FOLDABLE AND PORTABLE SOLAR MODULE BASED ENERGY GENERATION SYSTEM TO MEET COMMUNICATION SECTOR POWER DEMAND IN MILITARY REMOTE CAMPS

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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 (BSEEE)**.

Department of Electrical and Electronic Engineering

Date of submission: 26th December 2022

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Declaration

It is hereby declared that:

1. The Final Year Design Project (FYDP) submitted is our own original work while completing our 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 complete and accurate referencing.
3. The Final Year Design Project (FYDP) does not contain material that has been accepted, or submitted, for any other degree or diploma at a university or other institution.
4. We have acknowledged all main sources of help.

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Approval

The Final Year Design Project (FYDP) titled "**Foldable and Portable Solar Module Based Energy Generation System to Meet Communication Sector Power Demand in Military Remote Camps**" submitted by

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Ethics Statement

Legitimacy of the entire report has been justified by investigating plagiarism with modern software. Since making plagiarism is one of the illegal practices in developing research work, we tried our best to make our report free from plagiarism. In this regard, we have used **Turnitin**, a renowned plagiarism checker software to check plagiarism and generate plagiarism report. This software has found 15% similarity in our report. As less than 35% similarity is acceptable, we can surely acknowledge the validity of our report.

Abstract

This work demonstrates the utilization of solar modules to meet the power demand of communication devices used by the military in remote camps. Solar radiation as an abundant source of energy can be a prominent way of providing power to different communication devices without any interruption. To get rid of the hazards and threats of the use of conventionally used diesel generators or local grid power supply systems, a sustainable solution is very much required in this critical platform. But just introducing a typical PV module-based system is not a sustainable cure. Considering the heavy weight of the solar panels and batteries, the efficiency of the solar cells, and the feasibility of carrying the entire system, an attempt to introduce a viable solution has been made.

Keywords: Military, Photovoltaic cells, communication devices, foldable, portable, storage system

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List of Acronyms

PV: Photo Voltaic

SAGE: Smart and Green Energy

PR: Performance Ratio

WHE: Watt-Hour Efficiency

SOC: State of Charge

DOD: Depth of Discharge

Chapter 1: Introduction-[CO1, CO2, CO10]

1.1 Introduction

Photovoltaic power generation systems are a reliable and cost effective solution in remote areas. A sustainable arrangement of this power generating system can make life easier for the inhabitants of such areas by powering their houses and workplaces . Moreover, different professionals like armies and different service holders who are responsible for their duties in such areas will also be able to perform their duties without difficulties.The sunlight is playing the role of a renewable energy in this case and there are no limitations of getting sunlight in nature .Since photovoltaic system have the capability of serving power both day and night hours with the help of efficient energy storage system , it has become one of the most reliable solutions for delivering power in remote areas.But many researches are being done to make this system more sustainable. Increasing the efficiency and size of the cells, the weight of the panels , efficient battery storage and proper power management are the main points of attention for research. Many articles also show the methods and goals of optimization in terms of cost, reliability, and environmental impact in remote areas .

Military small communities and remote camps confront distinct energy supply and management challenges across the world. They require secured energy supplies and durable infrastructure due to the importance of military missions and the risks associated with disruptive situations. Transportation costs and dangers are connected with traditional energy solutions, which mostly require massive supply lines.

1.1.1 Problem Statement

In remote areas, the militaries have to depend on either the local grid or diesel generators .Depending on the local grid in such areas creates additional demand which is difficult to be fulfilled as very few transmission lines reach those areas . Moreover, there always remains a risk of power outage which can make militaries fall into an awkward situation as they always have to run their military graded devices and other appliances. Operating diesel generators presents difficulties such as unfavorable noise and air pollution, continuing maintenance, and a continuous fuel supply. This logistical necessity raises transportation costs and puts energy resiliency at risk **[1]**.Transportation costs and dangers are connected with carrying diesel. Because, diesel generators need to be refueled after each period. As a result, transportation arrangements and cost make the situation infeasible. Communication is a critical element of effective Command & Control. Any military operation's success is contingent on maintaining reliable and uninterrupted communication. And that requires uninterrupted power supply and logistical support from the main camp. Communication equipment accounts for a significant portion of the military's total power usage and expenditure.

1.1.2 Background Study

According to the Atlantic Council analysis, between 2003 and 2007, one out of every twenty-four gasoline convoys resulted in a US casualty, with over three thousand US military and DOD contractor deaths related to fuel convoys in Iraq and Afghanistan **[2]** . In 2008, more than 68 percent of our worldwide electrical supply was generated by burning fossil fuels, mostly coal and natural gas, releasing 11.9 gigatons of carbon dioxide into the sky **[3]**. The majority of this carbon dioxide will remain in the atmosphere for hundreds to thousands of years, functioning as a greenhouse gas that heats the Earth and may disturb the climatic patterns to which our civilization has been used for thousands of years. Consistent with the difficulties outlined in the QDR (Quadrennial Defense Review), the US Army has begun to work toward achieving total Net Zero sites. This comprehensive strategy to tackle energy, water, and waste at military locations is a force multiplier because it helps the military to better manage available resources, save costs, and ensure the long-term viability of essential services. To attain these Net Zero targets, DoD facilities must be able to evaluate, develop, and deploy integrated systems that efficiently handle all elements of waste, water, and energy streams, from energy generation to consumption, greenhouse gas emissions, and solid waste.**[3]** To achieve these facilities, The US Department of Defense are going to invest $1.6 billion in research, development, testing, and evaluation (RDT&E) that is directly related to energy (Robyn and Marqusee, 2022).**[4]** In today's world, according to (Frączek, Górski and Wolaniuk, 2022), military around the world basically rely on one of two methods to power their equipment and military gadgets: linking various devices to the national power grid or using diesel-electric generators.**[5]** While interviewing different military personnel, we came to know that currently, Bangladesh army mainly pivots on local support for steady power supply of their communication sector. In some cases, they carry power banks with a limited power backup option.But, purely generator dependency requires on-time delivery of massive amounts of fuel**.[5]**Also, there may come situations where local support or national grid support won't be available. So, in that case power cuts have to be taken into account.**[5]** If any kind of power outage happens in between a mission, they have to declare that mission abandoned or take it as defeat. Further, in this kind of situation, there may be a big risk of casualties. If somehow they lost communication with the main camp, they won't be able to ask for any logistical support and quick reinforcements (QRF) for any instant adverse situation. Furthermore, Local assistance can often lead to breaches of the privacy of various missions. This kind of scenario encourages us to look for innovative solutions that may efficiently suit the demands of a squad as well as command centers.

1.1.3 Literature Gap

In this project we are trying to meet up the functional and nonfunctional requirements of our targeted group. But there are some scopes where we could extend our analysis.

Cell oriented study: With the rapid demand of solar panels at this age, many advancements have already been executed in developing efficient cells. PV cells normally have efficiency around 15-25% (without considering temperature affect).**[6]** But lots of studies and research are still being done to make it more improved. Even the journey of cell advancement has been divided into 4 generations. But in our study we are not dealing with deep analysis about efficient cell development and installation. Rather we are only focusing on the basic requirements of our stakeholders and trying to fulfill them by using commercially available cells which are used in general.

Power consumption management : In this particular study we are not implementing any subsystem regarding power management systems .

1.1.4 Relevance to current and future Industry

Reserving resources and maximizing energy efficiency have become crucial components of planning military camps. It is especially important in the case of forward operating basis. In 2009, The Senior Energy Council of the US Army released an Army Energy Security Implementation Strategy that has five strategic objectives for energy security: Reduce energy use, improve energy efficiency across platforms and facilities, use more renewable and alternative energy resources, ensure access to adequate energy supply, and reduce negative environmental effects.SAGE (Smart and Green Energy) addresses each of these goals.**[7]**The Army and Navy are looking at adopting portable solar power devices to produce electricity and lessen the risks associated with field convoys.**[8]** Therefore, it is quite evident that this type of energy production system conveys a high importance in the military base camps. Though this type of system is not implemented in most of the camps yet, it has become a very promising method of energy production to the decision makers.

1.2 Objectives, Requirements, Specification and constant

1.2.1 Objectives

Our objective is to meet the energy demand of military graded communication devices in order to:

- Reduce fuel dependency in camps
- Diminish the risk of communication breach
- Equip the soldiers with a conveyable lightweight system of power supply
- Assist a whole military base to reduce its annual energy budget.
- Reduce the impact of the traditional energy generation system on Global Climate Change.

To reduce fuel dependency in camps

Conventionally, the forward operating bases are equipped with fuel oil-powered generators for electricity production **[9]**.Protection of the supply convoys dramatically increases cost of each commodity. Moreover, there remains a concern of refueling the generators and that requires an additional operation and maintenance arrangement . These issues create extra burden on the soldiers and they always need to be aware of these concerns irrespective of any emergency situation. So one of our core objectives is to reduce fuel dependency in military camps.

