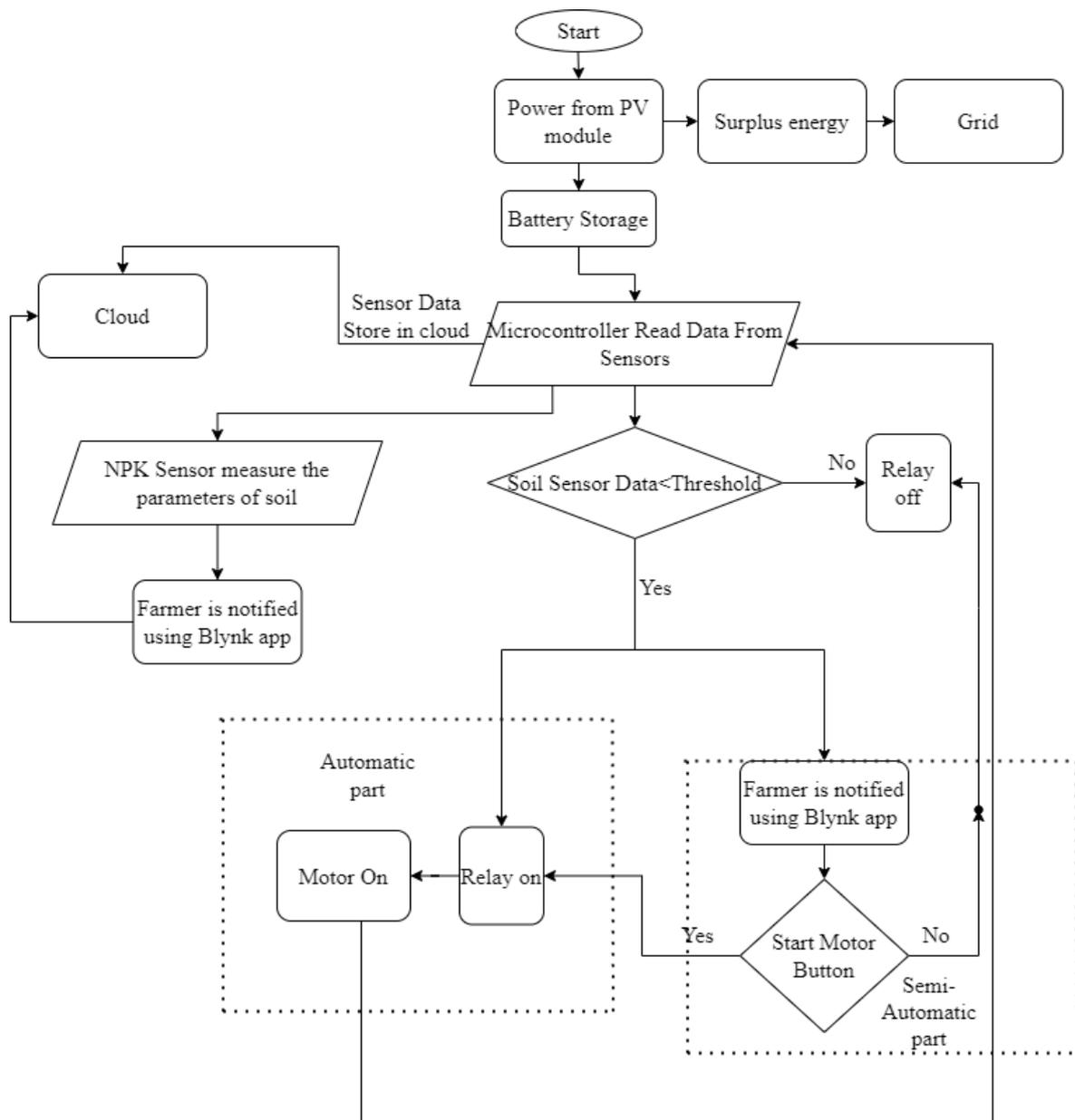


Fig. 6 . Flow chart of Design approach 3

The pv module will generate energy and will be stored in the battery, then the battery will power the microcontroller which will read the value of the attached sensor and store the values in cloud. After reading the value of soil sensor it will compare the value of soil sensor data to threshold value and if value is less than threshold value then it will notify the user and will automatically start the water pump and when the value will be greater than threshold value the pump will automatically shut off. The user will also be able to turn off the water pump motor manually using a mobile blynk application. Besides the microcontroller will read the value from NPK sensor and will notify the values through blynk interface to the user

2.4 Analysis of multiple design approach

2.4.1 Qualitative assessment:

TABLE 5: Qualitative assessment the three design approaches

Topics	Design Approach 1	Design Approach 2	Design Approach 3 (proposed)
Optimum Power Production	(X)	(√)	(√)
Crops Production	(√)	(X)	(√)
Automated Irrigation	(X)	(√)	(√)
Cloud Database	(X)	(√)	(√)
Smartphone Application	(X)	(X)	(√)
Energy Storage	(√)	(√)	(√)
LCD Screen	(√)	(X)	(√)
Automatic Monitoring System	(√)	(√)	(√)

2.4.2 Quantitative assessment:

TABLE 6: Quantitative analysis of the three design approaches

Selection Criteria	Percentage out of 100	Design Approach 1	Design Approach 2	Proposed Approach
Ease of Use	15	10	11	14
Durability	10	7	8	9
Ease of Manufacture	10	7	6	9
Feasibility	12	6	7	10.5
Availability of Components	15	10.5	9.5	14.5
Complexity level of working	10	7	9	11
Budget	15	9	9	13.5
Environmental Friendliness	5	3	4	4.5
Risk and Safety	5	2.5	3	4.5
Total (Out of 100)	100	62	66.5	90.5

*Scoring is done by the four members

2.5 Conclusion

To sum up, a smart Agrivoltaic system design approach is an optimistic solution to the challenge of generating clean energy and by ensuring the bilateral use of land we can co-generate clean energy with selected crops along with incorporation of IoT to get notified about soil nutrient and improving water management to ensure proper irrigation with less amount of water.

As world's leading nations and organizations become aware of generating clean energy to reduce the carbon footprint, the demand for renewable energy is likely to grow. With the practical functionality this setup is extremely beneficial for the country and farmers like us because it not only generates and meets the demand of electricity but also saves the crops from extreme heat along with reduction in manual labour and water waste. The development and

implementation of smart Agrivoltaic systems will undoubtedly play a key role in achieving these goals.

Chapter 3: Use of Modern Engineering and IT Tool.

3.1 Introduction

Smart Agrivoltaic system has been developed by using modern engineering tools like NPK sensor, soil moisture sensor, automated solar pump and smartphone application which makes the system feasible and fruitful.

3.2 Select appropriate engineering and IT tools

In order to design our project numerous engineering tools are required. They can primarily be divided into three sections.

1. Design tools.
2. Simulation tools.
3. Coding tools.

3.3 Use of modern engineering and IT tools

Design Tools

TABLE 7 : Selection of Design Tools

Criteria	Sketchup 3D	Autocad	Blender
Prerequisite of Usage	√	×	×
Ease of Learning	√	×	√
Architectural Model Design	√	×	×
3D Rendering	×	√	√
Quality of Design	√	√	√

The Sketchup is a 3D modeling software that can be used to produce 3D objects in a 2D terrain. Whether you plan to model for 3D printing or for other purposes, Sketchup offers all the tools demanded to produce professional and quality results indeed for a freshman. It's designed for high-quality 3D modeling programs in architectural design. The software is veritably friendly to design anything with the knowledge of 1 or 2 tutorial sessions from YouTube.

Blender is a free and open-source 3D creation suite. It supports the wholeness of the 3D channel i.e. modeling, apparel, vitality, simulation, picture, compositing and stir shadowing, indeed videotape editing and game creation. Though this tool provides some unique features, it

requires previous knowledge and is tough to learn the designing styles. also it isn't that good in architectural design which is a crucial demand for us.

AutoCAD is the CAD software used by millions around the world. It can be used to produce precise 2D and 3D delineations and models, as well as electrical plates, construction delineations, and more. Despite having a large community and good quality design, AutoCAD isn't good for architectural model design compared to SketchUp and it isn't friendly to learn. Moreover learning this tool for a freshman is very time-consuming.

Simulation tools

TABLE 8: Selection of Circuit Simulation Platforms

Criteria	Proteus	Tinkercad	AUTOCAD Eagle
Component availability	√	×	×
Ease of Learning	√	×	×
Schematic design	√	√	×
User Interface	√	√	√
Pricing	√	√	×

Tinkercad Circuits is a popular digital and analog electronics simulator for hobbyists, students, and makers. But it is more like an online 3D modeling program that runs in a web browser. So it is good for 3D design. The components library is not that rich and the schematic diagram from Proteus is better than this. We are not familiar with this.

EAGLE is electronic design automation (EDA) software that lets printed circuit board(PCB) designers seamlessly connect schematic diagrams, component placement, PCB routing, and comprehensive library content. Mainly it is good for PCB designing and it is new for us.

Proteus is a popular software tool used primarily for electronic design automation. Because our project is based on an Arduino, the majority of the components can be found easily in the most recent software updates. We used various sensors from the Proteus software library. If a component is not discovered in the library, we may quickly gather and upload it in the library. For real-world simulation experience, we must execute circuit design code and evaluate the results. It is simple to upload code into the circuit through CodevisionAVR or Arduino, which was required for this project. Furthermore, we are already familiar with this software. from lab courses. So based on this analysis, we have selected Proteus for our circuit design.

TABLE 9: Selection of solar energy simulation Platforms

Criteria	PVsyst	PVWatt	HelioScope
Detailed Analysis	√	×	√
Ease of Learning	×	√	√
Financial Analysis	√	×	×
User Interface	√	√	×
3D Scene design	√	×	√

HelioScope is a web-based sales and design tool for solar professionals. It features a 3D design engine and energy yield simulation, a detailed financial calculator and a drag-and-drop proposal editor. HelioScope has become one of the most popular solar PV design tools today. It is easy to use and simple to understand. It has a lot of functionalities that are essential to anyone who is new into solar energy. This tool aims to simplify the process of designing and engineering of solar power systems. But CAD drawings are very basic here, and Off-grid/Hybrid system design is not possible. Moreover financial analysis is not possible.

PVWatts is a calculator developed by NREL (National Renewable Energy Laboratory) that estimates the energy production of grid-connected photovoltaic (PV) energy systems throughout the world. It allows homeowners, small building owners, installers and manufacturers to easily develop estimates of the performance of potential PV installations. However, it is important to note that photovoltaic system performance predictions calculated by PVWatts include many inherent assumptions and uncertainties and do not reflect variations between PV technologies nor site-specific characteristics except as represented by PVWatts inputs. Moreover, in this app/website we cannot import new components, updated meteo data and 3D design is not possible here. This is a basic analysis tool for beginners but for those who need detailed analysis that can't be possible here

PVsyst is a PC software package for the study, sizing and data analysis of complete PV systems. It deals with grid-connected, stand-alone, pumping and DC-grid (public transportation) PV systems, and includes extensive meteo and PV systems components databases, as well as general solar energy tools. This software is geared to the needs of architects, engineers, researchers and is also a very useful educative tool. It includes a detailed contextual Help menu that explains the procedures and models that are used, and offers a user-friendly approach with a guide to develop a project.

So based on this analysis, we have selected PVsyst for our solar energy calculation.

Coding Tools:

TABLE 10: Selection of Coding Platforms

Criteria	Arduino IDE	Platform IO	Geany
Component Library	√	√	×
Ease of Learning	√	×	×
Development board variety	√	×	×
User Interface	√	×	×
Community Help	√	×	×

Geany is the coding platform for Raspberry Pi. It provides several features. Variation of development board supported by Geany is lower compared to Arduino IDE and Platform IO. In terms of the availability of the components library, other good options are available. The supporter community is lower and its a bit tough to learn this platform. Moreover Raspberry pi is currently very expensive.

Overall this one is perfect for this project, Platform IO is used for coding platform purposes. But most of the users are not familiar with this platform. As the user base is lower compared to Arduino IDE, the available community is smaller and the setup of this platform is quite hard. Limited tutorial sessions make it difficult to learn the techniques. The variation of the development board is lower compared to Arduino IDE.

The Arduino IDE is the most used platform nowadays. It has a huge collection of component libraries and there is a huge community available for helping if any kind of problem is detected. As there are lots of users, a huge amount of tutorial sessions are available. So, it will be easier to learn.

Based on this analysis we have selected Arduino IDE as the coding platform.

3.4 Conclusion

In order to develop our project efficiently and successfully, we choose the design, simulation, and coding tools based on the criteria shown above. While doing so, we also evaluated the possibilities of simplicity of use, time constraints, and resource availability so that we could design the project as needed. When selecting a design tool, usability was a primary priority. Selected tools provide straightforward interfaces and user-friendly features to assist designers in quickly and accurately creating models and simulations. Prioritizing usability allows designers to spend more time designing and testing projects rather than struggling with complex tools and features, resulting in more efficient projects. Another crucial factor to consider while selecting an appropriate design tool was time restrictions. The tools of choice facilitate rapid prototyping, allowing the team to swiftly construct and test several project iterations. This is crucial for fulfilling tight project timelines while keeping high quality and accuracy standards.

In conclusion, selecting the appropriate design, modeling, and coding tools is crucial to the successful implementation of a Smart Agrovoltaic System. Projects can be done promptly and effectively while retaining high quality and accuracy by considering simplicity of use, time restrictions, and resource availability.

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

4.1 Introduction

In order to meet the functional and nonfunctional requirements, three different design approaches were proposed. Moreover, the three design approaches have been compared in terms of requirements. The design that is considered to be the optimal solution and selected to proceed for implementation is optimum in terms of energy generation, crops production, automated irrigation, soil fertility detection and providing the data in mobile phone application. Furthermore, implementation of this design approach is cost effective as well.

4.2 Optimization of multiple design approach

4.2.1 Design Approach1

Approach 1 Simulation:

This is the simulation of our Approach 1. We simulated the circuit in Proteus.

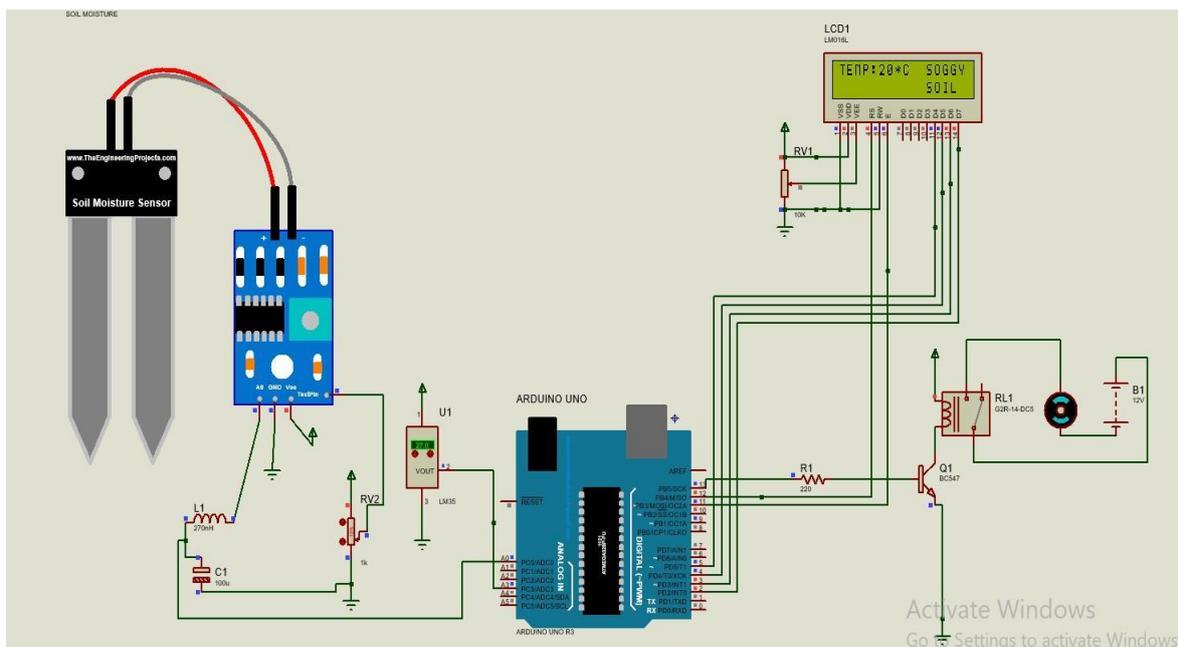


Fig. 7. Proteus Simulation of Approach 1

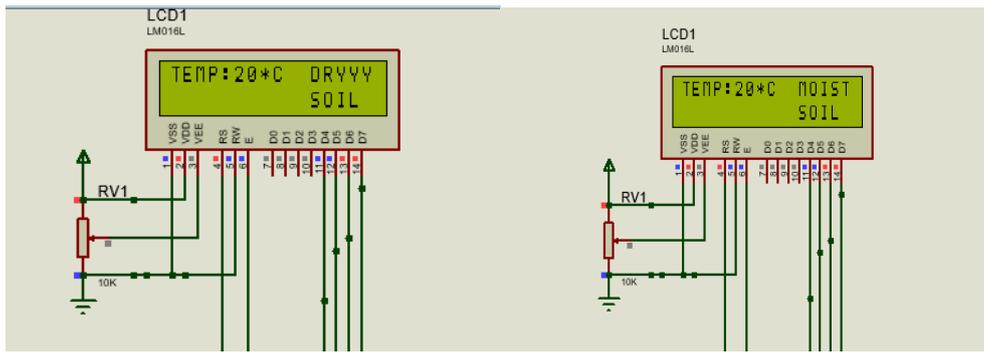


Fig. 8. Displaying the Temperature value & Soil Moisture Condition in LCD.

Our approach 1 is a manual approach. The system will be under a Greenhouse structure. Here we used a Soil Moisture sensor and a temperature sensor. We used a potentiometer to increase and decrease the values of the soil moisture sensor. When the potentiometer is in low state it means the soil is soggy. There is no dryness in the soil. So we don't need to start the water pump. So the temperature value and the soil condition will be shown in the display like this. Farmers can see the LCD screen and can take steps. When the potentiometer value is high it means soil is very dry. So after seeing this on the screen, Farmer can start the motor manually.

4.2.2 Approach 1 3D design:

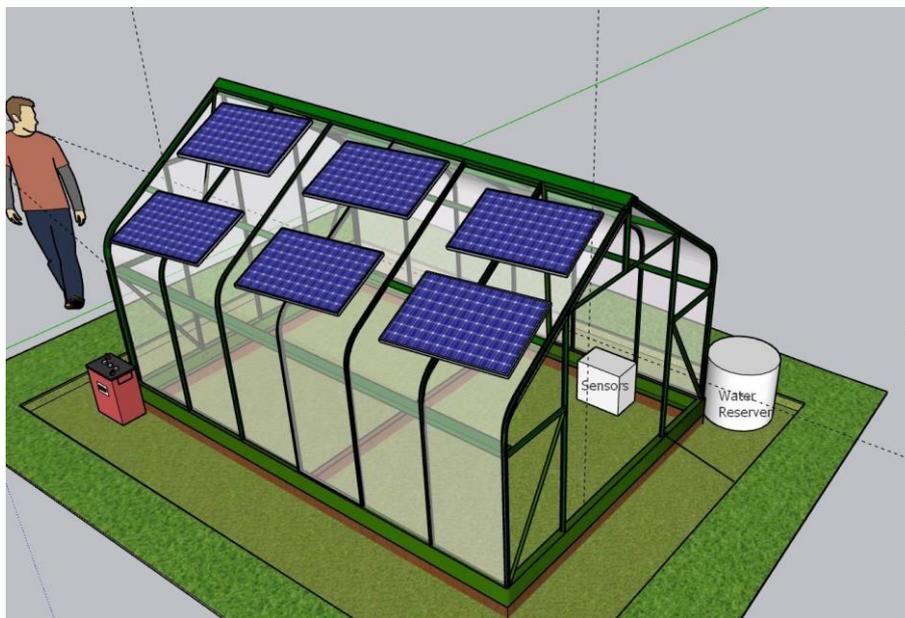


Fig. 9. 3D Design of approach 1

4.2.3 Approach 2 Simulation:

Our second approach is a solar tracker-based approach. Here before the solar tracker simulation we simulated the energy. We did the energy simulation in PVsyst software. But in this approach the shading effect on crops will be more but the energy production is high.

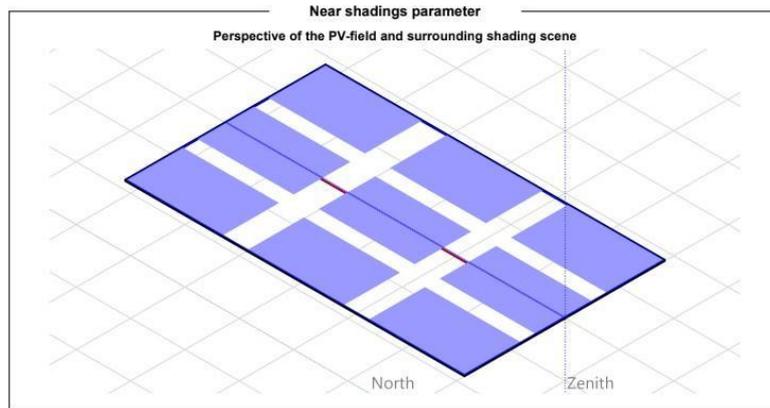


Fig. 10. Solar Tracker Orientation (East-West)

In this approach, our main focus is to generate more electricity. So we simulated the tracker by doing North South orientation & also East West orientation. We found that East West orientation of the tracker gives us better power output. So we selected The East West orientation.

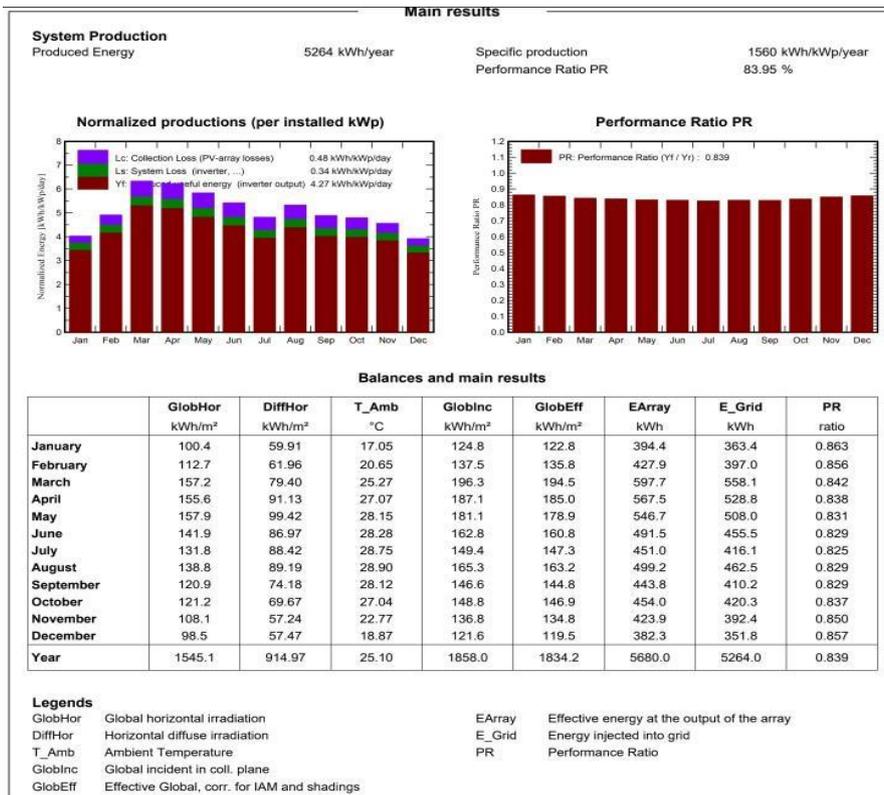


Fig. 11. Energy Production & Supply to the Grid

From our simulation report we got that with this East West orientation of our tracker and with Minimum tilt angle -60 degree & maximum tilt angle +60 degree, we can supply 5264 kWh/year of energy to the grid from our 9 PV module.

Proteus Simulation:

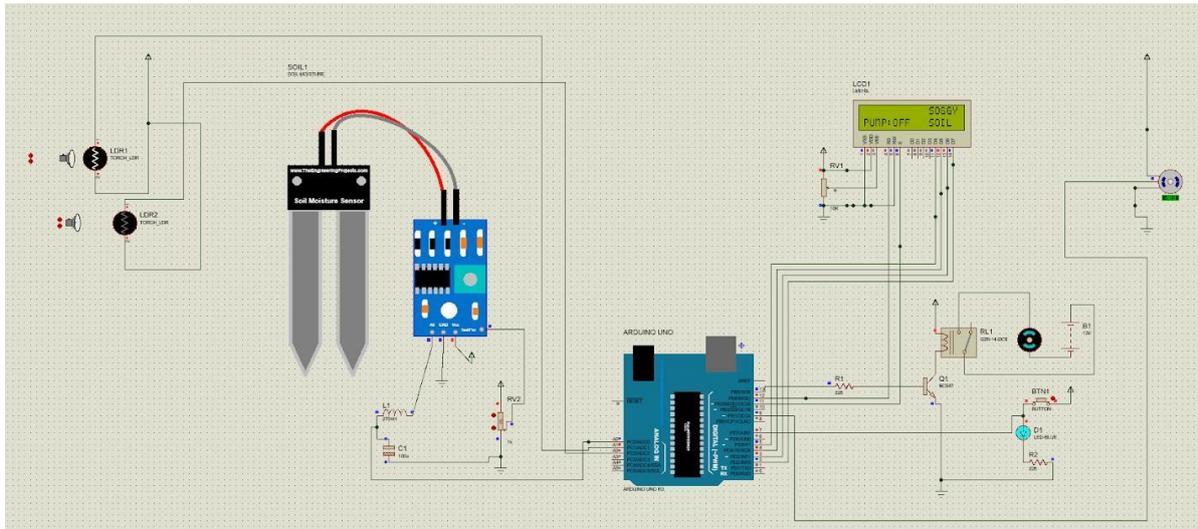


Fig. 13. Proteus Simulation of Approach 2

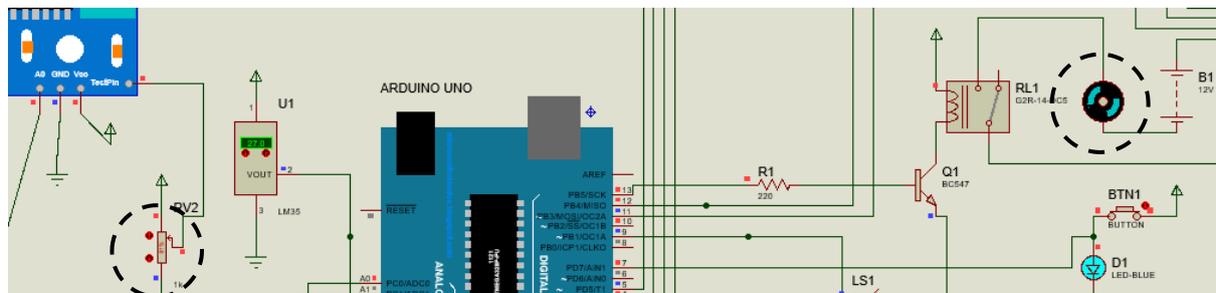


Fig. 14. Potentiometer value low, Motor on

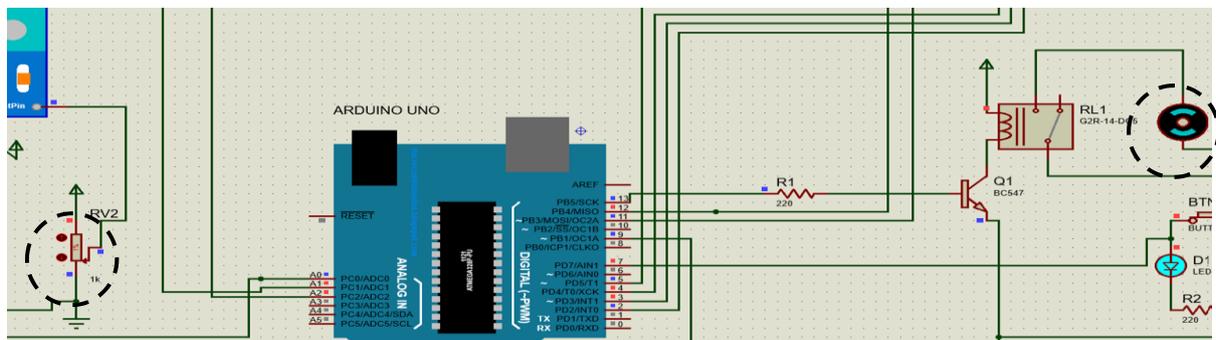


Fig. 12. Potentiometer value High, Motor off

Here we are using LDR sensors to track the light and servo motor to rotate accordingly. Like the previous approach we are using a moisture sensor to get the data and show it on the lcd screen. But in this approach the starting of the water pump or motor is autonomous. When the moisture sensor value is low it means the soil is soggy. So no water was needed. Motor will be off. But when the value of potentiometer is high it means the soil is very dry then the motor will be started automatically because we code the micro-controller in this way.

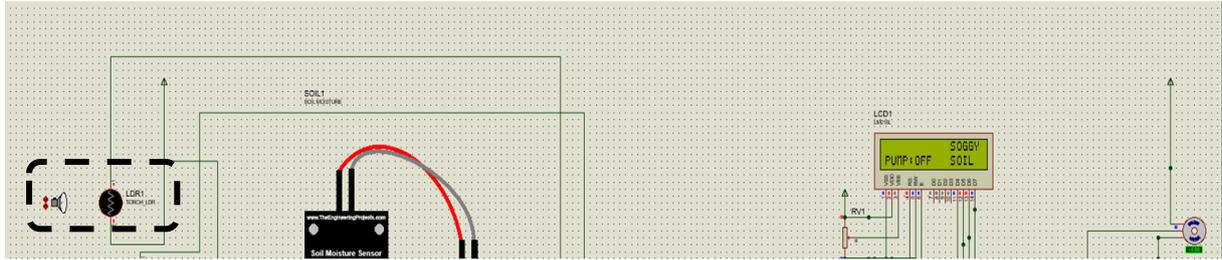


Fig. 15. Light is away from the LDR so the motor is not rotating

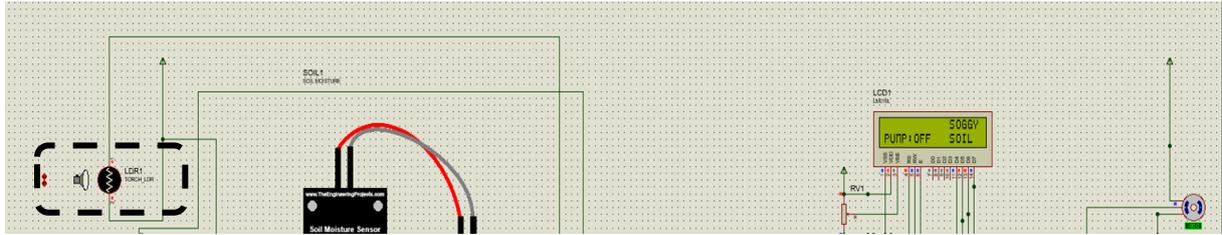


Fig. 16 . Light is away from the LDR so the motor is rotating

Here when the light is away from the LDR sensor, the servo motor is not rotating. It means the solar tracker will not rotate at that time. But when we bring the light closer to the LDR the motor starts rotating backward. It means there will be backward rotation of the solar tracker and it will track the full sun path to capture the sunlight.

4.2.4 Approach 2 3D design:

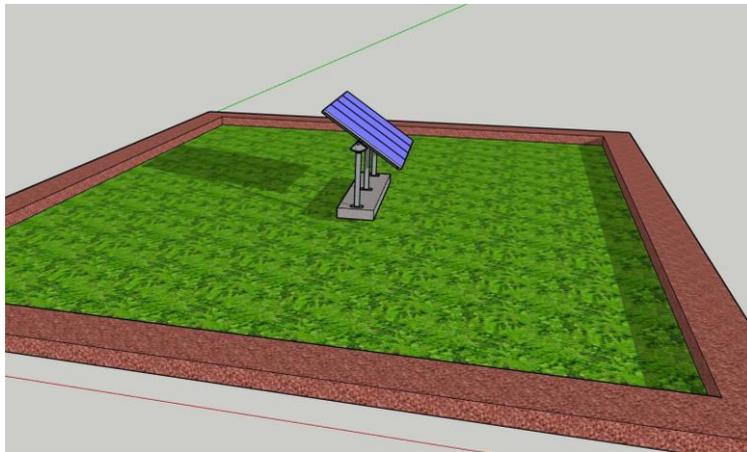


Fig. 17. 3D Design of approach 2

4.2.5 Approach 3 Simulation (Proposed One):

We are considering our third design approach as the best design approach. This is based on a fixed tilted P panel. In this approach we tried to minimize the shading effect on crops by pv panel sizing and shading analysis. We also tried to generate the maximum electricity while minimizing the shading effect.