To diminish the Risk of communication Breach

The small squads carry communication devices with them to maintain a continual communication with forward operating base (FOB) and the forward operating base maintain communication with the main operating base. So, this is a very sensitive part of military communication. Any disruption of communication may lead them into a diverse situation.So our goal is to diminish the risk of communication breach.

To equip the soldiers with a conveyable lightweight system of power supply

It is said before that the soldiers depend on fuel oil powered generators which are so heavy in weight. As a result, additional manpower and transport systems are required to handle and carry this heavy weight system .So , one of our main motives is to introduce a system which is easy to convey.

To assist a whole military base to reduce its annual energy budget

In military operations, there is frequently an economic issue. Since many cost-cutting initiatives are expensive, they must at least be partially subsidized by local administrations or authorities.[9].So this replicates how much a cost saving system is required in military operations. Our goal is to address this demand with such a power puppy system which will be cost effective and which will ultimately reduce the annual energy budget.

To reduce the impact of the traditional energy generation system on Global Climate Change

Since traditional stand-alone power generators emit toxic gas like CO_2 and CO, these types of systems are harmful for the environment . So one of our vital objectives is to overcome the pollution hazard .

Figure 1: Using communication devices in operation

1.2.2 Functional and Nonfunctional Requirements

We have categorized the requirements in two parts : i) Functional Requirements ; ii) Nonfunctional Requirements .

Functional Requirements

Functional requirements are mandatory requirements which are usually defined by the user and developers must implement them to enable users to accomplish their tasks.

In our Final Year Design Project, our stakeholders (Bangladesh Army) placed the energy demand for a bunch of military graded communication devices. From the interview of military personnel we have selected the models of different devices. As manpack radio, we have selected Codan 2110m. In 2018, The Bangladesh Army purchased 200 Codan Patrol 2110M to modernize their portable communication solutions **[10]**. Along with this, we have considered military grade laptops, Personal role radio, Handheld Atex Dmr Rugged smartphone lte ex - two way radio army walkie talkie mobile phone, Signal jammer and Satellite phone. The list is given below with proper quantity and work time for a remote camp. The first table shows the **Load Requirement.**

Consumer side load profile :

Communication Devices	Model	Work Time	Quantity
Manpack radio	Codan 2110m	12	1
Military Grade Laptop	L140TG-414" Intel® Core™ i5-1135G7 Rugged Laptop	1	1
Personal role radio	H4855	5	2
Walkie talkie	RS-538DE	8	10
Signal jammer	X16B	2	1
Satellite phone	Iridium-9555	3	2

Table 1: Load Model

The table below shows the hourly power consumption of the loads in a day :

Time Span	Devices	Power Consumption/ Hour
0:00-1:00	Manpack radio(20min),signal jammer(40 min), walkie talkie(10),satellite phone(1),military grade laptop, PRR(1)	0.164
1:00-6:00	signal jammer, walkie talkie(5),satellite phone(2)	0.072W
6:00-7:00	signal jammer, walkie talkie(10),satellite phone(2),personal role radio	0.107W
7:00-13:00	signal jammer, walkie talkie(10),satellite phone(2)	0.097W
13:00-14:00	signal jammer, walkie talkie(10),satellite phone(1)	0.087W
14:00-17:00	signal jammer, walkie talkie(10),satellite phone(2)	0.072W
17:00-20:00	signal jammer, walkie talkie(10),satellite phone(2),PRR(2)	0.082W
20:00-21:00	Manpack radio(20min),signal jammer(40 min), walkie talkie(10),satellite phone(1),military grade laptop, PRR(1)	0.164W
21:00-22:00	signal jammer, walkie talkie(10),satellite phone(1),military grade laptop	0.137W
22:00-23:00	Manpack radio(20min),signal jammer(40 min), walkie talkie(10),satellite phone(2),military grade laptop,PRR(2)	0.174W
23:00-00.00	signal jammer, walkie talkie(10),satellite phone(1),military grade laptop	0.137

Table 2: Hourly Load Consumption

Overall Load requirement:

Total load requirement	2.37 kWh/ Day.
Average power consumption	100W
Highest power Demand	174W-h
Load factor	57%
Battery Backup Requirement	Minimum 10 hours
Battery Autonomy days	1 day

Table 3: Overall load requirement

Non- Functional requirements

We are aiming to meet three major non-functional requirements. They are **Foldability**, **Portability**, and **Scalability**. Current military power solutions need big space and heavyweight. But, it's not an ideal or feasible way. If we can ensure the foldability of our system, the system may easily suit in a very small place. Secondly, we are aiming to ensure the portability of the system by lowering its weight so that they can easily carry this solution to any remote operation. Thirdly, our system will have scalability. Now, we are making this device for remote camps only. But, in the future we can use it for bigger loads like large base camps.

1.2.3 Specifications

Battery Sizing:

Here, we are considering a lead-acid battery. Regarding the necessary battery storage of D number of days, the battery capacity (A-h) in ideal condition is obtained as follow : $Ct = (E_L * D)/(Vs * C_D)$ where Vs = the system voltage = 12V; E_L : the daily energy requirement in Wh/day = 264Wh/day; D : the required number of storage days ; and C_D = the maximum permissible Depth of discharge.**[11]** According to this relationship, the ideal battery capacity can be calculated at 100% charge-discharge efficiency, but, in the regular case,about 25% of the total capacity is lost throughout the charge-discharge process. While the discharge losses apply to the battery side, the charge losses apply to the PV side. It is defined as

WHE = charge efficiency * discharge efficiency [11]

The watt-hour efficiency (WHE) for a lead-acid battery is 75% .

Again, the discharge efficiency which is Ah_t should only be estimated for their side. The total battery capacity (BCT) is calculated by factoring in the maximum allowable state of charge SOC (M) and the discharge efficiency:

$$BCT=(Ah_t*D)/\{C_D* \sqrt{(WHE*M)}\}$$ **[11]**

For this equation, we have to determine and estimate the different parameters needed.

Firstly, The ampere-hour required per day is :

$$Ah_t = E_L/V_S = 264/12 = 22.$$

Here on, another correlation between The required number of storage days(D) and The maximum allowable Depth of discharge (C_D) is, $C_D = 1-(C_D/D)$.

Now, the necessary maximum permissible DOD (C_D)in case of Lead-acid battery is 50%.

So, the minimum number of storage days, D =1.

The watt-hour efficiency (WHE) for a lead-acid battery has a value of 75% .

And, let, the maximum permissible state of charge SOC (M) =50%

Finally, after calculation, The total battery capacity (BCT) = **71.85A-h. [11]**

So, for round capacity, we can use a 12V 100A-h battery.

PV module sizing:

Total wattage of PV panel: E_L/sunshine period= 571.4286W

We will thereby use 2*300W Pv module.

Current determination:

The average PV system current is : $I_a = Ah_t$/(number of sunshine hours/day)

Here, we are assuming an average 7 hours of sunshine/Day.

So, $\mathbf{I_a=3.1428A}$

Considering charging efficiency, this current should be :

$$\mathbf{I_{a1} = I_a/\sqrt{WHE} = 4.1904A}$$

The average current should be increased by 5% by plugging the low-level insolation and heavy dust deposition. Then the PV output current is,

$$\mathbf{PVC = I_{al} * 1.05 = 4.4A}$$

Voltage determination:

The voltage required to charge a 12 V battery is 13.6 V. The required system voltage should be large enough to charge the batteries, so:

Vs = (number of batteries in series)* 13.6 + voltage drop across blocking diode

So, V_s = 2*13.6+0.7 =27.9V. [11]

PV module configuration:

So, Number of system module:=Integer part of(System voltage/module voltage)+1

=(27.09/18.2)+1= 2+1=3.

String current(SC) = Ah_t/24= 22/24=0.916 [11]

Number of Parallel string = Photovoltaic current/String current(SC) = 4.8034

Inverter Sizing:

Total wattage/hour = 264W/hr.

Assuming, unity power factor, Therefore, Inverter VA rating**= 264VA.**

Assuming, additional future load 20%=264+ 264*20%= **316.8VA**.

Further, we are expecting 80% efficiency. Thus, the inverter rating will be 380.16VA

So, we can work with a 500VA inverter

Charge Controller Sizing:

CCr=Nsp * Imp

Where Nsp = number of strings in parallel, Imp=Maximum power current of the array, CCr = PWM charge controller rating. **[12]**

From our previous calculation, Nsp=4, Imp= 4.4

So, CCr= 17.6A

Summary :

Modules	Rating
Inverter	500VA
battery	12V-1000Ah
Pv module	300W
Diesel Generator	300W
Charge Controller	17.6A

Table 4: Specification summary

1.2.4 Technical & Non-technical Constraints

Technical Constraints	Heavy battery weight
	Lower solar irradiance in rough weather
	Power loss in auxiliary equipment like inverter
	Emergency high load demand
Nontechnical constraints	Getting adjust with this new type of system
	Threat of heavy storm

Table 5: Technical and non-technical constraints

1.2.5 Applicable compliance, standards and codes

IEEE 937

- IEEE Recommended Practice for Installation and Maintenance of Lead-Acid Batteries for Photovoltaic Systems.
    - **Description:** This standard provides design guidelines and instructions for lead-acid storage battery storage, position, mounting, ventilation, assembly, and maintenance for solar power systems. Battery manufacturers may provide detailed instructions for battery installation and maintenance even while suggested procedures are included.