At first we did the energy simulation in PVsyst software. Here is the simulation report:

System Production

Available Energy 69082 kWh/year
 Used Energy 972 kWh/year
 Excess (unused) 67460 kWh/year

Specific production 1410 kWh/kWp/year
 Performance Ratio PR 1.21 %
 Solar Fraction SF 100.00 %

Loss of Load

Time Fraction 0.0 %
 Missing Energy 0 kWh/year

Battery aging (State of Wear)

Cycles SOW 93.1 %
 Static SOW 90.0 %

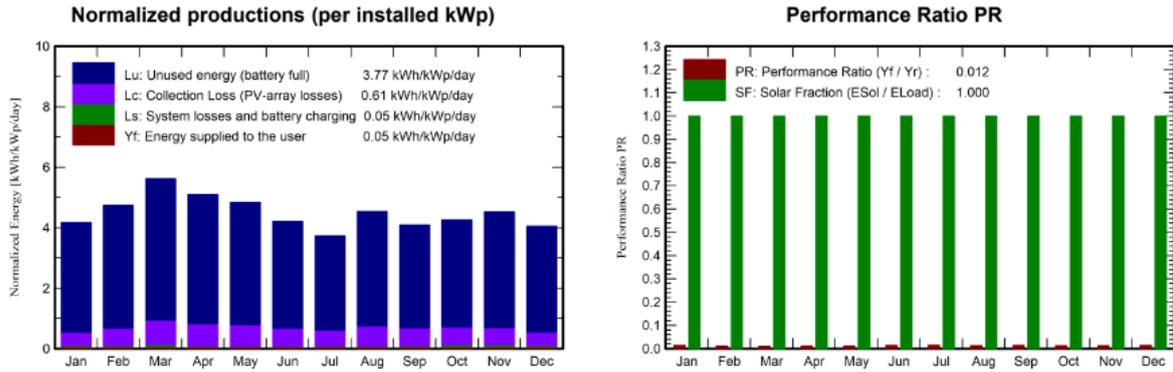


Fig. 18. System production & Performance ratio graph

TABLE 11 : Month Wise Energy Production and uses

Month	GlobHor kWh/m ²	GlobEFF kWh/m ²	E_Avail kWh	E_Unused kWh	E_load kWh
January	103.2	126.9	5640	5494	82.58
February	113.1	130.3	5686	5556	74.59
March	159.5	170.8	7283	7097	82.58
April	154.0	149.6	6374	6263	79.92
May	159.4	145.9	6230	6126	82.58
June	137.8	122.8	5274	5173	79.92
July	125.0	112.2	4818	4705	82.58
August	145.5	137.1	5860	5747	82.58
September	118.8	119.8	5108	4987	79.92
October	119.1	129.3	5540	5377	82.58
November	109.1	133.4	5797	5619	79.92
December	98.2	123.3	5471	5317	82.58
Year	1542.7	1601.5	69082	67460	1000

Legends

GlobHor	Global horizontal irradiation
GlobEff	Effective Global, corr, for IAM shadings
E_Avail	Available Solar Energy
EUnused	Unused Energy
E_Load	Energy need of the user(Load)

With our fixed tilt angle we can inject 4289.1 kWh/year energy to the grid. We achieved this result by doing shading analysis, panel sizing and fixed tilt angle by minimizing the shading effect on crops.

Proteus Simulation:

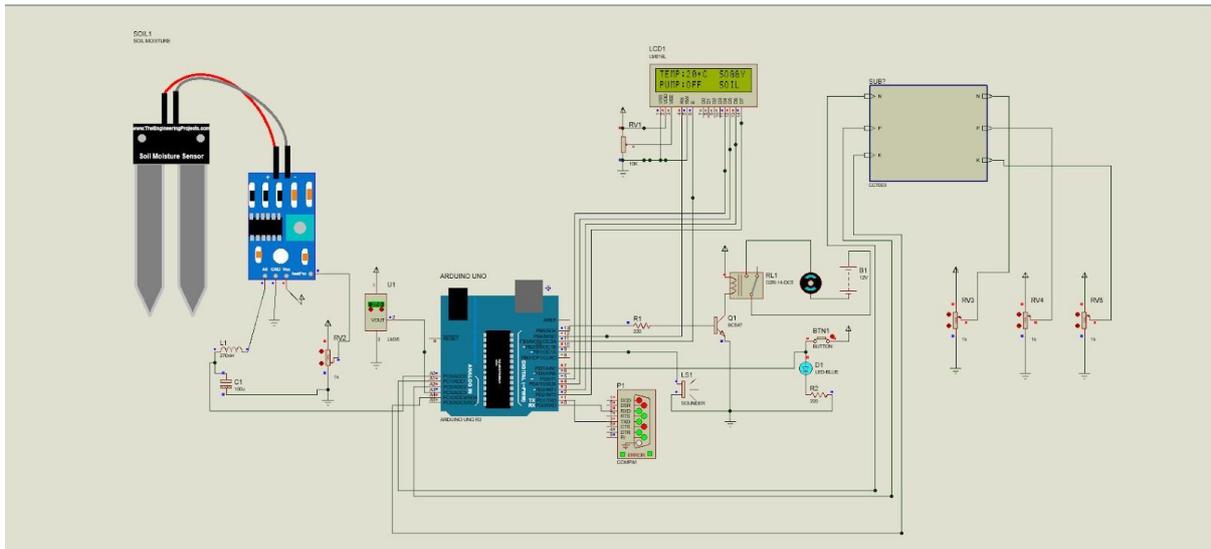


Fig. 19. Schematic diagram of proposed design approach.

Here we are using NPK sensor. There are no such simulation libraries for NPK sensor, so we used 3 potentiometers as N,P & K to demonstrate the simulation. We used a Compim to make a virtual connection between our Proteus simulation file, cloud and mobile app. We can monitor the N,P,K values in our Lcd screen. We can monitor it from the cloud as well.

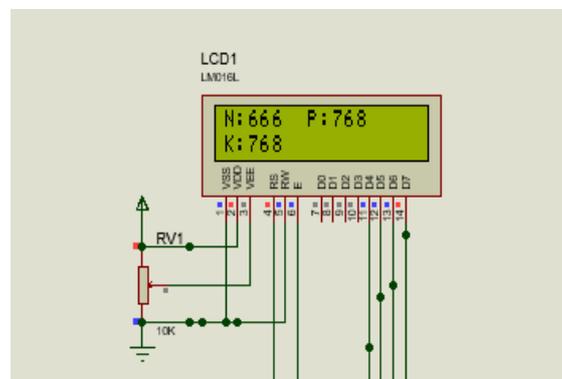


Fig. 20 . N, P, K values shown in the Field Device screen

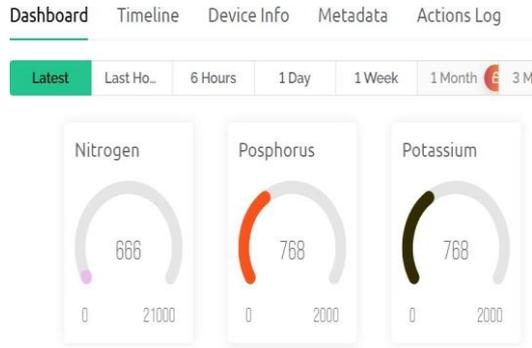


Fig. 21 . N, P, K values shown in the blynk website

Here also when the soil is soggy the motor will be off. When it is dry then the motor will start automatically like the previous one.

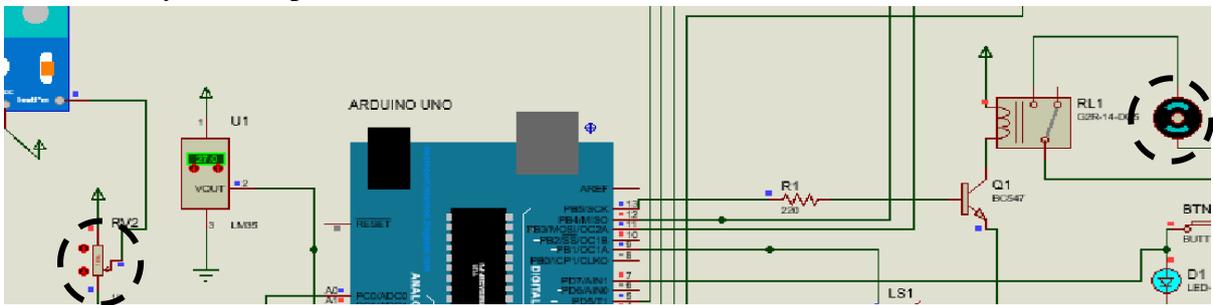


Fig. 22. Dry soil (low potentiometer value) so motor automatically turns off

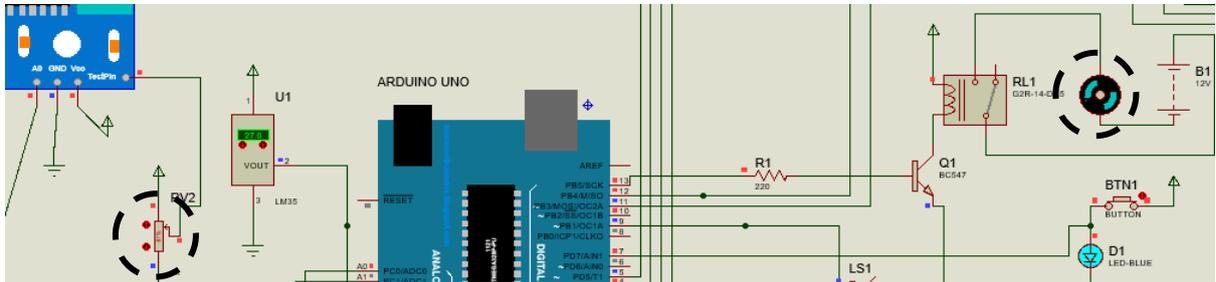


Fig. 23. Soggy soil (High potentiometer value) so motor is on

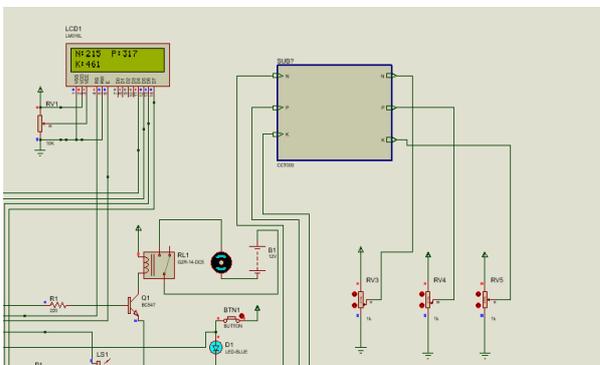


Fig. 24 Lcd values after changing

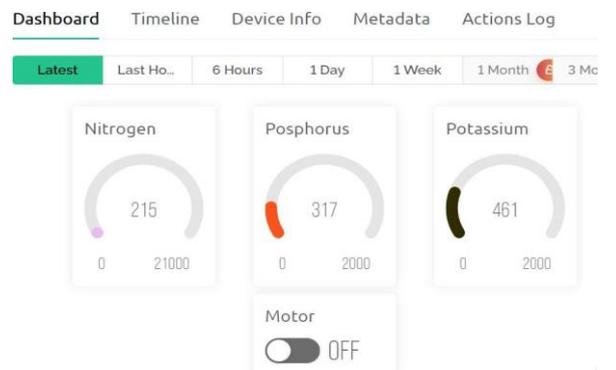


Fig. 25. Cloud Values after changing

After changing the values of N, P & K we are getting the same values in LCD screen and Cloud. We also got the same values in our Mobile application.

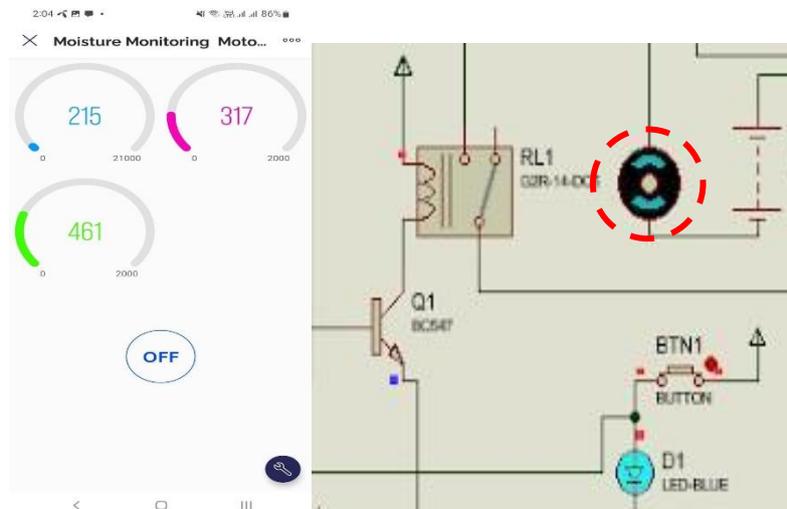


Fig. 26. Motor Control & Monitoring soil nutrients (Motor Off)

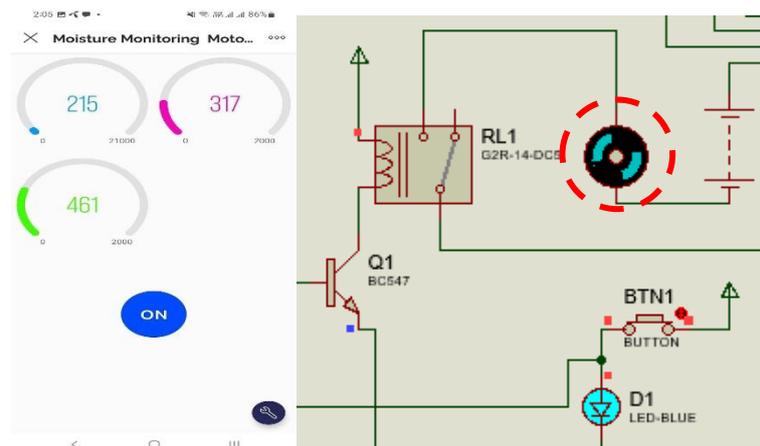


Fig. 27 Motor Control & Monitoring soil nutrients (Motor On)

In this approach we can turn on & off the motor from our real time mobile device through the app. Here in the above pictures we can see that, when the button of our mobile app is off, the motor is also off & When the button is pressed and it is On, the motor is also On. The motor will start automatically based on the soil moisture sensors data and the code in our microcontroller. But we can also control the motor from our mobile application if we want.

4.2.4 3D Design of proposed approach:

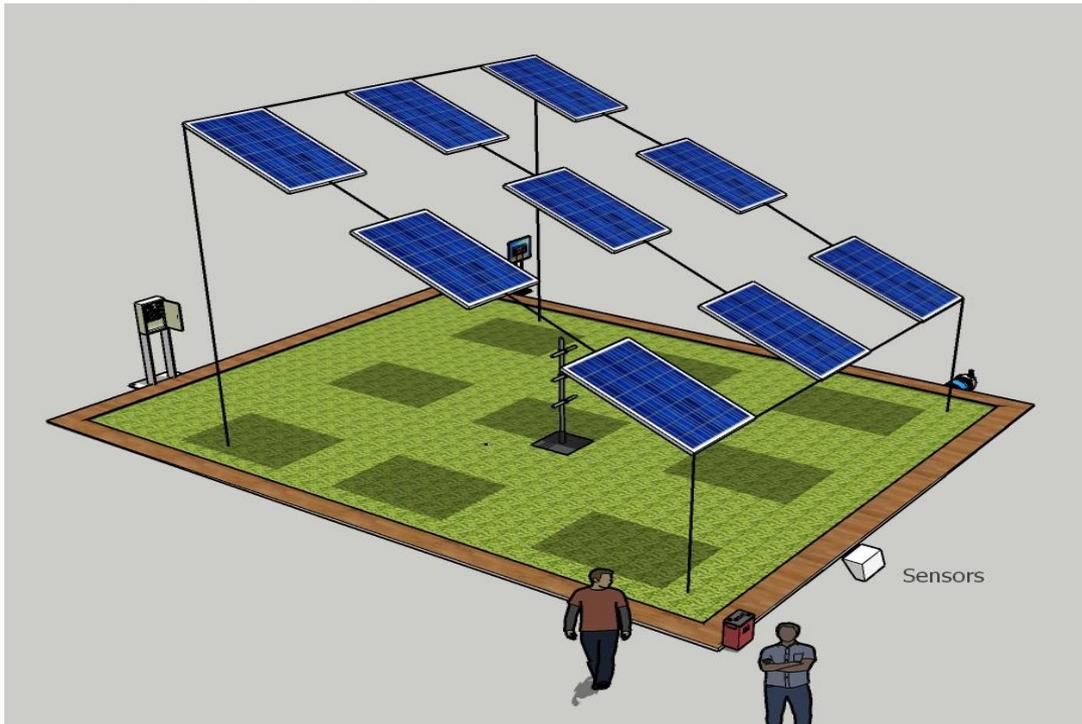


Fig. 28. Left view of 3D design for approach 3 (proposed)

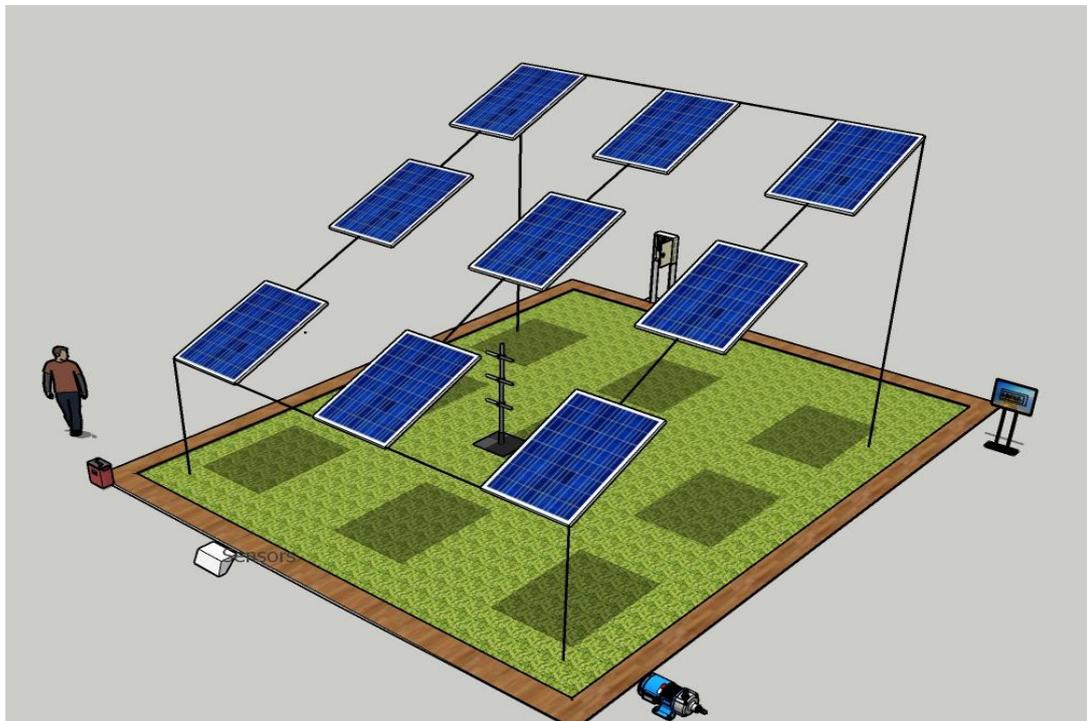


Fig. 29. Right view of 3D design for approach 3 (proposed)

4.3 Identify optimal design approach

TABLE 12: Validation of Existing Approach 1

Requirements	Expected Outcome	Status
Power Production	Production of optimum electricity in order to add income source	Moderate
Effects on Crops	Production of crops should not get affected negatively	Not suitable for all crops
Automated Irrigation	Irrigation should be automated in order to decrease the water consumption and manual interruption	No
Energy Storage	Energy storage is needed in order to use the electricity anytime	Yes
Automatic Monitoring System	All the sensors and data should be monitored by a control processing unit	Yes
Cost	Budget should be cost effective	No

TABLE 13: Validation of Existing Approach 2

Requirements	Expected Outcome	Status
Power Production	Production of optimum electricity in order to add income source	High
Effects on Crops	Production of crops should not get affected negatively	Not suitable for crops
Automated Irrigation	Irrigation should be automated in order to decrease the water consumption and manual interruption	Yes
Energy Storage	Energy storage is needed in order to use the electricity anytime	Yes
Automatic Monitoring System	All the sensors and data should be monitored by a control processing unit	Yes
Cost	Budget should be cost effective	No

TABLE 14 : Validation of Existing Approach 3

Requirements	Expected Outcome	Status
Power Production	Production of optimum electricity in order to add income source	Optimum
Effects on Crops	Production of crops should not get affected negatively	Suitable for crop production
Automated Irrigation	Irrigation should be automated in order to decrease the water consumption and manual interruption	Yes
Energy Storage	Energy storage is needed in order to use the electricity anytime	Yes
Automatic Monitoring System	All the sensors and data should be monitored by a control processing unit	Yes
Cost	Budget should be cost effective	Yes

TABLE 15: Analysis of 3 design approaches

Criteria	Approach 1	Approach 2	Approach 3
Based on	Greenhouse structure.	Solar Tracker.	Optimum tilt angle, shading, panel sizing.
Implementation	Easy	Difficult	Moderate
Power production	Moderate	High	Optimum
Effects on crops	Not suitable for all crops	High shading impact on crops	Moderate
Cost	High	High	Moderate
Acceptance	Low	Low	High

In the above mentioned table we can see the comparison among the three design approaches under the criteria base, implementation, power production, effects on crops, cost and acceptance. The first design approach is based on greenhouse structure which has low acceptance to mass people as it is not suitable for all crops and costs very high but its implementation is easier than other approaches. On the other hand, the design approach 2 is based on solar tracker which also has low acceptance as the shading impact is very high on crops and it is very costly as well. Although solar trackers can help to produce a high amount of electricity, it is very difficult to implement. Here comes the design approach 3 which is

based on Optimum tilt angle, shading, panel sizing having high acceptance among mass people as it is not difficult to implement and has less shading effect on crops compared to the power that can be generated.

4.4 Performance evaluation of developed solution

TABLE 16: Performance evaluation of the proposed model

Requirement	Expected outcome	Validation
Panel sizing & spacing	With the optimized tilt angle the shadow on the agricultural crops will be minimum so shading will be less on the crops.	Validated
Optimized tilt angle	The tilt angle of the PV panels are optimized in such a way so that it can generate maximum amount of energy throughout the year and less shadow over the crops.	Validated
Charging battery through charge controller	PV panels will take solar power and it will store this energy in a battery through charge controller .	Validated
Powering up the sensors and motors	Microcontroller, sensors and the motor take the power which is stored in battery to be powered up.	Validated
NPK Value detection	NPK sensor detects Nitrogen, Phosphorus, Potassium value from the soil and shows it in the oled screen.	Validated
NPK value validation	Comparing the values of N,P, &K from NPK sensor and the soil lab.	Partially validated
Sensor value detection	Soil moisture sensor senses the moisture in the soil and DHT11 senses the temperature and humidity of the surroundings.	Validated
Automatic Irrigation	Motor is automatically turned on/off on the basis of soil moisture value. When the soil moisture value is low the motor is automatically turns on and if the soil moisture value is High the motor is automatically turns off	Validated
Mobile app & web integration	The irrigation process can also be controlled from mobile app or web interface. All the sensors value can be monitored real time in both web dashboard and mobile app.	Validated
Full physical implementation	All the process should be done under the real PV panels in the real agricultural field.	Not Validated

In this performance evaluation table, NPK value validation point was partially validated. The motto was to compare N, P & K values for the NPK sensor and the soil lab. NPK sensor shows the value of N, P & K accordingly 92,23,99. Same soil had been sent to the soil lab of Sher-E-Bangla Agricultural University. But the lab could only manage to provide the potassium content value. And the potassium value from the lab matches with the sensor value. Lab couldn't provide the nitrogen and phosphorus values so the nitrogen & phosphorus values were not validated. Another point which is not validated is the physical implementation of the PV modules. All the process of this project was supposed to be done under the real PV modules in the real agricultural field. But this thing was not possible because it was too much costly to implement. So a small prototype was made.



শেরেবাংলা কৃষি বিশ্ববিদ্যালয়
Sher-e-Bangla Agricultural University
শেরেবাংলা নগর, ঢাকা-১২০৭

Sample -1 = ~~92~~ 100 (PPM)
Sample -2 = 100.01 (PPM)
Sample 3 = 99.9 (PPM)


3/9/2023

Prof. Dr. Md. Saiful Islam Bhuiyan
Chairman
Department of Soil Science
Sher-e-Bangla Agricultural University
Dhaka-1207

Fig. 30. Potassium value from lab test

4.5 Conclusion

In conclusion, we concluded that the third design approach we offered not only fulfills but also surpasses the required objectives after conducting a thorough review of three design approaches utilizing different criteria and taking into account both stakeholder needs and practical testing data.

Chapter 5: Completion of Final Design and Validation.

5.1 Introduction

Completion of final design refers to the implementation of an optimal design approach that meets the functional and nonfunctional requirements and objectives of the project. The implementation will be based on the design with no modifications. In order to complete the evaluation process of the performance of the project, the validity of output and following the feedback is also important.

5.2 Completion of final design

5.2.1 Methodology

- Used Tin as a PV panel in a 120 sq feet field to see the difference between the weight and other parameters of crops of shaded and unshaded area.
- After getting the result, Used the latitude-longitude of the selected land to determine the optimized tilt angle and did the shadow analysis for the solar panel in the selected field.
- Choose the most optimized tilt angle where the produced electricity will be high and the crop production will hamper the least.
- Calculated the overall Incident energy of the selected area using MATLAB.
- Used PVSyst software to calculate the overall produced energy, surplus energy, and how much money farmers can earn by selling the produced electricity.
- The produced energy from the solar panel will be stored in the battery through a solar charge controller and from the battery and motor and everything will run from the battery. For our Prototype we used a 12V battery.
- The output data from multiple sensors, will all be kept in the cloud database.
- The soil's levels of nitrogen, phosphorous, and potassium will be determined from the data gathered by the soil sensor.
- This system will be controlled by a smartphone application and it has been built using the principles of digital logic. Motor will be turned on/off automatically based on the soil moisture sensor data.
- The electricity produced by the PV panels will be used to power the irrigation system.
- Online real-time data on soil conditions, and irrigation activities would be available to stakeholders.

5.2.2 Analysis for the design

To implement the project, energy analysis is required. It is required to calculate the incident energy to know the fact that how much energy can be produced by the solar panel. Monthly incident energy and daily average incident energy for a whole year has been done in Matlab Software using the formulas.

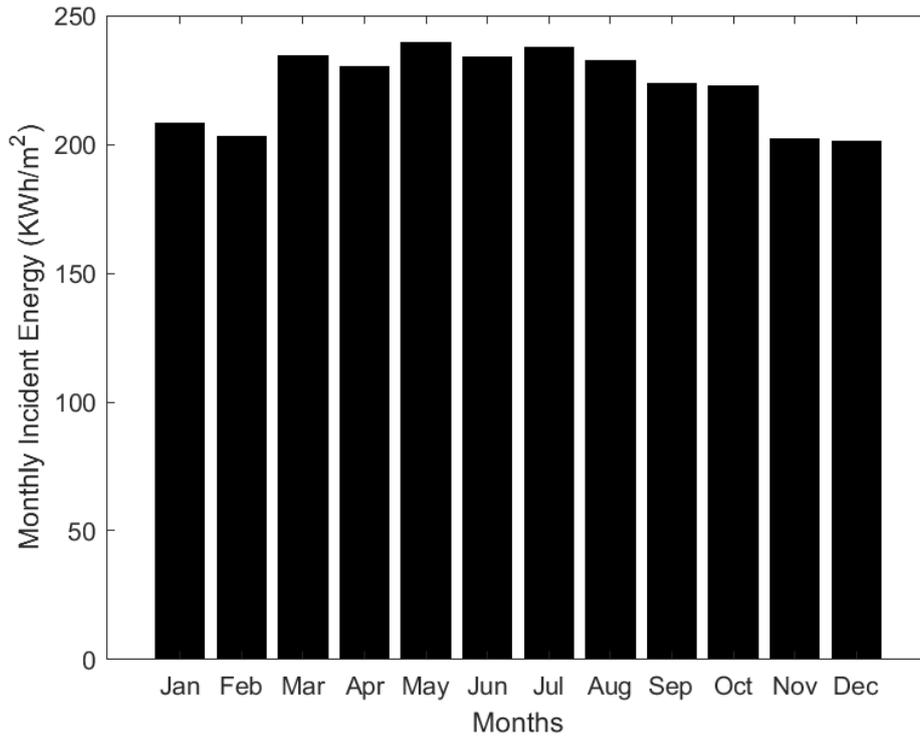


Fig. 31. Monthly incident energy

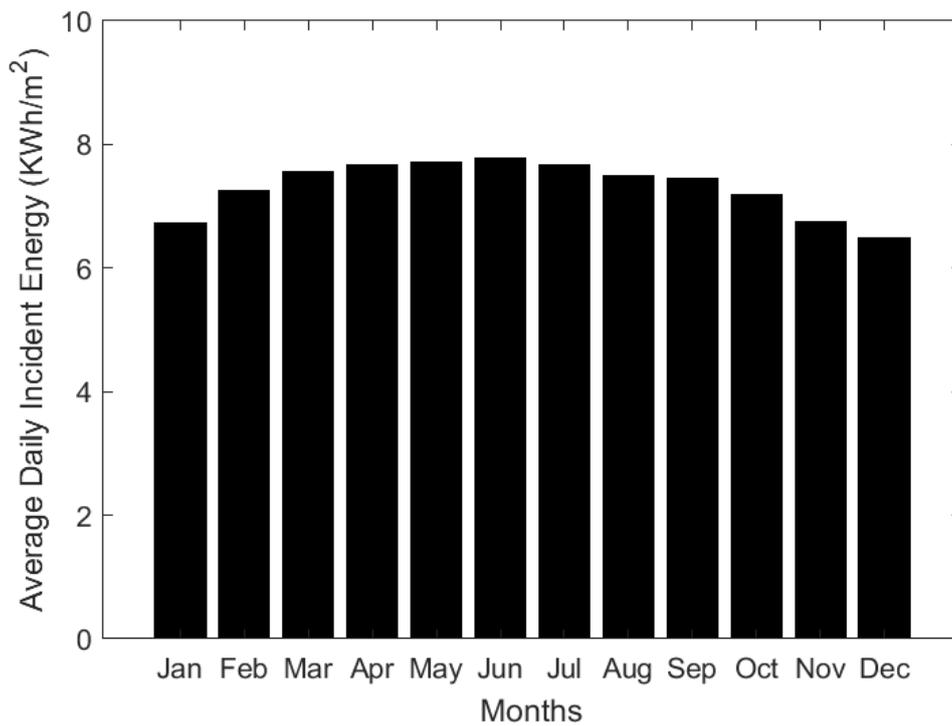


Fig. 32. Daily average incident energy

After calculating these things it is important to know if the PV panels are placed with the optimum angle and optimum position, how much energy can be produced by the PV panels. This simulation has been done by PVsyst Software. The below graph shows how much energy can be produced by the PV modules.