- **IEEE 1361**
    - IEEE Guide for Selection, Charging, Test and Evaluation of Lead-Acid Batteries Used in Stand-Alone Photovoltaic Systems.
        - **Description:** Choosing the appropriate amount of cells for the inverter and derating the arrays to compensate for inadequate airflow, tilt, and azimuth angles.
- **IEEE 1661**
    - This guide is specifically prepared for testing and evaluation of lead-acid batteries in a PV hybrid power system.
        - **Description:** This manual was created to offer a battery test process for photovoltaic (PV) hybrid power systems that can be used to help determine battery capacity and the proper PV fast charging needs. By using this manual, funding agencies, battery producers, PV system integrators, and customers should be able to contact area that could advantage from improved system design and the recharging criteria that follow.

- **IEEE 1547 to 1547.8**
    - These IEEE Standards cover distributed resource connections, certification, implementation standards, design, administration, control, supervision, and sharing of information..
        - **Description:** The integration and compatibility of distributed sources of energy with electricity generation networks are standardized in this protocol. It outlines standards for the installation, testing, and operation of interconnection and interoperability as well as for security, upkeep, and security risks.

1.3 Systematic Overview / Summary of the proposed project

After carefully analyzing the stakeholder's requirements and different drawbacks of conventional power generating systems we observed what type of system they actually need. So we have come up with such a system which is a renewable energy-based system with less fuel consumption, easily conveyable and the least environmental effect features. This system will be enough for satisfying the power demand of the communication devices used by the militaries in a squad.

1.4 Conclusion

From the discussion of this chapter we have learnt how important implementing a renewable based power generation system is in terms of remote military camps. This type of system will benefit this group of people in many ways. It will help them by producing efficient power even in emergency cases and also make them economically sustainable.

Chapter 2: Project Design Approach [CO5, CO6]

2.1 Introduction

In this chapter we will be discussing our proposed design approaches to meet the overall requirements. We have proposed two systems with optimized design, generic calculation and database. We used different commercial softwares to validate the designs.We proposed these designs according to our objectives, specification, requirements and constraints.

2.2 Identifying Multiple Design Approaches

2.2.1 Design Approach 1 with Hybrid Energy Source:

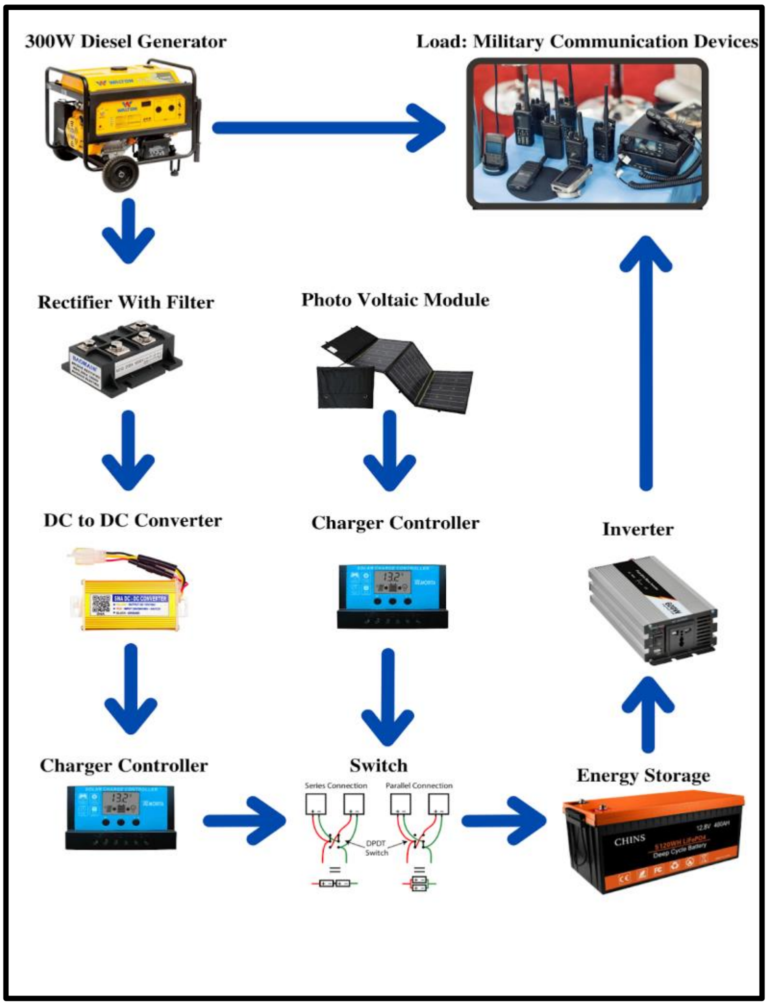


Figure 2: Block diagram of design 1

Description: A Hybrid system combines multiple types of energy generation systems together to generate electricity. This is a valuable method in the transition away from fossil fuel- based economies. On this design approach, we used a hybrid system combining a diesel generator and a Photo-Voltaic Module to generate electricity and meet the demand. During the operation, the diesel generator will generate Alternating Current (AC). And, that current will divide into two portions. One will directly go to the load end and another will go to a rectifier with a filter circuit. The filter is a device that allows passing the dc component of the load and blocks the ac component of the rectifier output. Thus the output of the filter circuit will be a steady dc voltage. And, after that the DC voltage will go through a DC to DC converter. A DC-to-DC converter is an electronic circuit or electromechanical device that converts a source of direct current (DC) from one voltage level to another. It is a type of electric power converter. We need this converter to lower the voltage level which comes from the filter circuit and match the level with our Battery Storage system. In between the output voltage will go through a Charge Controller to our storage system. A charge controller works by regulating the voltage and current flow to a battery. It detects and monitors the battery voltage, reducing the current when the battery is fully charged. The controller maintains a float charge to keep the battery ready for use. As this system is a hybrid system, there will also be a Photovoltaic Module connected with the charge controller. These two energy generation systems can work simultaneously, connected to a switch which will determine the electricity generation system depending on the solar intensity and supply the necessary current to our demand-end. If the solar intensity is high then the generated electricity mostly comes from the Photo-Voltaic Module. Otherwise, the generator will generate the electricity. As a last stage of our design, we need to connect the load-end and the battery storage with an inverter to meet our highest power requirement at a time.

Summary of design 1 parameters:

Project Design and Simulation	Stand Alone
Diesel Generator Size	300 W
The Solar Panel Tilting angle	25° (Area: Chittagong)
Area	1.93m^2
PV Power	300Wp
Battery-Mod. in Series/No. Strings	1/1
Battery 9	12V/134Ah
Battery-Modules in series/parallel	1/2
Technology	Polycrystalline (Cost Cutting and availability)
Module Type	Flat plate
Mounting Disposition	Ground Based
MPPT based Charge controller	12V/300W MPPT

Table 6: Summary of Design 1 parameters

2.2.2 Design Approach 2 with renewable energy resource:

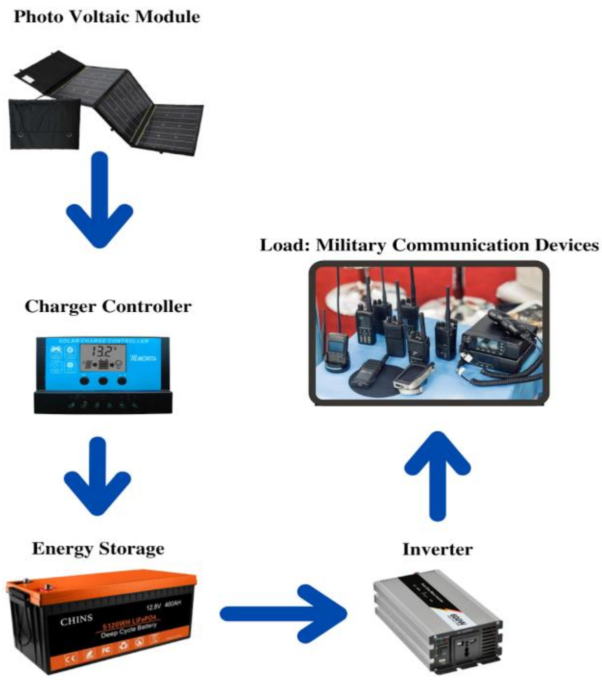


Figure 3: Block diagram of design 2

Description:

Renewable energy stands in contrast to fossil fuels, which are being used far more quickly than they are being replenished. In this design approach, we solely generate the electricity from renewable sources such as Photo-Voltaic modules. During the day time with low to high solar intensity our Photo-Voltaic Module will generate electricity and we will get the output as DC. Due to the solar intensity, the generated electricity will go through the charge controller. The charge controller works by regulating the voltage and current flow to a battery. It detects and monitors the battery voltage, reducing the current when the battery is fully charged. The controller maintains a float charge to keep the battery ready for use. Through this charge controller the generated electricity will be stored in the energy storage system. We need to connect an inverter in between the load and energy storage system. We would require an inverter in this case. An inverter is one of the most important pieces of equipment in a renewable energy system. It's a device that converts direct current (DC) electricity to alternating current (AC) electricity. Finally, our generated AC electricity will go to the load end to meet the power requirement.