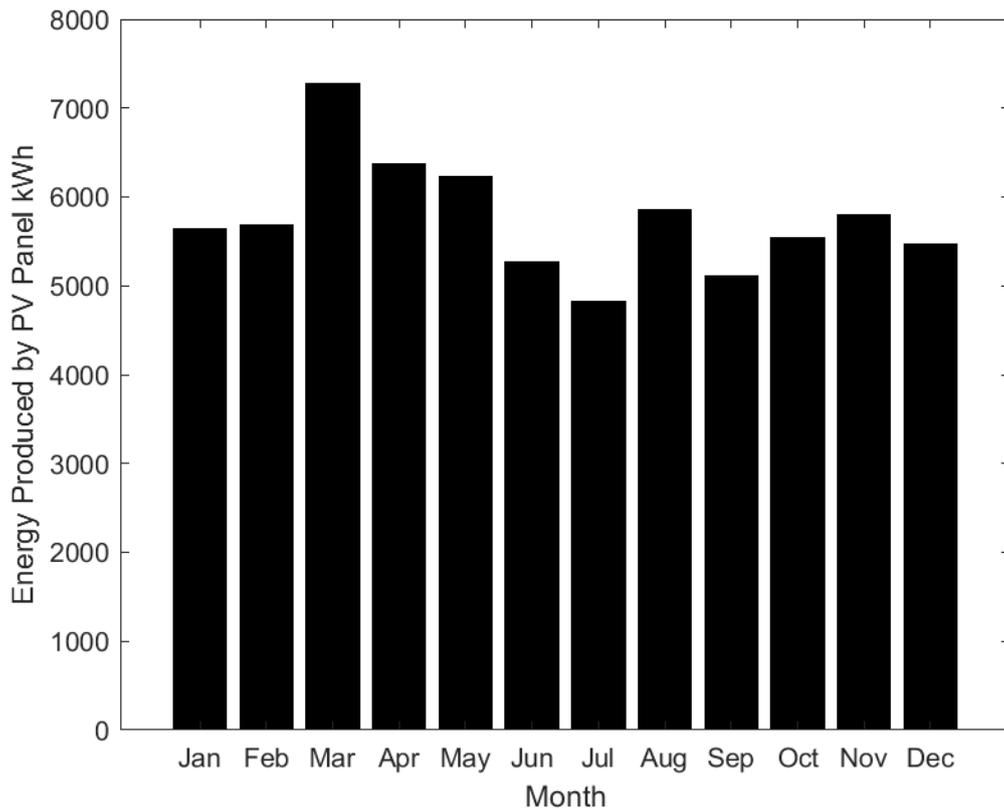


Fig. 33 . Energy produced by PV panels each month

5.2.3 Physical implementation and results:



Fig. 34. Test site

This is the physical implementation of the system. Here tin has been used to see the worst case. No sunlight can be transmitted through tin. So the use of tin as a PV module will cause more shadow to the crops. It is implemented over 120 square feet of area.



Fig. 35. After harvesting



Fig. 36. Paddy from unshaded region



Fig. 37. Paddy from shaded region

This is the result of the weight of crops in shaded and unshaded areas. The area (120 sq feet) which was under the tin is considered as Shaded area and the other part is considered as an unshaded area. It was found that production of the crops in 120 square feet shaded area was 5.770 kg and production of the crops in 120 square feet unshaded area was 7.01 kg. There was a 1.24 gap in production between the two areas. But if the PV panel were used instead of tin, the crops in the shaded region could increase because light can be transmitted through solar panel and crops could get more sunlight. Total grain of some the shaded and unshaded region was also calculated manually for some of the samples. The below graph is based on the total grain of shaded & unshaded regions for 15 samples.

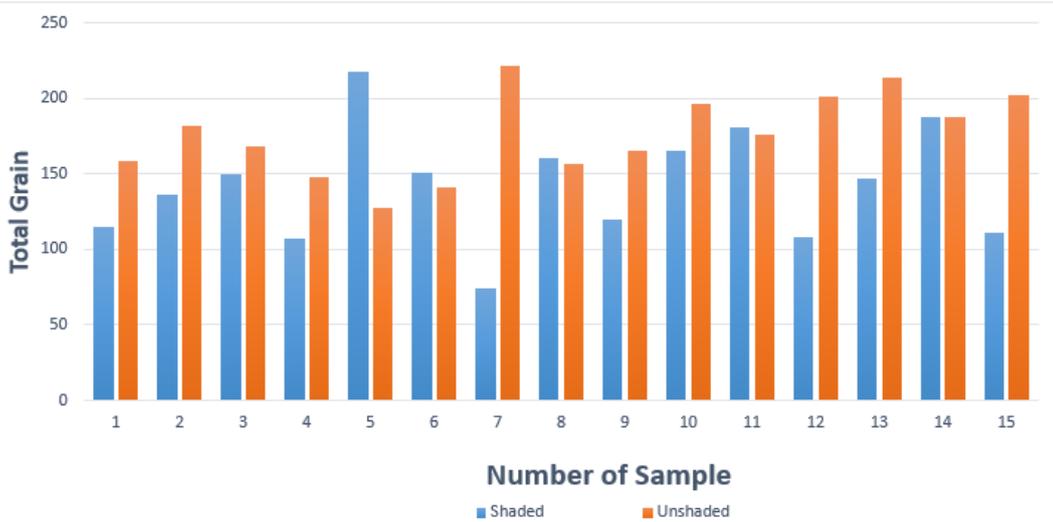


Fig. 38. Shading Impact

Prototype concept design

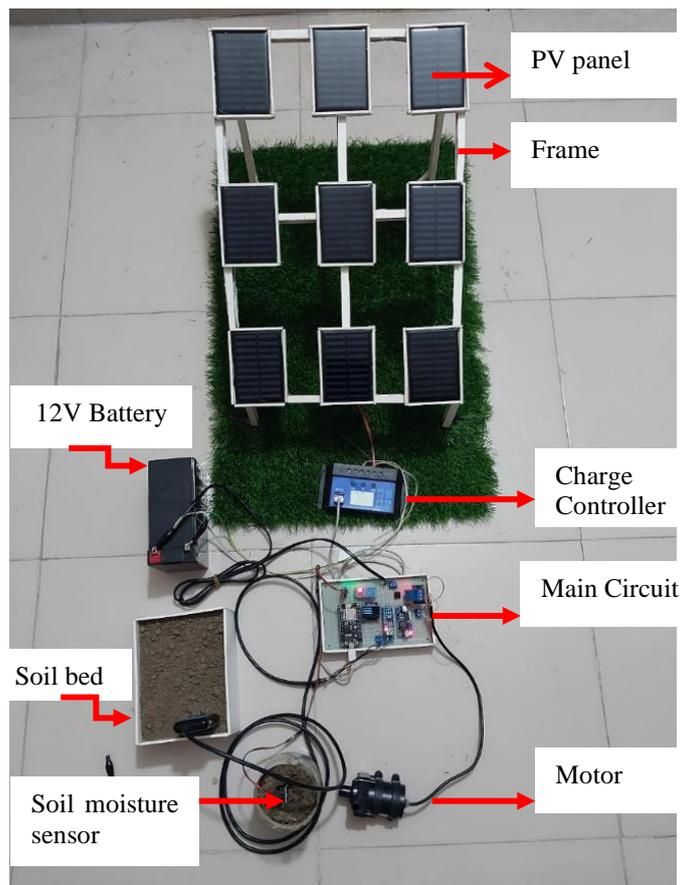


Fig. 39. System Prototype

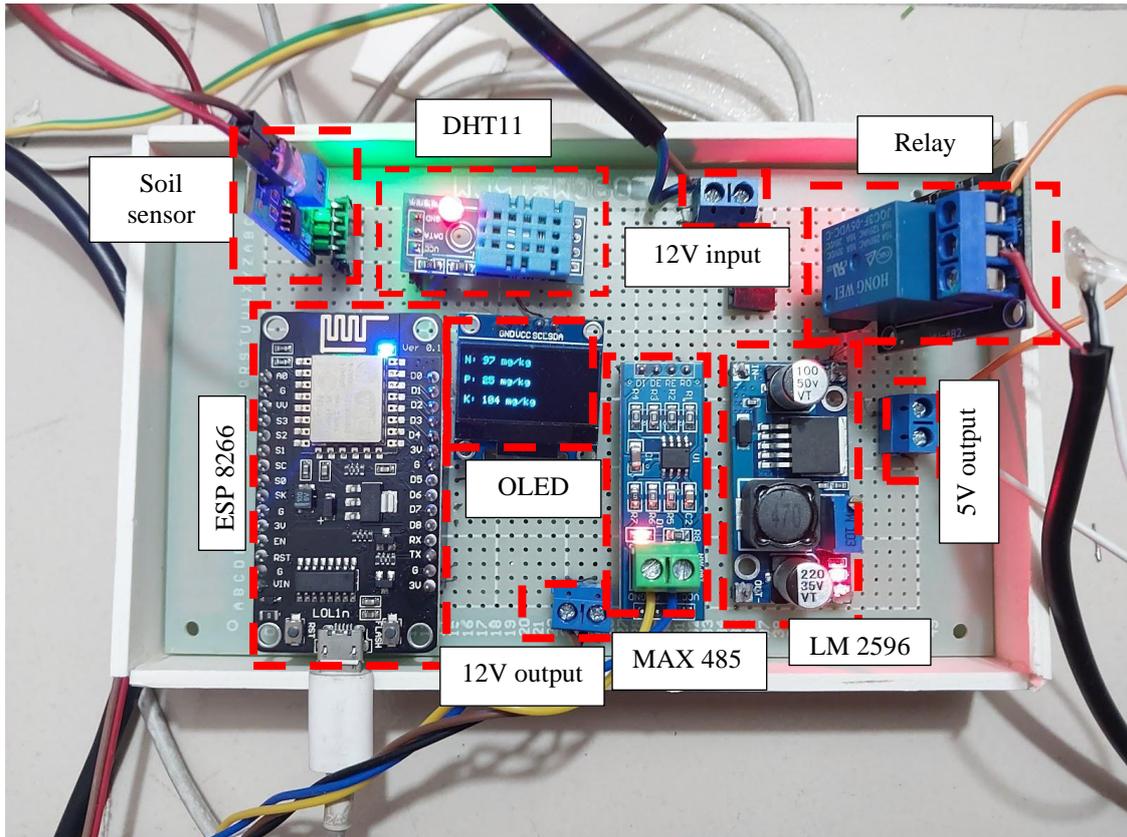


Fig. 40. Main Circuit

This is the prototype design and the circuit of the prototype. In the prototype, the solar panels were placed exactly the same way that has been done in the physical field implementation. Here every solar panel is 5 watt panel (5V,1A). 9 panels are used in the prototype. The output voltage from the solar panel was approximately 12.5 Volt. The output voltage passes through the charger solar charge controller and charges the battery. From the battery main circuit and all the sensors got powered. In the main circuit every sensor and all the components have been placed in the Veroboard. Code was uploaded in the Esp8266. After getting the power, the microcontroller starts working properly. When the NPK sensor is placed on the soil, it starts showing the values of N, P & K on the oled display. The 12 Volt Motor also starts working (On/Off) based on the Soil Moisture Sensor values. The values of N, P, K, soil moisture, humidity & temperature also show up in the web dashboard and the mobile application. Users can control the motor using the web dashboard or the mobile application.



Fig. 41. Web dashboard & pic

5.3 Evaluate the solution to meet desired need

5.3.1 Verification of the prototype

The desired needs and their evaluation stated below.

Panel sizing, spacing & optimum tilt angle: This prototype is done with the optimum tilt angle and with the proper spacing so shading impact over the crops becomes less. At the same time panel, panels are placed in such a way that it can generate the maximum energy throughout the year. Here in Fig.41 & Fig.42 it shows the shading over the field when the sun is rotating throughout the day.



Fig. 42. Shadow on the prototype land



Fig. 43. Shadow is moving when sun rotates

Charging Battery through Controller: In fig.43 it is indicating that charge controller is receiving the energy from the PV modules & it is storing this energy in a battery which is shown in fig.44.

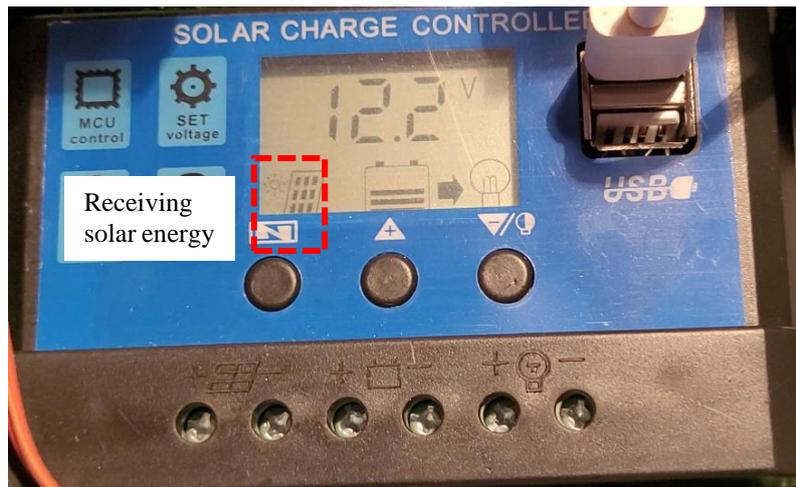


Fig. 44. Charge controller receiving solar energy from PV panels



Fig. 45. Energy storing in Battery from PV module through the controller

NPK value Detection: Before injecting the NPK sensor into the soil npk value is showing 0 in the mobile application which has been shown in Fig.45. Later after injecting the npk sensor into the soil, the sensor detects the Nitrogen, potassium & phosphorus values and it shows the values in oled display and mobile application.



Fig. 46. NPK sensor before injecting in the soil



Fig. 47. NPK sensor after injecting into the soil

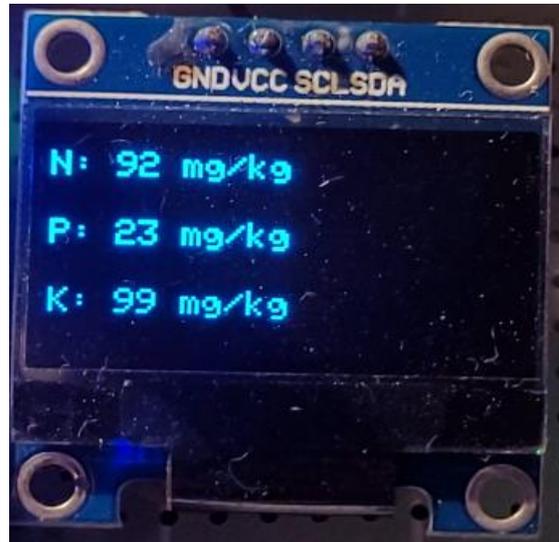


Fig. 48. NPK Value showing in the display

Real Time Monitoring: In fig.48, Soil moisture value, NPK values, Temperature & Humidity values are showing both in the web dashboard and in the mobile application. So real time values monitoring has been done here.



Fig. 49: Sensor value in web dashboard and mobile app

Automatic Irrigation: Irrigation has been automated based on the soil moisture sensor's value. In Fig.49, soil moisture sensor is outside the wet soil. It means that the field requires water because the soil is dry. So the motor turns on automatically without human interference. The opposite thing is happening in In Fig.50, soil moisture sensor is injected in the wet soil. It means that the soil has water & it doesn't require more water. That's why the motor turns off automatically here. There is a switch in both web dashboard & mobile application in Fig.48. User can turn off/on the motor from their mobile app and web dashboard as well.



Fig. 50: Automatic irrigation (Motor on)



Fig. 51 Automatic irrigation (Motor off)

5.4 Conclusion

Finally, final design execution is a critical stage in meeting the project's stated needs. To reduce variation and ensure best performance, we must execute our design exactly as planned. The proper implementation of design elements and functionality allows the project to meet its demands and objectives.

Furthermore, it is necessary to validate project results, assess input, and evaluate performance. This method provides insight into the effectiveness of the project, identifies areas for improvement, and enables for the necessary changes to maximize project functionality. The final design implementation, as well as the associated verification and evaluation procedure, enable the project team to achieve successful project results. Compliance with defined parameters and precise design execution guarantee that the finished product meets the desired objectives. Finally, feedback verification and evaluation ensure that the project meets or exceeds the expectations of the stakeholders.

Chapter 6: Impact Analysis and Project Sustainability.

6.1 Introduction

Sustainability and positive impact is required in order to develop a project. This analysis should be done considering social, cultural, health, safety, legal context so that the objectives of the project get accomplished by solving a real life problem.

6.2 Assess the impact of solution

There are a few places in Bangladesh where electricity did not reach yet again. There are some places where electricity has reached but electricity stays there for a maximum of 8-12 hours a day. Bangladesh now has a power generation capacity in excess of 21,000 MW. On the other hand, power demand and generation in mid-February this year were in the range of 9,000 MW, less than half of the overall capacity. Even last summer the peak demand and generation hardly reached 12,000 MW. Considering the fact that the ideal power generation reserve margin for most countries is 10-20 percent, the excess capacity in Bangladesh is a mismatch with the demand, for being "overly fatty" so to say[20]. In this case this project can come in and bear a heavy impact on the electricity generation of our country. Again if our project got vast popularity then we will be able to implement it all over the country as a result we will be able to connect it via local or micro grid alongside with national grid.

Social impact

Here farmers will be able to produce electricity along with crops that will open a new source of earning extra revenue from the same field. As Agrivoltaic system is totally a new concept in our country's perspective so for some days there will be lots of interest and misconception among the people in its surroundings. But as the day grows, people will be more interested about it and misconceptions will disappear.

Cultural context

Ethnically people of our region like copy culture so if any farmer make this project in his field and can make extra source of income, people will come forward to implement this project in their own land also thus the project will get vast popularity

Health Impact:

- Because solar panels create no air pollution or greenhouse gasses, the likelihood of individuals being harmed or developing health concerns is relatively low.
- Many harmful substances (silicon, lead, hazardous compounds) are used while making solar panels and these have a lifespan of around 20 years. After that, if these are not recycled properly then its hazardous elements will harm people. Moreover, people might develop a variety of ailments such as skin disorders, TB, chest infections, heart difficulties, and so on.

Safety:

As Solar panels produce DC electricity there will be a very low chance of its users getting shocked. But all safety precautions should be maintained while working and doing this project. As electricity will be produced there so there will be a lot of wires. In this case, wires should

be routed and covered properly to avoid any type of electrical injury. near it. Moreover, certified circuit breakers, wires, and other electrical items should be used to prevent any type of electrical accidents.

Legal Context:

There is little legal ramifications for our project. One concerning issue is the copying of our project design and concept. Legal action may be required to prevent such incidents. Another thing to consider is that if our project fails to produce the calculated amount of electricity and crop production rates fall below what we predicted, we may face legal action for destroying agricultural land. As a result, we intend to prevent such a blunder from occurring. Again while implementing the designed system selling surplus energy to the local electricity distribution company all standards should be maintained.

6.3 Evaluate the sustainability

From the sustainability matrix table, we can see a weighted sum of different features of this project in terms of sustainability criteria. The weighted sum of each feature refers that this project named “Design and implementation of smart Agrivoltaic system” is sustainable as all the features contain a higher than average score under sustainability criteria.

TABLE 17 Sustainability Matrix

Sustainability Criteria						
Features		Environmental (25)	Social (25)	Economical (25)	Technical (25)	Weighted Sum (100)
	Energy Cogeneration	23	20	25	20	88
	Crops Cogeneration	25	25	25	23	98
	Irrigation	25	23	25	23	96
	Energy Storage	23	23	25	20	91
	Sensors Data Collection	20	20	20	25	85
	Automatic Monitoring System	23	25	20	25	93

From the sustainability matrix table, we can see a weighted sum of different features of this project in terms of sustainability criteria. The weighted sum of each feature refers that this project named “Design and implementation of smart Agrivoltaic system” is sustainable as all the features contain a higher than the average score under sustainability criteria.

TABLE 18 SWOT Analysis

Strengths	Weaknesses
<ul style="list-style-type: none"> • Scope of monitoring (Moisture & Nutrients) • Sustainable • No chance of emitting greenhouse gas • New source of income 	<ul style="list-style-type: none"> • Initially expensive. • Bad weather conditions • Need to clean weekly
Opportunities	Threats
<ul style="list-style-type: none"> • Reduces the cost of energy • Self-reliant in terms of electricity generation • Less irrigation • Less manual intervention 	<ul style="list-style-type: none"> • Need some time to get used to it. • Number of Insects may multiply Electrocutation or other electric hazards • Pollination may decrease.

6.4 Conclusion

Finally, impact analysis and sustainability evaluations are highly appreciated in every project to determine the project's impact on the environment, society, and economy, as well as to ensure that the project is developed and implemented safely and responsibly. This enables stakeholders to take more cautious approaches while also contributing to the development of more robust mitigation measures.

Chapter 7: Engineering Project Management.

7.1 Introduction

Engineering project management is the process of organizing a team to solve a challenging engineering problem while taking into account a variety of factors, including planning, budget estimation, component availability, a well-planned schedule, work assignment, and progress monitoring. Technical engineering expertise and project management methods are combined in this procedure to provide a thorough project plan that keeps a project moving forward.

7.2 Define, plan and manage engineering project

7.2.1 Defining Project Management

The process of organizing, planning, and managing the resources required to complete an engineering project is known as engineering project management. It entails establishing the project scope, creating a project plan, controlling the budget and schedule, and making sure the project achieves its goals. There are multiple phases in a project. Planning for every phase and preparing the timeline for every phase is required so that the project can be done in time with the proper efficiency.

7.2.2 Project Management in Phase 1 (Planning & Proposal Preparing Phase)

In this phase, it is required to find a complex engineering problem which will have the complex engineering attributes. This stage involves defining the project's scope and developing the proposal as well as the project plan. The project plan includes the duties that must be carried out, the materials that will be required, and the project's schedule. This phase establishes the framework for the remainder of the engineering project, the planning and proposal preparation phase is crucial. This project "Design & Implementation of a Smart Agrivoltaic system" was selected considering the fact that there is a shortage of electricity and land in Bangladesh. This project can help to overcome this problem by producing sustainable green energy. To understand and design the project it was necessary to do the background research. After literature review, 3 design approaches were selected. After that project plan, budget, ethical considerations, risk management, expected outcomes, and applicable codes were determined.

7.2.3. Gantt chart for phase 1

This is the gantt chart of phase 1,[Fig.52] where the tasks for this phase were divided between the group members and there was a timeline so that everything completes within the time period.

Project Title: Design and implementation of smart Agrivoltaic system

Group no: 01
(Maliha, Tanvir, Almas, Fahad)
Semester: Fall 2022 (FYDP-P)
Project start date: 28/9/2022

Task/Particulars	Assigned to	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13
Discussion regarding Topic selection	All	█	█	█										
Topic Finalization	All				█									
Literature review: Finding gaps, multiple design approach and spec	All				█									
Specifications, Requirements & Constraints analysis	Tanvir, Almas, Fahad					█								
Concept Note drafting & Progress Presentation 1	All						█							
Optimal solution finding	Maliha, Almas, Fahad							█						
Component selection	Tanvir, Almas							█	█					
Assess impact and Sustainability check	Maliha, Fahad								█					
Applicable standard and codes	Maliha									█				
Planning & Budget	Tanvir, Almas									█				
Ethical issues , safety consideration and Project proposal drafting	All										█	█		
Preparation for progress presentation 2	All											█	█	
Project proposal report	All												█	█

Fig. 52. Phase 1 Gantt chart

7.2.4 Project Management in Phase 2 (Design and Development)

During FYDP-D our project milestones were to achieve optimum design approach based on various criteria and to do so we have to make e task list according to which we divided the work among the members such as developing simulation files, write codes for controlling the microcontroller, for physical implementation to design 3D graphics.

Prior to starting work on phase 2, FYDP-D, we made a gantt chart so that we can ensure effective teamwork and during this period we have done all the work according to the gantt chart. At the end of the phase 2 we get our desired result, the optimum design approach, based on variables such as power calculation, stakeholder demand, and other factors such as safety concerns and risk management.

Currently the project progress is satisfactory and we are running ahead of the schedule. We have achieved the desired milestone and no work is left in the pipeline for this phase.

7.2.5. Gantt chart for phase 2

Prior to starting work on phase 2, we created a Gantt chart to ensure effective teamwork and task completion. The gantt chart of phase 2 is given below.

Project Title: Design and implementation of smart Agrivoltaic system														
Group no: 01 (Maliha, Tanvir, Almas, Fahad)														
Semester: Spring 2023(FYDP-D)														
Project start date: 28/9/2022														
Task/Particulars	Assigned to	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13
Evaluation criteria Discussion & Literature review about system design.	All	█												
Software finding & designed draft circuit for Approach1&2	Almas, Tanvir		█											
Designed draft circuit for Approach3	Fahad, Maliha			█										
Draft circuits of All design approach completed	All		█	█	█									
Progress presentation and discussion on the corrections suggested in progress presentation	All					█								
Update in the Design Approches	All						█							
3D design & Energy Simulation report of Design Approach 1&2 +	Maliha, Fahad+ Almas, Tanvir							█						
Energy Simulation report of Design Approach 3	Tanvir, Almas								█	█				
Shading Analysis	Almas, Maliha										█			
Preperation for Final presentation	All											█		
Report writing and submission	All												█	█

Fig. 53. Phase 2 Gantt chart

7.2.6 Project Management in Phase3 (Completion & execution)

Final design approach has been implemented from the three proposed design approaches in Final Year Design Project-D phase. At first, we have bought all the components that is required to make a prototype of the project. Secondly, we have tested if all the components were working or not. Subsequently, we have compiled all the sub systems which includes the NPK Sensor, Humidity and Temperature Sensor and Soil moisture sensor using a microcontroller in a veroboard and made sure the circuit works properly.

For the Agrivoltaic part, we have made a prototype of an agricultural field and using PVC Board and small solar panels that is required to run the circuit and automated motor. We have used a lamp to work as an acting Sun to make the solar panels work. Later, we have connected a solar charge controller with panels to validate the generation of energy. For shading analysis we have used tin shade to observe the worst case scenario effect on the crops.

The budget was made along with the cost benefit analysis for both prototype and real field implementation according to the project management execution process. Thus, the implementation of the proposed design approach is completed successfully.

7.2.7. Gantt chart for phase 3

The gantt chart of phase 3 is given below, where each member's contribution to specific tasks following the time management procedure has been mentioned.

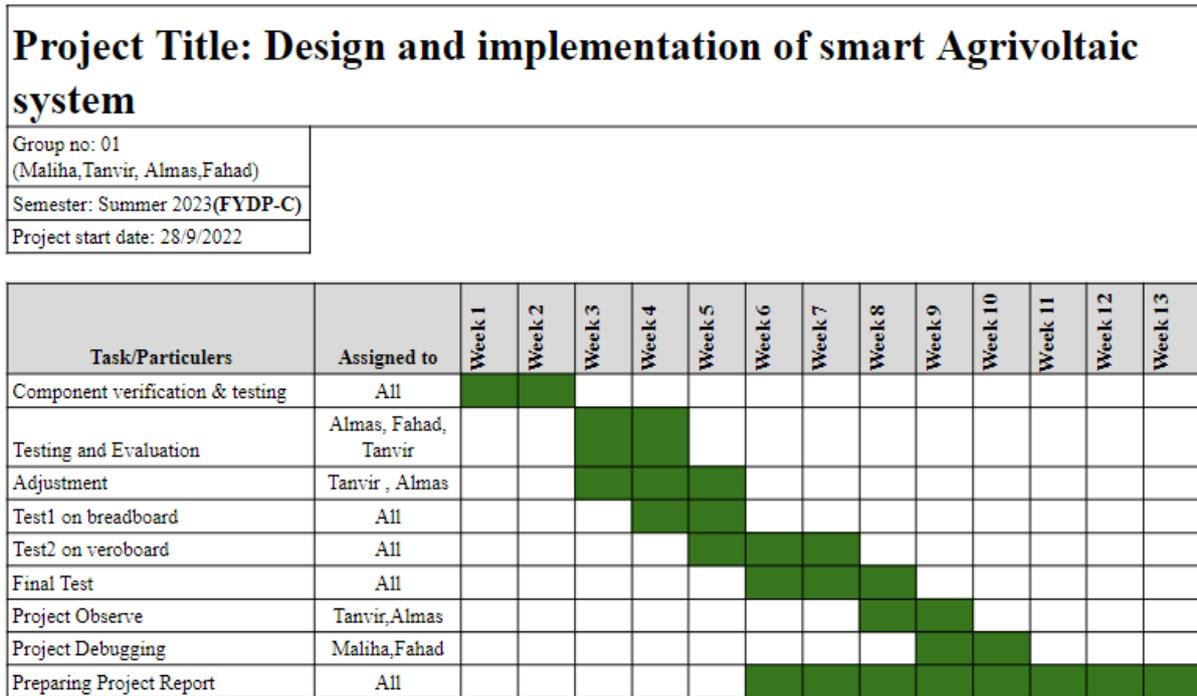


Fig. 54. Phase 3 Gantt chart

7.3 Evaluate project progress

Group meeting played the most important part in this project. Most of the issues were solved Through the group meeting. All the members divided the work and did it on time. Whenever any serious problem occurred, the ATC panel helped to solve the problem. All the comments and feedback from ATC panel was recorded and noted down in the book. This helped to complete the project on time with the perfect manner. Noting down in the logbook helped to keep track of the progress. The gantt chart were prepared before every phase which helped everyone to complete the project on time.

7.4 Conclusion

To meet the project’s milestone we face issues like restricted supply, budget issue work distribution and so on as we are relatively new in project management and here we need to demonstrate situation management abilities to overcome the hurdles and achieve the required goals. We confronted numerous problems during our Final Year Design Project (FYDP) but with our ability and right decision we were able to resolve all the issues satisfactorily through round-robin and help from ATC panel members.

Chapter 8: Economical Analysis.

8.1 Introduction

Economical Analysis refers to the budget and payback period of the project. Although the initial budget of implementing a smart Agrivoltaic system is high but the land owner can get payback after a certain period of time. This cost analysis is important in order to make the project objective prominent. Furthermore, economical analysis is required to convince the stakeholders about the positive outcomes.

8.2 Economic analysis

TABLE 19: Breakdown of budget

Item	Quantity	Cost (In BDT)	Total (In BDT)
PV modules	98	23,000	22,54,000
Batteries	6	30,000	1,80,000
Controllers	3	1,00,000	3,00,000
Motor	1	80,000	80,000
Structure		5,00,000	5,00,000
Soil Moisture Sensor	2	5000	5000
NPK Sensor	2	12000	12000
DHT11+Relay		3000	3000
		Total	33,34,000

8.3 Cost-benefit analysis

While doing the cost analysis, 0.25 acres of land is considered. 0.25 acres = 10890 sq feet. 98 PV panels will be placed in this much of area. Because of the shading of PV panels over the crops, there will be a little decrease in the production. In a 120 sq feet area, 1.2 kg yield was lost. So,

Paddy Yield loss in 120 sq ft = 1.2kg

Yield loss in 10,890 sq ft = 108.9kg

Price of 1kg Paddy = 30tk

108kg price = 3240tk

There will be yield loss of 3240 tk worth.

From the simulation it has been found that,

Surplus Energy=67460 kw/yr

Surplus Energy=5621.66 kw/mo

This much amount of energy will be surplus.

If 1 unit =6.50Taka

So, There is a chance of Seasonal income=5621.666.503=109622.37 Tk

Chance of Yearly income=674606.50=439660Tk

Investment will be recovered in $33,34,000/439660= 7.6$ year

8.4 Evaluate economic and financial aspects

As our designed project focuses on the bi lateral use of land to produce energy along with crops and will help the government meet the demand of energy, it will surely reduce the price of per unit energy as well as will save the foreign currency by reducing the dependency on imported crude oil together with help increase in the income of farmers whose land will be used for the setup. As a result, public monies can be saved and diverted to other sectors such as education, health, research and so on and as the project designed to give clean energy it will reduce carbon emission thus keep the environment clean.

8.5 Conclusion

Economic analysis is the methodology from which we can know about the economics and practices which enable us to make the right economic decision because an endeavor that is unrealistic cannot benefit the community in the long run. We base our analyses on pricing comparisons at times, and on long-term success at others. As our designed product or solution is not fully comparable with any existing solution present in the market, we chose sustainability, efficiency, cost-benefit analysis and produced financial and economic achievement.

Chapter 9: Ethics and Professional Responsibilities

9.1 Introduction

The incorporation of ethical ideals and professional obligations has a significant impact on the project's development in order to ensure the ethical, legal, and diligent management of a project. This entails considering moral standards, regulatory compliance, and the potential effects on all imaginable parties.

9.2 Identify ethical issues and professional responsibility

As our project is not familiar with the people of our country and environment we have to take care of the ethical sides and professional responsibilities. We have to make the people, living surrounding, acknowledge the benefit of our project and ensure that no elements of nature get harmed. As our project will cover half of the farmland so there will be a chance of getting a lower quantity of crops than before but we have to make them understand that they can easily recover this loss from the sale of produced electricity from the land
To implement this project we need permission from

- Agrivoltaic system should not be at the expense of people's essential rights
- Our system should be environmentally sustainable
- Agrivoltaic system should not bear any negative impact on current agricultural production and we have to make sure that there should be no genetic change or downgrade due to shading effect
- Our proposed Agrivoltaic system should not bear any impact on wildlife ecosystem as the land will cover half with panel so there may be a chance birds failed to eat insects
- Costs and benefits of solar energy should be distributed in an equitable way
- **From the neighbour Land Owner:** In our system. we might need to draw electric wires over other lands. So we need to take permission from that land's owner to do so. Furthermore, we can apply a microgrid system. So we will sell our produced electricity to our neighbour lands. That's why we need to be concerned if they are willing to buy electricity from us or not.
- **From Owner:** We have to take their acknowledgment that some days the energy production may not reach the desired or planned level due to weather issues and crops may produce in lower quantity than before.

9.3 Apply ethical issues and professional responsibility

Consent Form

Date.....

Project information:

Title: Design and Implementation of Smart Agrivoltaic System

I ...Property owners name.....give permission to this group of BRAC University for
....**Smart Agrivoltaic Project**.... to use the property located at ...Place.... for the term
ofyears beginning..... and ending.....