Summary of Design 2 Parameters :

Project Design and Simulation	Stand Alone
The Solar Panel Tilting angle	25° (Area: Chittagong)
Area	5m^2
PV Power	300Wp
Mod. in Series/ Parallel	1/3
Battery	12.8V/103Ah
Modules in series/parallel	1/2
Technology	Polycrystalline (Cost Cutting and availability)
Module Type	Standard
Mounting Disposition	Ground Based
Universal Converter	12V/1000W MPPT

Table 7: Summary of Design 2 parameters

2.3 Analysis of Multiple Design Approach

2.2.1 Design Approach 1 Simulation Using Homer Pro Software

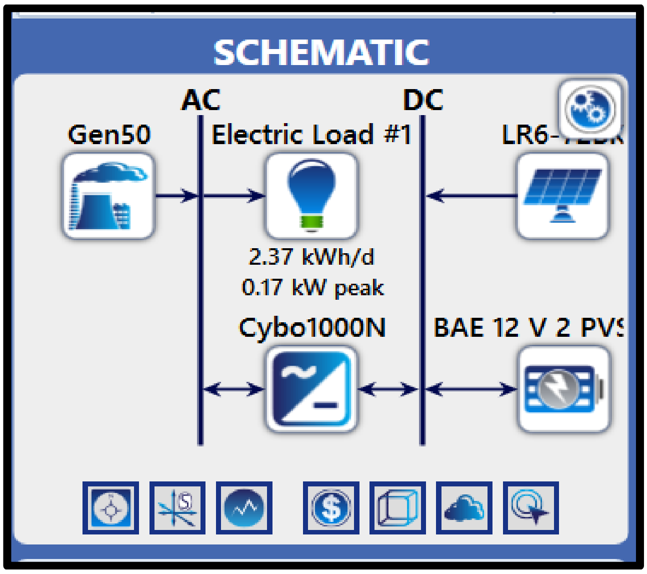


Figure 4: Schematic Diagram in Homer

Parameter setup of Generator :

We have chosen the Standard Narrow Carburetor (size your own) alternative to build the generator. This generator adapts dynamically to the load. The generator's capability will be the least possible without causing a capacity shortfall in any sensitive scenarios or in the years that followed. Additionally, it modifies its fuel consumption to fit its size.

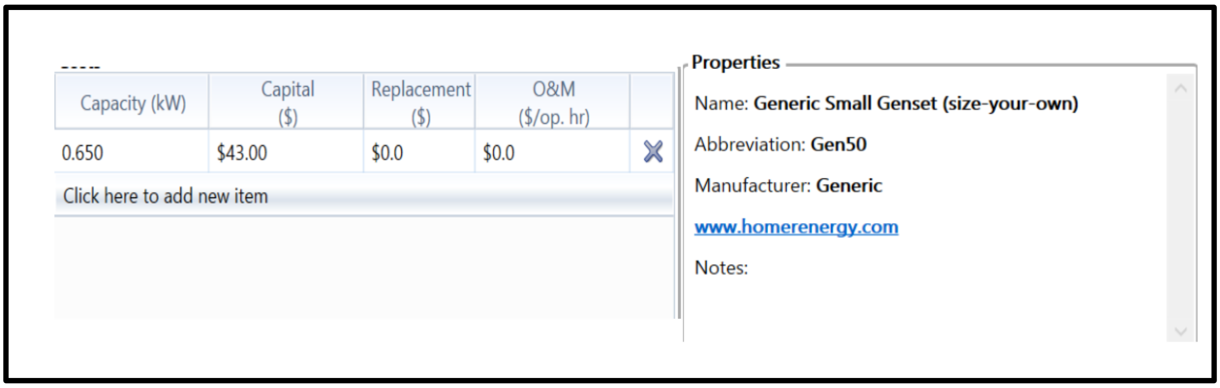


Figure 5: Parameter setup of generator

Minimum Load Ratio and Runtime setup:

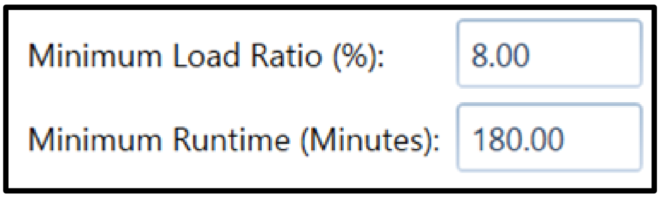


Figure 6: Minimum Load Ratio and Runtime setup

Minimum Load Ratio: The proportion of the generator's entire capacity that represents the minimal load that is legally permitted. We chose 8% for the simulation while it was running. The generator runs at 40% of its performance if the electricity usage is at or below that level. If 4% of the power is needed, it runs at 8%, with the extra power going to the dispatchable load or charging the batteries. The generator is shut off if no electricity is needed.

The minimum run time is set to 180 minutes /day according to our planning.

Operating Schedule of Generator

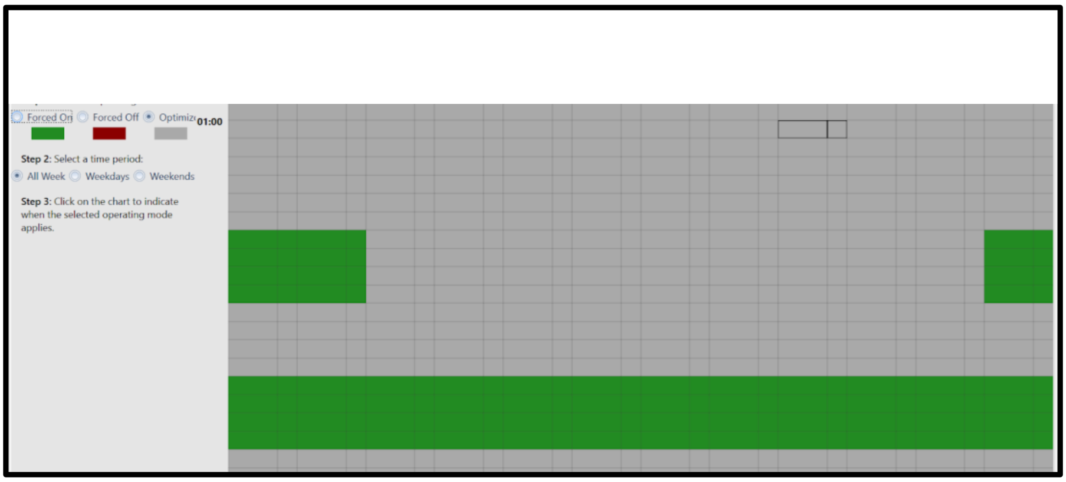


Figure 7 : Operating schedule of generator

Month	Operation schedule	Reason
December, January, February	· 7 AM- 10 AM · 3 PM - 6 PM	These are winter months and Solar intensity is low during morning
Other Months	· 3 PM - 6 PM	No need to operate in the morning hour, since during these months solar intensity is average all around the day.

Table 8 : Operating Schedule of Generator

PV Panel Setup

In this design approach, we have considered a 300W 12V Flexible Foldable Solar Panel. The Derating Factor is considered 80%.The derating factor is a scaling factor that HOMER uses to adjust the PV array power output for decreased output under actual operating circumstances. Compared to the conditions under which the PV panel was rated.

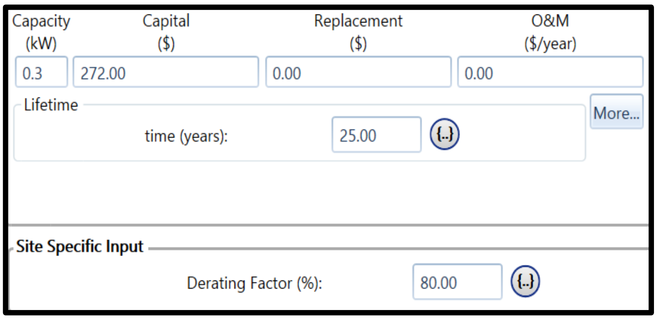


Figure 8 : PV panel setup

MPPT Tracker

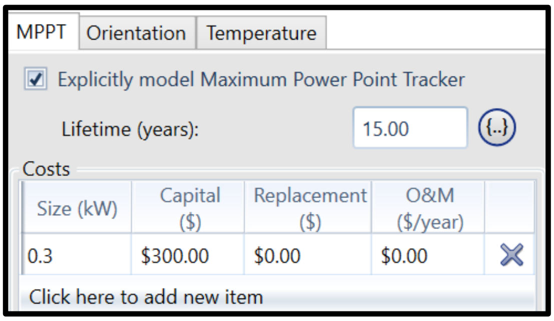


Figure 9: MPPT Tracker setup

Storage

A 12 V-134 Ah battery has been considered.