This agreement may be renewed with the approval of both the property owner and the group implementing ‘Smart Agrivoltaic system’ at the end of the agreement period. All questions about the project, its nature, risks or hazards, have been discussed with my workers and stakeholders to my satisfaction.

This group agrees to indemnify and save harmless the property owner from all damages and claims arising out of any act, omission or neglect by the community garden, and from any and all actions or causes of action arising from the Smart Agrivoltaic system’s occupation or use of the property.

As the property owner, I agree to notify this group implementing the ‘Smart Agrivoltaic system’ of any change in land ownership, development, or use 60 days prior to the change in status.

Please sign above the line
Signature of the property owner

Date:

9.3.1 Apply ethical issues and professional responsibility

Consent Form

Date:27/09/2022

Project information:

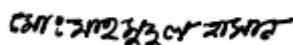
Title: Design and Implementation of Smart Agrivoltaic System

I, Md.Mahmudul Hasan, give permission to this group of BRAC University for **Smart Agrivoltaic Project** to use the property located at Sonatola, Bogura for the term of 8 months beginning September, 2022 and ending March, 2023

This agreement may be renewed with the approval of both the property owner and the group implementing 'Smart Agrivoltaic system' at the end of the agreement period. All questions about the project, its nature, risks or hazards, have been discussed with my workers and stakeholders to my satisfaction.

This group agrees to indemnify and save harmless the property owner from all damages and claims arising out of any act, omission or neglect by the community garden, and from any and all actions or causes of action arising from the Smart Agrivoltaic system's occupation or use of the property.

As the property owner, I agree to notify this group implementing the 'Smart Agrivoltaic system' of any change in land ownership, development, or use 60 days prior to the change in status.



Please sign above the line
Signature of the property owner

Date: 27/09/2022

Fig. 55. Land owner consent form

9.3.2 Risk Management and Contingency Plan

Solar flare and radiation:

Solar flare and radiation are significant issues when using solar panels as an energy source. The sun's radiation can sometimes reach the earth's atmosphere and cause severe damage to the components that are exposed to it. By contaminating the circuit boards inside these components, this radiation can cause internal and external damage.

Natural Calamities:

Our target customers are farmers and they will implement it at open farmland where natural calamities like storms can have a devastating impact, as there is no big tree or man-made structure nearby the land to stop the storm, on the Agrivoltaic structure and make them fall in loss. To overcome this issue we have to design the structure in such a way that strong wind or storms can easily get through it.

Electrical Failure:

This problem is related to solar panel power supply issues, energy storage and consumption issues, and AC/DC converter issues. Our main intention is to produce enough power in daylight so that our farmers can sell it on the grid and earn money and also can use it for their own usage. But the panel might fail to produce enough electricity due to the sun angle and to overcome the issue we will set the panel in such a direction that the panel can give maximum electricity. Moreover, due to overflow the current wires can be damaged internally and there can be a leakage in the transmission line which may cause life risk for farmers we will overcome the issue by installing double-layer insulated cable.

Lacks in Photosynthesis:

As half of the farmland will be covered with PV panels there will be lack of photosynthesis among the plants under the shade as a result we might not get the crops as open fields. As a result there is a chance of getting a lower quantity of crops than before. To tackle the issue we have to design the panel holding frame in such a way that all the paddy will get direct sunlight on alternative days.

Fragile Components:

In our proposed system we have sensitive components such as soil moisture and nutrition sensors, microcontrollers, and various circuit boards. Because we are dealing with water, these electrical components are easily damaged. Without these components, the system cannot be automated and for this, the main objective of this project will be obstructed. Because sensors will calculate the water level, and nutrition and microcontrollers will pass through commands.

Physical Damage:

As our project is designed for field implementation in an open place physical damage can occur in any physical component such as solar panels damaged due to weather (hail, debris from extreme winds). It could be damage from a tree limb falling from a storm wouldn't surprise anyone, often the biggest culprits of damage are much smaller. Twigs, leaves and dirt or sand can be blown across the glass of solar panels. Again the structure can be damaged if any heavy farming equipment hits the structure. Every situation should be handled with care and to do so we have to ensure that there is no big tree nearby and if then we have to trim the branches that may become a threat for the project .

TABLE 20: Risk level management

Frequency of circumstances	Risk Level		
	Low	Medium	High
High Certainty	N/A	Electrical Failure	Physical Damage
Moderate Certainty	Lacks in Photosynthesis	Fragile Components	Natural Calamities
Low Certainty	Solar flare and radiation	N/A	N/A

Safety Consideration:

Farmer's Safety:

Farmers will not need any special kind of safety equipment because the project does not contain any harmful substances. But while using, they should care or consider certain thing.

Check electricity tester:

They should check the electricity tester before entering the field as the project contain electricity there is a very minor chance of getting electrified by the tear wire though the chance is very low.

Visual inspection:

Before entering field they should check the area visually that if there are teardown or physical damage.

Electric Hazards Sign: Add stickers with the device so that the users can stay safe by following the instructions.

Engineers' safety (While building the project):

They have to wear:

Smart Glasses: Using goggles and protective eyewear to save us from any dust particles and dangerous sharp objects

Anti-dust mask: As our project is field oriented and we need to work with an angle grinder, welding machine etc there will be surly dust which may cause a problem in the respiratory system and to prevent these mask will help us.

Cut resistant gloves: As we need to design and build steel frames to hold the panels we have to use an angle grinder to cut the steel material and to avoid any kind of accident we have to use cut resistance gloves.

Insulated gloves: To keep protected from electrical hazards.

Robber Sleeves and Boots: To protect from electrical hazards

Welding helmet: To protect the face from welding flashes and spark.

Earmuff: To protect the ear from noise while building the project.

Safety helmet: Save us from contacting electrical hazards and falling objects.

TABLE 21: Contingency planning

Contingency planning				
Risk event	Trigger	Response	Reason	Responsible
Solar panel interconnection failed	city Transmission will Shut off	Check all the connections and if vital then call technician	Mouse bite, loose connection due to heavy storm	Maliha
Physical Damage	The system will be in operation unless major problem occur	Hardware repair, components replacement needed	Public, user, man-made calamities, Natural Calamities and other animals	Tanvir
Electrical Failure	All the sub system will shut down and sensor, irrigation pump, microgrid all will stand still	System will be no longer in operation and call for technician	Short circuited, Voltage up-down, not enough power production along with battery failure	Almas (Call fire service if the situation is severe)
Backup failure	No one will get electricity at night and cloudy time	Check the battery health and if need replace the battery	Over charge-discharge, lifetime expired	Fahad
Sensor failure	The irrigation system and fertilizer spraying system will collapsed and if sensor give misread rather then shut off it may flood the field with water or excess fertilizer	Calibrate the sensor and if need change it	Lifetime expired, over voltage, Too harsh weather issue	Maliha
Motor failure	The irrigation system or fertilizer spraying system will collapsed	Call technician if possible repair it and if not change it	Over voltage and current, water penetration	Fahad
Micro-controller failure	The whole system will shutdown or started misbehaving	Call technician if possible repair it and if not change it	Over voltage and current, water penetration	Tanvir, Almas
Natural Hazards	The system will physically breakdown	Call the manufacturer or repair it by own if possible	Lightning, heavy wind, Tornado	Call the Technician

9.4 Conclusion

To recap, they are critical components of the project development lifecycle since they help ensure that the project is completed properly and ethically. Finally, ethical and professional obligations are essential components of every project since they help to ensure that it is carried out responsibly and ethically. Project managers can promote the well-being of the community while simultaneously assuring the project's success and sustainability by analyzing the potential consequences of the project on stakeholders and adhering to legal and ethical norms.

Chapter 10: Conclusion and Future Work

10.1 Project Summary/Conclusion

Our main goal or expectation from the project is to co generate electricity along with crops to maximize the use of land and automate the irrigation system to reduce the manual workload of farmers as well as to ensure the best use of each drop of water and fertilizer. For successfully completing the task, we have gone through various research papers and survey data and analyzed them rigorously. After going through these analysis we come to clouser with three possible approaches. Our first proceeding includes a green-house model which is not feasible because greenhouse may produce good amount of electricity but it is applicable for limited number to crops or vegetables and second with the help of solar teacher which may able to give good number of electricity but the crops will be in shadow for all the time which will affect crop production in large scale. It is mentionable that both these design thoughts includes soil sensor, moisture sensor, drip or pump irrigation system but for their above limitations we have to emphasis on our third designed approach which includes soil sensor, moisture sensor, pump irrigation system , cloud database and all of these will able to structured on any conventional farm land without any above concern .The Cloud database will comprise sensor output data (Soil sensor, Moisture sensor), agricultural data, and electricity usage data in this technique. The soil sensor data will reveal the existence of Nitrogen, Phosphorus, and Potassium levels in the soil. The moisture sensor data will be utilized to visualize the presence of water in the soil. Crop data will include crop production information as well as crop shading analysis data from PV panels. The power consumption data applies to the automatic watering system and insect light trap device's electricity usage, as well as any extra electricity that will be put back into the grid. The automatic watering approach will be based on digital logic design theory, with moisture sensor data handled by a smartphone app. This irrigation operation will be powered by electricity generated by the PV panels on the Agrivoltaic system. Before final proceeding we used stakeholder feedback to create a final product that will be acceptable by the majority of consumers while still leaving room for future improvements.

10.2 Future work

As the current world is fighting an energy and water crisis there is an urgent need to develop sustainable solutions where our designed project will help to tackle this situation by providing clean energy without any toxic emission and reducing the need of water for irrigation by limiting the water evaporation. But this clean energy slightly hamper in crop production and to solve the issue in future we can install the pv module on movable track so that it can move its position horizontally after each 24 hour and by this the crops will get maximum sunlight as a result the production will increase and we will be able to install this design on shade intolerance crops also.

Moreover, we can incorporate ML to identify the disease and we can do this by introducing a high-resolution camera drone which will make go round in the preselected flight path beneath the pv module. Last but not the least, we can set up higher resolution cameras with ML to keep an eye on the crops and predict the final result in mid harvest time.

In conclusion, the incorporation of machine learning algorithms, image processing, a developed slide system, and renewable energy sources has the potential to revolutionize Agrovoltatics and make it more efficient, cost-effective, and sustainable. We can create a more sustainable future by embracing technical advancement and creativity, as well as addressing the growing problem of energy crises, maximum food output, and maximum automation based on AI.

Chapter 11: Identification of Complex Engineering Problems and Activities.

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

In this project 6P's have been identified. The P' are ticked (√) below in the table along with with the relevancy of the project

Attributes of Complex Engineering Problems (EP)

	Attributes	Put tick (√) as appropriate	Relevancy with project
P1	Depth of Knowledge required	√	Knowledge of PV system, microcontrollers, sensor, energy storage, monitoring system
P2	Range of conflicting requirements	√	The Same land will be used for energy and crops production
P3	Depth of analysis required	√	Data will be analyzed from different type of sensors output data, for example, soil sensor, moisture sensor, humidity sensor according to optimum parameters.
P4	Familiarity of issues	√	Agricultural expertise is necessary. A significant component of this endeavor is the impact of shading on various crops.
P5	Extent of applicable codes		
P6	Extent of stakeholder involvement and needs	√	Farmers, Power Distribution Companies, and Researchers.
P7	Interdependence	√	Irrigation will be dependent on produced energy. The application will be dependent on collected data.

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

P1-Depth of knowledge required:

The knowledge of using microcontroller, sensors were required for this project. Special research knowledge about Solar photovoltaic cells, the shading effect on agricultural crops were also required. So literature review played a huge role in this project. Besides, knowledge of various simulation software like PVsyst, PVsol, Proteus, MATLAB etc was also required for the depth analysis. That's why it can be said that this project has P1.

P2-Range of Conflicting Requirements:

Same land is used for generating energy and producing crops. It is a trade-off scenario. Because crops are always under the shade of PV modules. So there are some negative shading effects on the crops which reduce a bit of crop production. There is a trade of between crops and energy. So, it can be said that this problem has P2.

P3-Depth of Analysis required:

Values are coming from the different sensors. To utilize these sensor's data analysis of these data is required. Such as after which soil moisture value the motor will turn on/off or how much Nitrogen, Potassium, Phosphorus is required for the paddy field these analysis is required.

P4- Familiarity of issues:

To construct an Agrivoltaic system, one must have a thorough understanding of crops, their effects from shading, and how they are grown. Since these topics are not covered in any EEE courses, they are unfamiliar.

P6-Extent of stakeholder involvement and needs:

This smart Agrivoltaic system has to be designed according to the users requirements. The user are mostly the farmers, power distribution companies. It has to be implemented according to government policies and researchers' consultation.

P7-Interdependence:

Irrigation is dependent on the produced energy which is stored in battery. Mobile application and the web dashboard is depending on the sensors output data. Based on the sensors data irrigation is being automated. So interdependence is there in the project.

11.3 Identify the attribute of complex engineering activities (EA)

In this project 3A's have been identified. The A' are ticked (√) below in the table along with with the relevancy of the project

Attributes of Complex Engineering Activities (EA)

	Attributes	Put tick (√) as appropriate	Relevancy with project
A1	Range of resource	√	Resources of Agriculture, solar energy, microcontroller, communication.
A2	Level of interaction	√	Interaction with Farmers and Landowners.
A3	Innovation		
A4	Consequences for society and the environment	√	Enhancement of farmers' revenue, Clean energy generation
A5	Familiarity		

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

In this project there are three A's.

A1-Range of Resource:

So many resources were required to complete this project. Agricultural land, money, PV modules, microcontroller, sensors etc. Besides these things, different softwares was also required.

A2-Level of Interaction:

Consulting with the farmers, stakeholders was required. The data collection from the sensors and pass this data to the mobile application and web dashboard was required.

A4- Consequences for the society & environment:

The goal of the project is to enhance the farmers' revenue while producing green energy and reduce the water wastage during irrigation. So this project is beneficial for the society and also for the environment.

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Appendix

Logbook

FYDP (P, D & C) Summary of Team Log Book/ Journal

	Final Year Design Project		
Student Details	NAME & ID	EMAIL ADDRESS	PHONE
Member 1	Maliha Mahjabin (ID-19121054)	maliha.mahjabin@g.bracu.ac.bd	01771683582
Member 2	Tanvir Ahmed (ID-19121047)	tanvir.ahmed@g.bracu.ac.bd	01876408231
Member 3	Fahad Bin Abdullah (ID-19121112)	fahad.bin.abdullah@g.bracu.ac.bd	01679827051
Member 4	Almas Samin Hasan (ID-19121073)	almas.samin.hasan@g.bracu.ac.bd	01706336472
ATC Details:			
ATC 1			
Chair	Prof. Dr. Md. Mosaddequr Rahman	mosaddeq@bracu.ac.bd	
Member 1	Aldrin Nippon Bobby	nippon@bracu.ac.bd	
Member 2	Mohaimenul Islam	mohaimenul.islam@bracu.ac.bd	

General Notes:

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

FYDP (P) FALL22 Summary of Team Log Book/ Journal

Date/Time/Place	Attendee	Summary of Meeting Minutes	Responsible	Comment by ATC
29-9-2022	1. Maliha 2. Tanvir 3. Fahad 4. Almas	Topic: Introductory session by Mohaimenul Islam, Lecturer, Dept of EEE, BRAC University		N/A because ATC was not announced yet
6-10-2022	1. Maliha 2. Tanvir 3. Fahad 4. Almas	Topic: Introduction to Engineering Design Process taken by MD Mosaddequr Rahman, Professor and chairperson, Dept of EEE, BRAC University		
9-10-22 Meeting 1 (Discussion among group members)	1. Maliha 2. Tanvir 3. Fahad 4. Almas	Discussed our field of interests and finalized topics Agriculture related, IoT, Green energy based projects	1. Maliha 2. Tanvir 3. Fahad 4. Almas	
13-10-2022	1. Maliha 2. Tanvir 3. Fahad 4. Almas	Topic: Complex Engineering Problem Identification taken by Prof. Arshad Mahmud Chowdhury, Dean, School of Engineering.		
15-10-2022 Meeting 2 (Discussion among group members)	1. Maliha 2. Tanvir 3. Fahad 4. Almas	Evaluated if the selected topics are complex engineering problems or not	1. Maliha 2. Tanvir 3. Fahad 4. Almas	
16-10-2022 Meeting 1 with ATC panel members	1. Prof. Dr. Md. Mosaddequr Rahman 2. Mohaimenul Islam 3. Maliha 4. Tanvir 5. Fahad 6. Almas	Finalized two topics to present in front of ATC Panel members		Among two ideas we got the approval for 'Design and implementation of Smart Agrivoltaic system'
20-10-2022	1. Maliha 2. Tanvir 3. Fahad 4. Almas	Topic: How to Identify a Complex Engineering Design Project and Fulfill CO Criteria by Dr. Abu S.M. Mohsin, Associate professor, Dept of EEE, BRAC University	1. Maliha 2. Tanvir 3. Fahad 4. Almas	
23-10-2022 Meeting 2 with ATC panel members	1. Mohaimenul Islam 2. Maliha 3. Tanvir	Had a discussion regarding design approaches	1. Maliha	1. Prepare logbook 2. Start writing concept note