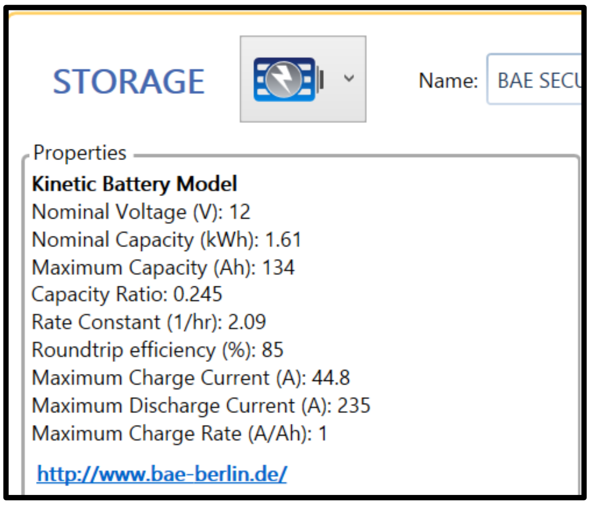


Figure 10 : Battery setup

- **Kinetic Battery Model:** The Kinetic Battery Model is employed by HOMER software to calculate the amount of energy that may be absorbed by or released from the battery system at each sampling interval. This model, which has two tanks, has kinetics that are similar to those of a lead acid battery. "Power generated," or electricity that is ready to be converted into DC power, is present in the first tank. Energy that is organically bound, or "bound energy," is present in the second tank but is not organisational type. The idea is illustrated in the diagram below.

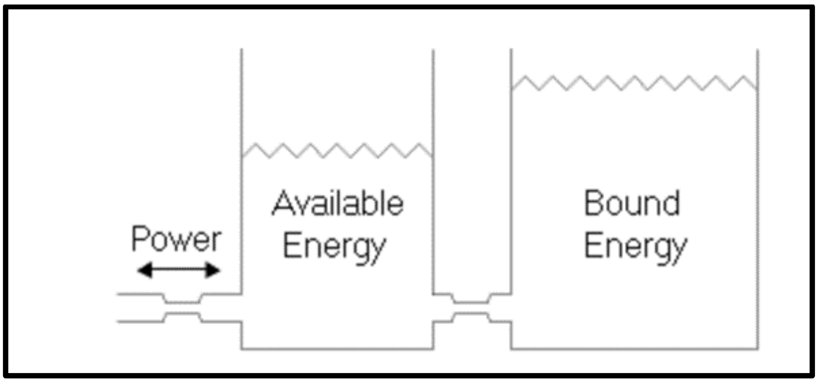


Figure 11: Battery Model

- **Capacity Ratio**: The ratio of the accessible tank's capacity to the sum of the two tanks' capacities.

- **Round Trip Efficiency:** The storage bank's efficiency on a round-trip basis from DC to storage to DC.

- **Rate Constant:** This represents the measurement of how fast energy can flow between the available and bound tanks.

- **Storage throughput:** the volume of energy that the holding bank processes annually. It describes the shift in the storage bank's intensity level that is monitored both before and after losses occur during discharge. In other words, the longevity of the storage vault is estimated using this parameter.

Converter (Inverter & Rectifier)

This Converter set up page has options for setting parameters for both inverter and rectifier. The system we are developing in Homer, a 12V-300W inverter has been considered.The Relative capacity option under Rectifier Input is given 100%. That means a rectifier of an appropriate size will be used.

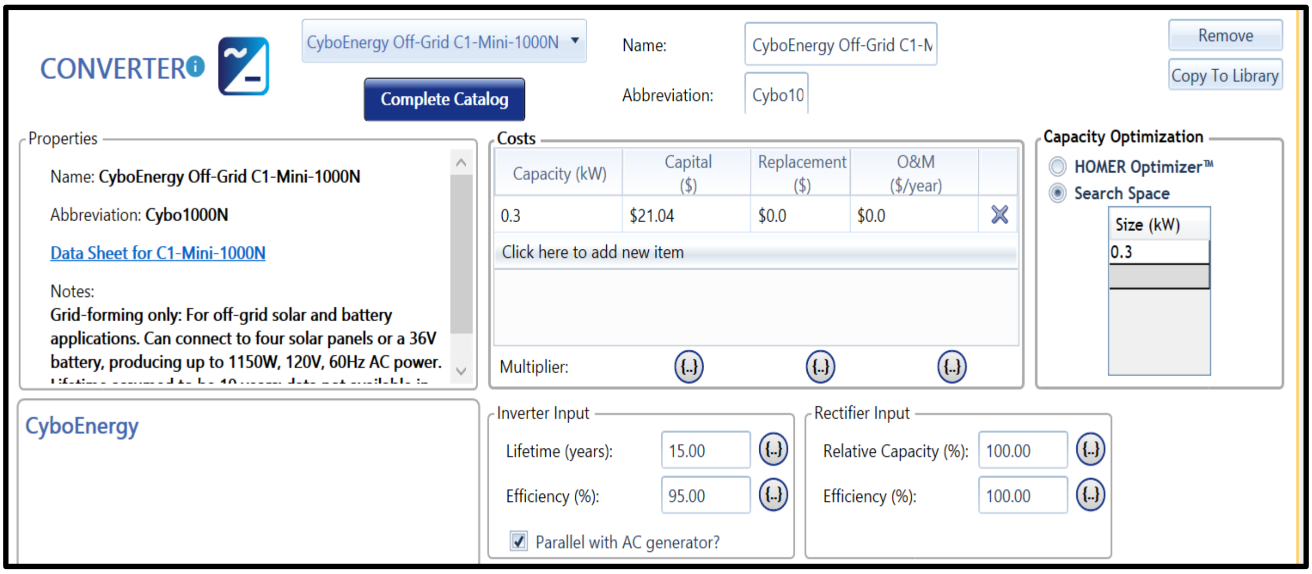


Figure 12: Converter Setup

2.2.2 Design 1 Simulation Result

Generator :

Quantity	Value	Units
Hours of Operation	3,189	hrs/yr
Number of Starts	730	starts/yr
Operational Life	4.70	yr
Capacity Factor	11.4	%
Fixed Generation Cost	0.0181	$/hr
Marginal Generation Cost	0.230	$/kWh

Table-1

Quantity	Value	Units
Electrical Production	652	kWh/yr
Mean Electrical Output	0.204	kW
Minimum Electrical Output	0.0520	kW
Maximum Electrical Output	0.397	kW

Table 2

Quantity	Value	Units
Fuel Consumption	246	L
Specific Fuel Consumption	0.378	L/kWh
Fuel Energy Input	2,424	kWh/yr
Mean Electrical Efficiency	26.9	%

Table 3

Figure 13: Generator Results

These tables show the overall output production and cost summary. **Capacity Factor** refers to the average output power of the generator divided by its total generating capacity. **Fixed generation cost** is the fixed cost of running the generator, in $/hr. **Marginal cost** is multiplied by the size of the generator, then added to the fixed cost, to determine the total cost for the event of maintenance.

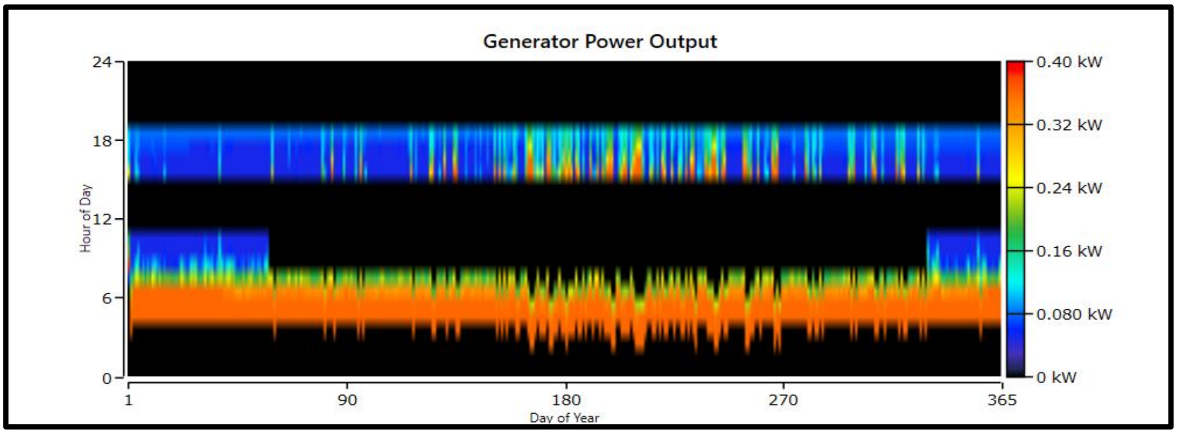


Figure 14 : Generator power output

The graph above gives the idea about the power delivered by the generator at a particular duration of a day in a year. For example, at the 18th hour (6.00 PM) we can see that the generator output power is coming out. It is because this hour is within the operating hour of the generator.

PV panel:

Quantity	Value	Units
Rated Capacity	0.300	kW
Mean Output	0.0461	kW
Mean Output	1.11	kWh/d
Capacity Factor	15.4	%
Total Production	403	kWh/yr
Dedicated converter	0.300	kW

Table-1

Quantity	Value	Units
Minimum Output	0	kW
Maximum Output	0.244	kW
PV Penetration	46.6	%
Hours of Operation	4,371	hrs/yr
Levelized Cost	0.110	$/kWh

Table-2

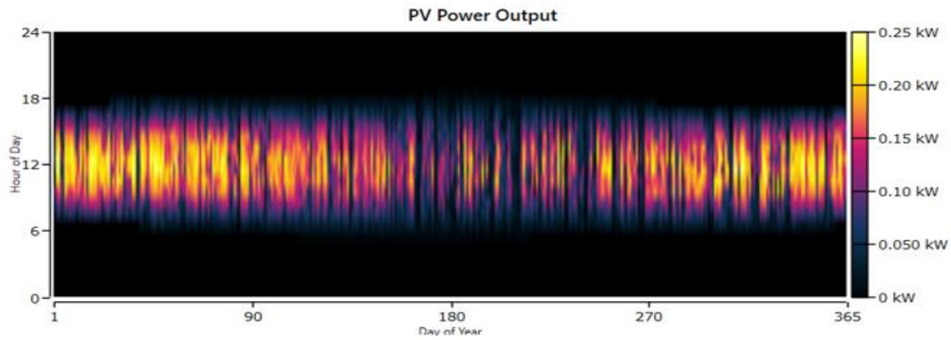


Figure 15: PV Results

At Table-1 we can notice that the Rated capacity is 0.300 kW. The capacity of each PV panel was 0.300 kW. Therefore, the required number of PV panels: 0.300/0.300 = 1. The average output power is 0.0461 kW & 1.11 kWh/day. Capacitor Factor is 15.4 %. **Capacitor Factor** means, The average power output of the PV array (in kW) divided by its rated power, in %. At Table -2 PV- Penetration results 46.6% and finally the levelized cost is 0.110 $ / kWh. **PV-Penetration** The average power output of the PV array divided by the average primary load, in % The graph below gives the idea about the power delivered by the PV panels at a particular duration of a day in a year. For example, at the 12th hour (12.00 PM) we can see that the PV output power is high. It is because at this hour the Sun shines at maximum intensity. Likewise, at 20th hour (8PM) the output power coming out from the PV panel is zero, since it is night time.

Battery Storage

Quantity	Value	Units
Batteries	1.00	qty.
String Size	1.00	batteries
Strings in Parallel	1.00	strings
Bus Voltage	12.0	V

Table-1

Quantity	Value	Units
Autonomy	13.0	hr
Storage Wear Cost	0	$/kWh
Nominal Capacity	1.61	kWh
Usable Nominal Capacity	1.29	kWh
Lifetime Throughput	1,860	kWh
Expected Life	3.81	yr

Table -2

Quantity	Value	Units
Average Energy Cost	0.227	$/kWh
Energy In	528	kWh/yr
Energy Out	450	kWh/yr
Storage Depletion	0.730	kWh/yr
Losses	79.3	kWh/yr
Annual Throughput	488	kWh/yr

Table-3

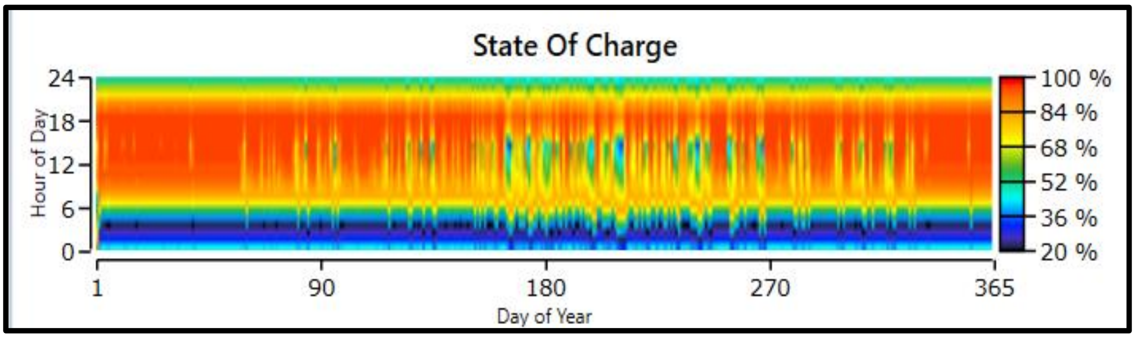


Figure 16 & 17: Battery output results

The graph gives the idea about the State of Charge of the Batteries at a particular duration of a day in a year. For example, within the 12th hour (12.00 PM) to the 18th hour we can see that the state of charge is high. It is because at this hour the Sun shines at maximum intensity and the battery stores from that. Likewise, at 2nd hour (2 AM) the state of charge is very slow. Because during night the batteries discharge power to energize the loads.

Electrical Production:

Production	kWh/yr	%
LONGi Solar LR6-72BK	403	38.2
Generic Small Genset (size-your-own)	652	61.8
Total	1,055	100

Figure 18: Overall Electrical production

Fuel Consumption:

Quantity	Value	Units
Total fuel consumed	246	L
Avg fuel per day	0.675	L/day
Avg fuel per hour	0.0281	L/hour

Fuel Consumption

Figure 19: Overall Fuel Consumption

Emission:

Quantity	Value	Units
Carbon Dioxide	645	kg/yr
Carbon Monoxide	4.03	kg/yr
Unburned Hydrocarbons	0.177	kg/yr
Particulate Matter	0.0241	kg/yr
Sulfur Dioxide	1.58	kg/yr
Nitrogen Oxides	3.78	kg/yr

Figure 20 : Rate of Emission

Time Series Plot:

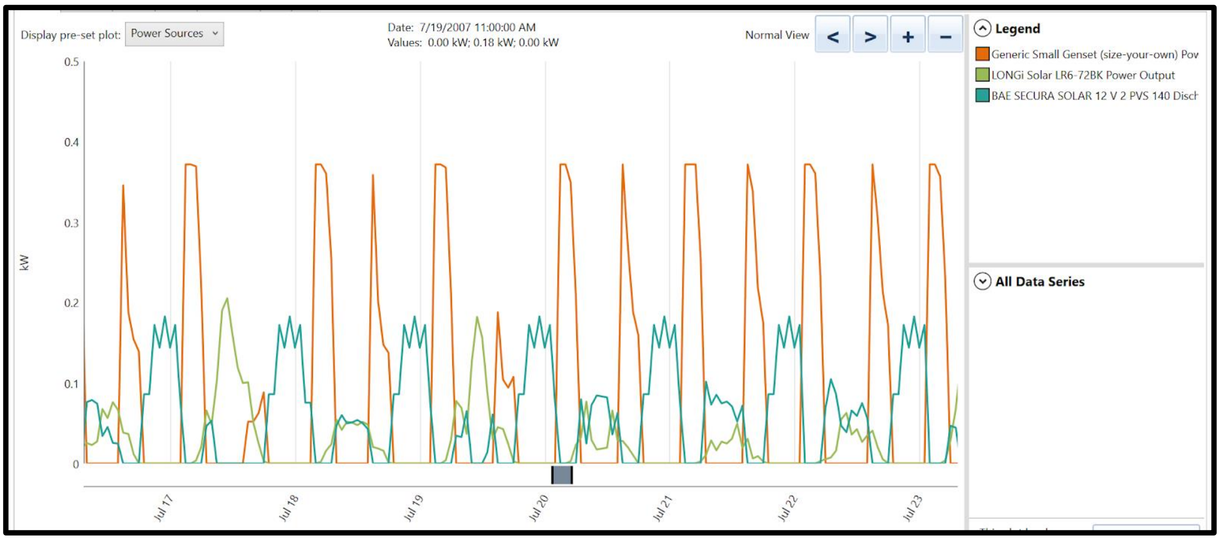


Figure 21: Time series plot

This graph says, which power supply component is responsible for delivering power to the loads at a particular time and how much power it is providing to load. For example, in the given graph the cursor is placed at the marked position and it is at 11 AM of 19th July. Here it says, Solar panels are giving output power of 0.18 KW, at the same time no power is coming out from the generator as this time is not included in the generator operation schedule and the batteries discharge power is also zero. Because in this duration either battery is in charging mode or in rest mode. Thus this graph implies for each duration in hours throughout the year.

2.2.3 Design Approach 2 Simulation Using PVSyst Software

Inputs Required in PVsyst:

- **Area Selection:**

Firstly, we need to select the area. Here PVsyst shows-up a message that invites you to load the Geographical site. We can do it through the 'load site' icon marked by an asterisk. Or through the Geographical coordinates we can select our desired location. In this case, we are selecting a Place at Thanchi, Bandarban whose Geographical Coordinates are Latitude 21.8223° and Longitude 92.4312 °.