	4. Fahad 5. Almas			
28-10-2022 Meeting 3(Discussion among group members)	1. Maliha 2.Tanvir 3. Fahad 4. Almas	Started working on Slide and Concept note	1. Maliha 2.Tanvir 3. Fahad 4. Almas	
27-10-2022	1. Maliha 2.Tanvir 3. Fahad 4. Almas	Topic: Expert of Safety, Environment Management by Mohaimenul Islam, Lecturer, Dept of EEE, BRAC University		
30-10-22 Meeting 3 with ATC members	1. Prof.Dr.Md. Mosaddequr Rahman 2.Mohaimenul Islam 3. Maliha 4. Tanvir 5. Fahad 6. Almas	Prepared the full slide and made the draft presentation Took feedback from ATC Panel members about slide and concept note	1. Maliha 2.Tanvir 3. Fahad 4. Almas	Figured out some mistakes in the slide and advised to correct it.
3-11-2022	Mohaimenul Islam & other FYDP Groups	Progress presentation	1. Maliha 2.Tanvir 3. Fahad 4. Almas	N/A
17-11-2022	1. Maliha 2. Almas	Topic: Report Writing and Presentation Techniques by Rakibul Islam, Lecturer, Dept of EEE, BRAC University		
24-11-2022		NO class		
1-12-2022	1. Maliha 2.Tanvir 3. Fahad 4. Almas	Review of Project Proposal Preparation and Project Management by Mohaimenul Islam, Lecturer, Dept of EEE, BRAC University		
8-12-2022		NO class		
14-12-2022 Meeting 4 with ATC members	1. Prof. Dr.Md. Mosaddequr Rahman 2.Aldrin Nippon Bobby 3.Mohaimenul Islam 4. Maliha 5. Tanvir 6. Almas	Mock presentation	1. Maliha 2.Tanvir 3. Almas	Figured out some mistakes in the slide and advised to correct it.

FYDP (D) SUMMER23 Summary of Team Log Book/ Journal

Date/Time/Place	Attendee	Summary of Meeting Minutes	Responsible	Comment by ATC
29-01-2023 Place: UB5 5th floor	1. Maliha 2. Tanvir 3. Fahad 4. Almas 5. Mohaimenul Islam	1. Discussed the evaluation criteria and step-by-step plan to fulfill that within given time 2. Literature review about system design.	1. Maliha 2. Tanvir 3. Fahad 4. Almas	Normal meeting
5-02-2023	1. Maliha 2. Tanvir 3. Fahad 4. Almas 5. Mohaimenul Islam	Discussion regarding softwares.	1. Maliha 2. Tanvir 3. Fahad 4. Almas	Find Software and start working
07-02-2023	1. Maliha 2. Tanvir 3. Fahad 4. Almas	Finding software & installation (Sketchup3D, pvsol, pvsyst, proteus)	1. Tanvir 2. Almas	
10-02-2023	1. Maliha 2. Tanvir 3. Fahad 4. Almas	1. Designed and simulated the draft circuit for Approach1 2. Started working on 3D visualization of pv panels	Task1: Tanvir Almas Task 2: Maliha	
11-02-2023	1. Maliha 2. Tanvir 3. Fahad 4. Almas	1. Designed and simulated the draft circuit for Approach2	Task1. Almas Tanvir	
12-02-23	1. Maliha 2. Tanvir 3. Fahad 4. Almas 5. Mohaimenul Islam	1. Showed circuit portion of Design Approach1 & 2 2. Discussion about Design Approach3.	Task1: Tanvir Almas Task2: Fahad Maliha	
19-02-2023	1. Maliha 2. Tanvir 3. Fahad 4. Almas 5. Mohaimenul Islam	1. Showed the Draft circuit part for Design approach3 2. Generated Solar Energy analysis report for Main Approach(3).	Task1. Maliha Fahad Task2: Tanvir Almas	Figured out some mistakes and were advised to correct them

26-02-23	1. Maliha 2. Tanvir 3. Fahad 4. Almas 5. Mohaimenul Islam	Draft Circuit of draft Design Approach 3 shown along with the updated circuits of Design Approach 1 & 2.	1. Maliha 2. Tanvir 3. Fahad 4. Almas	
01-03-2023	1. Maliha 2. Tanvir 3. Fahad 4. Almas	Preparation for Progress Presentation.	1. Maliha 2. Tanvir 3. Fahad 4. Almas	
5/3/2023	1. Maliha 2. Tanvir 3. Fahad 4. Almas 5. Mohaimenul Islam	Corrections suggested in the Progress presentation were discussed and reviewed.	1. Maliha 2. Tanvir 3. Fahad 4. Almas	Suggestions to do some modifications in Design Approaches.
12-3-2023	1. Maliha 2. Tanvir 3. Fahad 4. Almas 5. Mohaimenul Islam	1. Updated design Approaches showed.	1. Maliha 2. Tanvir 3. Fahad 4. Almas	Got instructions to do 3D visualization for getting more clear understanding of Design Approaches.
19-3-2023	1. Maliha 2. Tanvir 3. Fahad 4. Almas 5. Mohaimenul Islam	1. 3D Design of Approach 1 & 2 were shown 2. Energy simulation reports of the Design of Approach 1 & 2 were shown	Task 1: Maliha Fahad Task 2: Tanvir Almas	Feedbacks Given
02-04-23	1. Maliha 2. Tanvir 3. Fahad 4. Almas 5. Mohaimenul Islam	1. Showed the updated Circuit of Design Approach 3 2. Updated Solar Energy analysis report for Design Approach 3	Task 1: Fahad Tanvir Task 2: Maliha Almas	Suggestions to generate Heatmap and do shading analysis
09-04-23	1. Maliha 2. Tanvir 3. Fahad 4. Almas 5. Mohaimenul Islam	1. Showed Shading analysis	1. Almas	Suggestion to start writing Report

16-04-23	1. Maliha 2. Tanvir 3. Fahad 4. Almas 5. Mohaimenul Islam	Showed Slide for final presentation	1. Maliha 2. Tanvir 3. Fahad 4. Almas	Some corrections given
23-04-23	1. Maliha 2. Tanvir 3. Fahad 4. Almas	Updated presentation slide and started draft report writing	1. Maliha 2. Tanvir 3. Fahad 4. Almas	
27-04-23	1. Maliha 2. Tanvir 3. Fahad 4. Almas 5. Mohaimenul Islam	1. Final presentation 2. Showed draft report	Task1 & 2: 1. Maliha 2. Tanvir 3. Fahad 4. Almas	Feedback Given

FYDP (C) SUMMER23 Summary of Team Log Book/ Journal

Date/Time/Place	Attendee	Summary of Meeting Minutes	Responsible	Comment by ATC
04-06-2023	1. Maliha 2. Tanvir 3. Almas 4. Mohaimenul Islam	Discussion about the final component list	1. Maliha 2. Tanvir 3. Almas	Buy components as soon as possible.
11-06-2023	1. Maliha 2. Tanvir 3. Fahad 4. Mohaimenul Islam	Blueprint of the work	1. Maliha 2. Tanvir 3. Fahad	Start working on component verification
14-06-2023	1. Maliha 2. Tanvir 3. Almas 4. Fahad	Component test	All	
19-06-23	1. Maliha 2. Tanvir 3. Almas 4. Fahad	Circuit building on a breadboard	All	
25-06-2023	1. Maliha 2. Tanvir 3. Almas 4. Fahad	Building code to operate circuit	1. Tanvir 2. Almas 3. Fahad	
05-07-2023	1. Maliha 2. Tanvir 3. Almas 4. Fahad	Checking whether the designed circuit is working correctly or not	1. Tanvir 2. Almas 3. Fahad	
08/07-2023	1. Maliha 2. Tanvir 3. Almas 4. Fahad	Code finalization	1. Fahad	
10-07-2023	1. Maliha 2. Tanvir 3. Almas 4. Fahad	Building code to synchronize the monitored data Blynk cloud website & app	1. Fahad 2. Maliha	
25-07-2023	1. Maliha 2. Tanvir 3. Almas 4. Fahad 5. Mohaimenul Islam	Finalizing the Setup of the prototype on a breadboard	All	1. Use a Veroboard to avoid wire mess. 2. Start working on paper writing
31-07-2023	1. Maliha 2. Fahad	Started working on Slide and Concept note	1. Maliha 2. Tanvir	

	3. Almas		3. Fahad 4. Almas	
06-08-2023	1. Maliha 2. Tanvir 3. Fahad 4. Almas 5. Mohaimenul Islam	Completed writing Chapters 1,2	1. Maliha 2. Tanvir 3. Almas	Took some instructions for writing Chapter 3 & got feedback to improve some parts in Chapter 1&2
14-08-2023	1. Tanvir 2. Fahad 3. Almas	Completed full setup	1. Tanvir 2. Fahad 3. Almas	
16-08-2023	1. Maliha 2. Almas	Showed Final Prototype	1. Maliha 2. Almas	Got some corrections
19-08-2023	1. Maliha 2. Tanvir 3. Fahad 4. Almas	Poster Making	1. Maliha 2. Tanvir 3. Fahad 4. Almas	
22-08-2023	1. Maliha 2. Tanvir 3. Fahad 4. Almas 5. Mohaimenul Islam	Added chapters 3, 4, 5	1. Maliha 2. Tanvir 3. Fahad 4. Almas	Got some corrections on the poster
27-08-2023	1. Maliha 2. Tanvir 3. Fahad 4. Almas 5. Mohaimenul Islam	Added Chapter 6,7,8 and Corrected old 3D Design	1. Maliha 2. Tanvir 3. Fahad 4. Almas	
31-08-2023	1. Maliha 2. Tanvir 3. Fahad 4. Almas 5. Mohaimenul Islam	Added chapter 9,10,11 Completed FYDP Report	1. Maliha 2. Tanvir 3. Fahad 4. Almas	Feedback given

Related code/theory

```
#include <SoftwareSerial.h>
#include <Wire.h>
#include <Adafruit_GFX.h>
#include <Adafruit_SSD1306.h>
#include <BlynkSimpleEsp8266.h>
#include <DHT.h>

#define SCREEN_WIDTH 128
#define SCREEN_HEIGHT 64
#define OLED_RESET -1
Adafruit_SSD1306 display(SCREEN_WIDTH, SCREEN_HEIGHT, &Wire, OLED_RESET);

#define RE 2
#define DE 0
#define RELAY_PIN 15
const byte nitro[] = {0x01, 0x03, 0x00, 0x1e, 0x00, 0x01, 0xe4, 0x0c};
const byte phos[] = {0x01, 0x03, 0x00, 0x1f, 0x00, 0x01, 0xb5, 0xcc};
const byte pota[] = {0x01, 0x03, 0x00, 0x20, 0x00, 0x01, 0x85, 0xc0};

const int soilMoisturePin = A0;

byte values[11];
SoftwareSerial mod(14, 12);

char auth[] = "JDKFa8v4hTRcbrWqObWtsAZwUb_-U05X";
char ssid[] = "ABCD";
char password[] = "12345678";
BlynkTimer timer;

#define DHTPIN 13
#define DHTTYPE DHT11
DHT dht(DHTPIN, DHTTYPE);

int motorState = LOW; // Current state of the motor (OFF)
const int motorThresholdOn = 35; // Moisture threshold to turn on the motor
const int motorThresholdOff = 25; // Moisture threshold to turn off the motor

void setup() {
  Serial.begin(9600);
  mod.begin(4800);
  pinMode(RE, OUTPUT);
  pinMode(DE, OUTPUT);
  pinMode(RELAY_PIN, OUTPUT);

  dht.begin();

  display.begin(SSD1306_SWITCHCAPVCC, 0x3C);
  delay(500);
```

```

display.clearDisplay();
display.setCursor(25, 15);
display.setTextSize(1);
display.setTextColor(WHITE);
display.println(" NPK Sensor");
display.setCursor(25, 35);
display.setTextSize(1);
display.print("Initializing");
display.display();
delay(3000);

Blynk.begin(auth, ssid, password); // Blynk connection
}

void loop() {
  timer.run();
  byte val1, val2, val3;
  val1 = nitrogen();
  delay(250);
  val2 = phosphorous();
  delay(250);
  val3 = potassium();
  delay(250);

  Serial.print("Nitrogen: ");
  Serial.print(val1);
  Serial.println(" mg/kg");
  Serial.print("Phosphorous: ");
  Serial.print(val2);
  Serial.println(" mg/kg");
  Serial.print("Potassium: ");
  Serial.print(val3);
  Serial.println(" mg/kg");
  delay(2000);
  Blynk.virtualWrite(V0, val1);
  Blynk.virtualWrite(V1, val2);
  Blynk.virtualWrite(V2, val3);

  display.clearDisplay();
  display.setTextSize(1);
  display.setCursor(0, 5);
  display.print("N: ");
  display.print(val1);
  display.setTextSize(1);
  display.print(" mg/kg");

  display.setTextSize(1);
  display.setCursor(0, 25);
  display.print("P: ");
  display.print(val2);
  display.setTextSize(1);
  display.print(" mg/kg");

```

```

display.setTextSize(1);
display.setCursor(0, 45);
display.print("K: ");
display.print(val3);
display.setTextSize(1);
display.print(" mg/kg");

display.display();

int soilMoistureValue = analogRead(A0);
int moisturePercentage = map(soilMoistureValue, 0, 1023, 100, 0);

Blynk.virtualWrite(V3, moisturePercentage);
Serial.print("Soil Moisture: ");
Serial.print(moisturePercentage);
Serial.println("%");

float temperature = dht.readTemperature();
float humidity = dht.readHumidity();

Blynk.virtualWrite(V5, temperature);
Blynk.virtualWrite(V6, humidity);

Serial.print("Temperature: ");
Serial.print(temperature);
Serial.print(" °C\tHumidity: ");
Serial.print(humidity);
Serial.println(" %");

delay(2000);

// Automating motor based on moisture sensor value
if (moisturePercentage > motorThresholdOn && motorState == LOW) {
  digitalWrite(RELAY_PIN, HIGH); // Turn on the motor
  motorState = HIGH;
  checkRelayStatus(); // Update the relay status in Blynk app
}
else if (moisturePercentage < motorThresholdOff && motorState == HIGH) {
  digitalWrite(RELAY_PIN, LOW); // Turn off the motor
  motorState = LOW;
  checkRelayStatus(); // Update the relay status in Blynk app
}
}

byte nitrogen() {
  digitalWrite(DE,HIGH);
  digitalWrite(RE,HIGH);
  delay(10);
  if(mod.write(nitro,sizeof(nitro))==8){
    digitalWrite(DE,LOW);
    digitalWrite(RE,LOW);
  }
}

```

```

    for(byte i=0;i<7;i++){
        values[i] = mod.read();
    }
}
return values[4];
}

```

```

byte phosphorous() {
    digitalWrite(DE,HIGH);
    digitalWrite(RE,HIGH);
    delay(10);
    if(mod.write(phos,sizeof(phos))==8){
        digitalWrite(DE,LOW);
        digitalWrite(RE,LOW);
        for(byte i=0;i<7;i++){
            values[i] = mod.read();
        }
    }
    return values[4];
}

```

```

byte potassium() {
    digitalWrite(DE,HIGH);
    digitalWrite(RE,HIGH);
    delay(10);
    if(mod.write(pota,sizeof(pota))==8){
        digitalWrite(DE,LOW);
        digitalWrite(RE,LOW);
        for(byte i=0;i<7;i++){
            values[i] = mod.read();
        }
        Serial.println();
    }
    return values[4];
}

```

```

void checkRelayStatus() {
    int relayState = digitalRead(RELAY_PIN);
    Blynk.virtualWrite(V4, relayState); // Sync the relay status with Blynk
}
BLYNK_WRITE(V4) {
    int relayState = param.asInt();
    digitalWrite(RELAY_PIN, relayState); // Set the relay state based on Blynk app
    delay(100); // Add a small delay for stability
    checkRelayStatus(); // Update the relay status in Blynk app
}

```