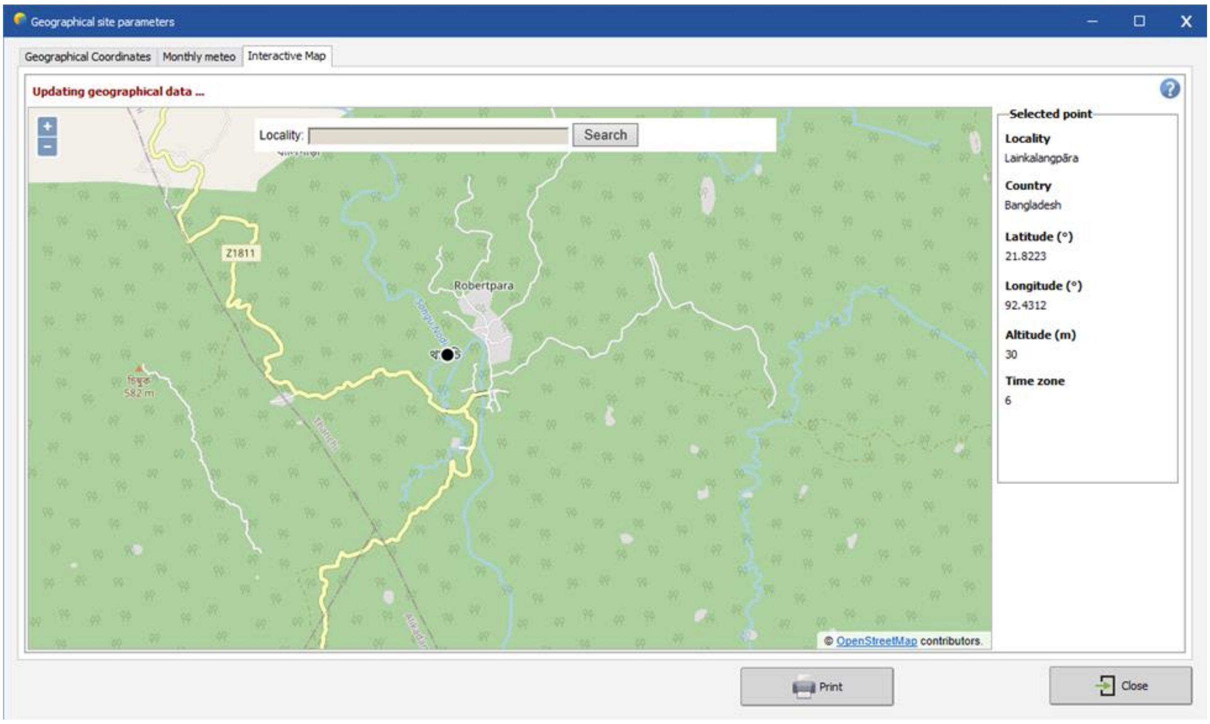


Figure 22: Geographical Site Coordinates

Monthly meteorological data Selection:

The list of meteo files is comprised of all the files found in the area around the currently targeted site. The simulation process requires the following meteorological hourly data:

- Horizontal Global Irradiance
- Ambient Temperature,
- Horizontal Diffuse Irradiance (optional, may be constructed by a model)
- Wind velocity (optional, for module temperature calculation).

PVsyst uses different data sources like Vaisala, Explorador Solar, Meteonorm, NREL's National solar radiation database, SolarGis etc to import these meteorological data. All these hourly and monthly data are imported as geographical sites files *.SIT, and it requires the formation of Synthetic Generated hourly data files for getting used in the simulation.

Geographical site parameters

Geographical Coordinates | Monthly meteo | Interactive Map

Site: Lainkalangpāra (Bangladesh)

Data source: Lainkalangpāra_MN80.SIT -- Meteonorm 8.0 (1981-2000), Sat=100%

	Global horizontal irradiation	Horizontal diffuse irradiation	Temperature	Wind Velocity	Linke turbidity	Relative humidity
	kWh/m²/mth	kWh/m²/mth	°C	m/s	[-]	%
January	125.7	56.6	21.1	1.99	4.138	66.4
February	136.0	56.2	23.9	2.31	4.325	62.7
March	165.7	74.9	26.8	2.60	5.619	66.8
April	178.2	84.5	28.4	3.29	6.169	74.7
May	167.1	95.3	29.1	3.19	6.519	77.1
June	143.9	88.8	28.2	3.39	5.976	83.7
July	109.3	82.4	28.3	3.70	4.896	84.6
August	141.3	86.3	28.4	3.20	4.476	84.2
September	138.1	81.3	28.2	2.50	4.127	83.9
October	136.1	71.7	28.2	1.61	3.907	78.5
November	135.8	43.6	25.3	1.49	3.872	72.7
December	126.2	46.1	22.3	1.59	4.001	69.7
Year	**1703.4**	**867.7**	**26.5**	**2.6**	**4.835**	**75.4**

Global horizontal irradiation year-to-year variability 4.7%

Figure 23: Geographical site monthly meteorological data

Parameter Selection

The steps of system design by PVsyst are:

1. Pre-sizing:

Here we need to define the desired PLOL, Autonomy, Battery voltage etc. Here we want the Loss of load (LOL) probability to be 5%, Battery voltage to be 13V, and a minimum one days of autonomy.

LOL Probability: This value is the probability that the user's needs cannot be supplied

Autonomy days: The number of days which the loading need may be satisfied solely by the cell, without the use of solar, and beginning from a battery that is "completely charged," is known as the isolation days.

2. Storage System

The suggested battery capacity by PVsyst is 217Ah. Thus we have selected a 12.8V 103 Ah Li-ion battery module. We will need 2 of them to connect in parallel in order to store the required capacity. In total, it will have a 27 kg weight. The minimum SOC (State of charge) will be 50% which is acceptable.

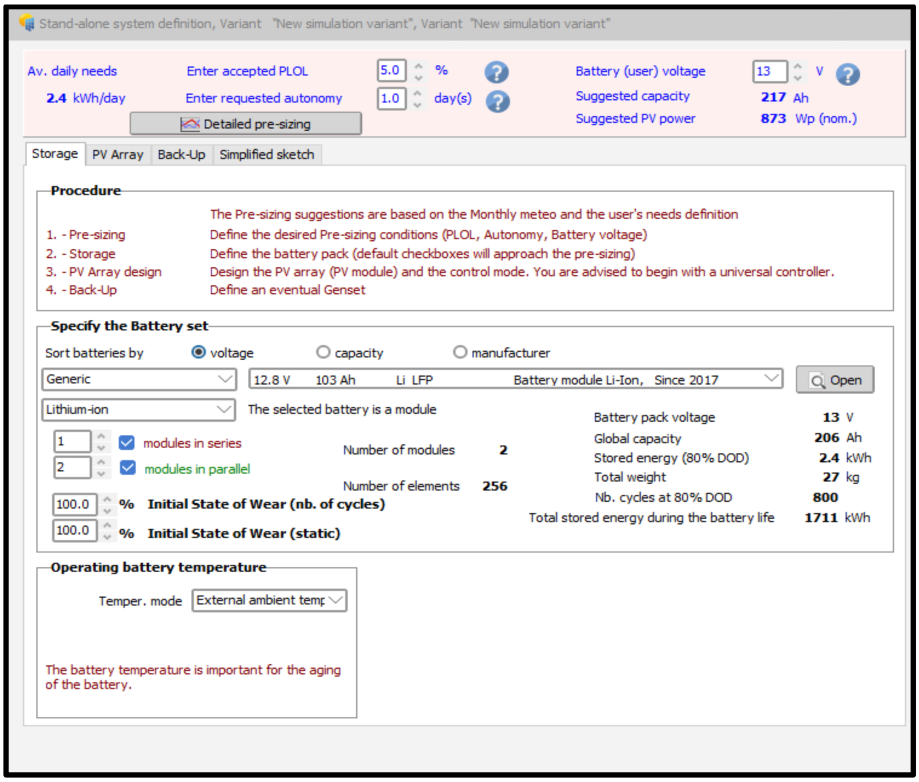


Figure 24: Storage system parameter

PV Orientation :

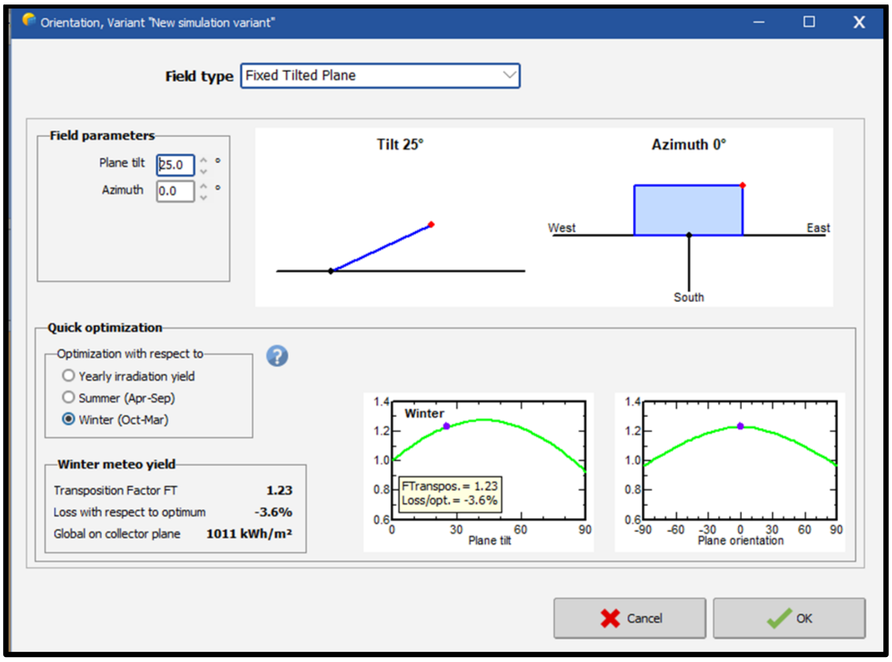


Figure 25: Field Parameters of the PV panel and Optimization by respect to yearly irradiance

Firstly, in PV configuration This Fig. represents the tilt angle which is 25.0 and orientation of the PV panel along with optimization details. Here the optimization was done w.r.t winter(October-March)

Horizontal Line of Solar:

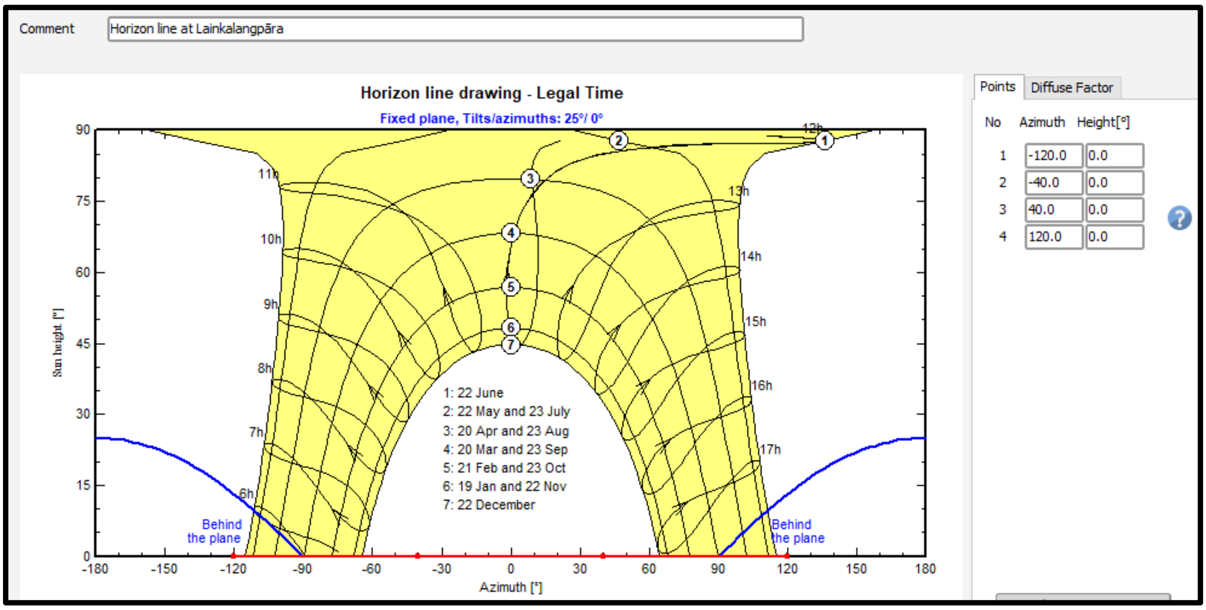


Figure 26: Horizon (For shading) definition at Lainklangpara

Configuration:

Subsequently, according to our orientation and other factors PVsyst optimizer suggests a system of 1242W to meet our requirements. As we didn't find any 12V PV, we picked up a 27V 300W PV panel to meet our requirements. Then we use a converter to manage our demands.

The system size, or the assessment of the rechargeable battery and PV array power in proportion to user needs and climatic conditions, is the main issue primarily in the early phases of a stand-alone system research. After the brief pre-sizing review, a thorough hourly simulation is needed to assess the results, such as PLOL and underutilized energy. To get rid of the control restrictions, PVSyst offers a flexible "generic" universal controller for the three alternative techniques. These particular devices will adjust their settings to the system during the scaling process in order to permanently involve the entire without controlling losses during the hourly exercise. In our scenario, the controller's adapted parameter is a 12V/1000W MPPT Converter.

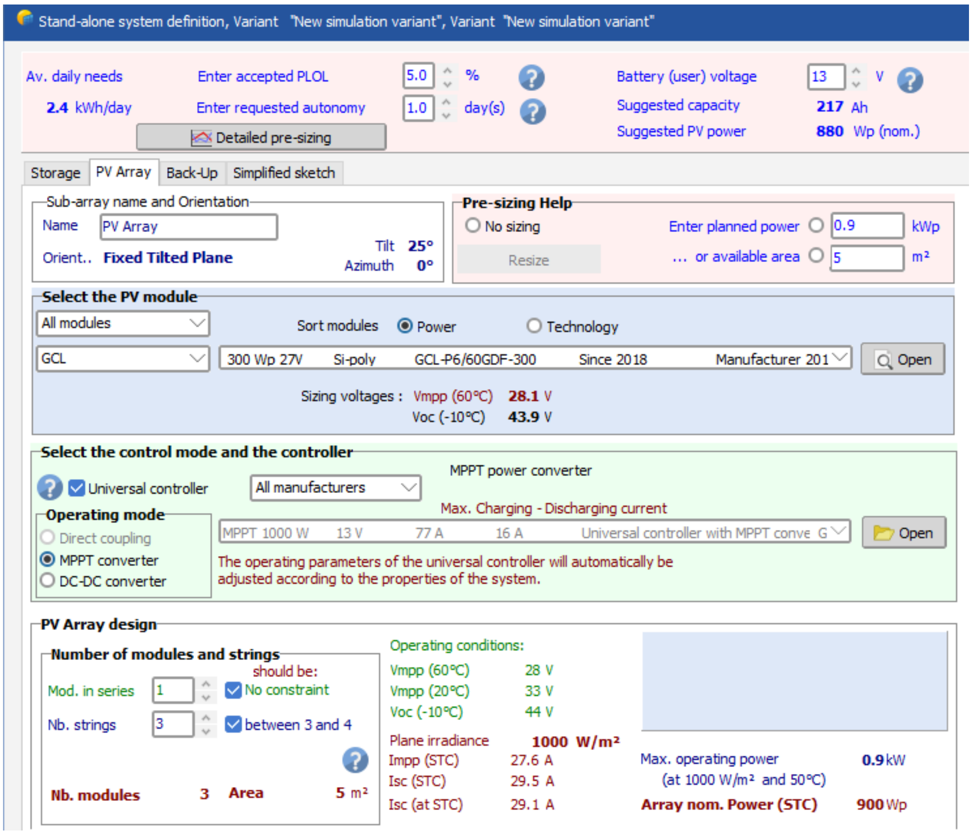


Figure 27 : PV and Converter parameter configuration

2.2.2 Design 1 Simulation Result

Parameter	Value
No. of PV modules	3
PV modules in series	1
PV modules in parallel	3
Module area	5m^2
Module quality loss	0.8%
Module mismatch loss	2.1%
No. of battery	2

Battery in series	1
Battery in parallel	2
PV module size	600Wp
Available energy	879.5KWh/yr
Used Energy(KWh/yr)	786.1KWh/yr
Specific production(KWh/KWp/yr)	1466KWh/KWp/yr
Excess (Unused) (KWH/yr)	62.8kWh/yr
IAM Factor on global (%)	1.71%
PV Losses due to temperature	10.56%
Performance ration/capacity factor	71.5%
Solar Fraction	89.2%
Loss of Load (%)	2.8%
Missing energy(KWh/yr)	95.2kWh/yr

Table 9: Design 2 Simulation Result

Loss Diagram:

By emphasizing the source documents of losses, the loss diagram offers a rapid and comprehensive view into the grade of a PV system design. Beginning with a preliminary estimation of the nominal energy by using the global effective irradiance and MPP efficiency at STC, the array losses are determined. The behavior of the PV model in relation to external variables is then described.

The figure for standalone systems provides detailed info about how the battery has been used, including the amount of energy actually passes through the battery. It's important to use batteries as little as possible to extend their lifetime. Since the percentage numbers are not cumulative, the overall percentage is not equal to the sum of the individual values when the losses are combined. To produce a consistent figure, the simulation procedure and several variable definitions have to be completely redesigned. Additionally, some contributions are impossible to objectively assess. In standalone systems, for instance, the ohmic losses are determined using the standard equation $P_{(loss)} = I^2 * R$. Because the array resistance changes the PV operating point and the overall circuit equilibrium, a more accurate estimate would likely involve simulating the entire system with and without this resistance and comparing the results. however, some loss contributions will be distributed among others.

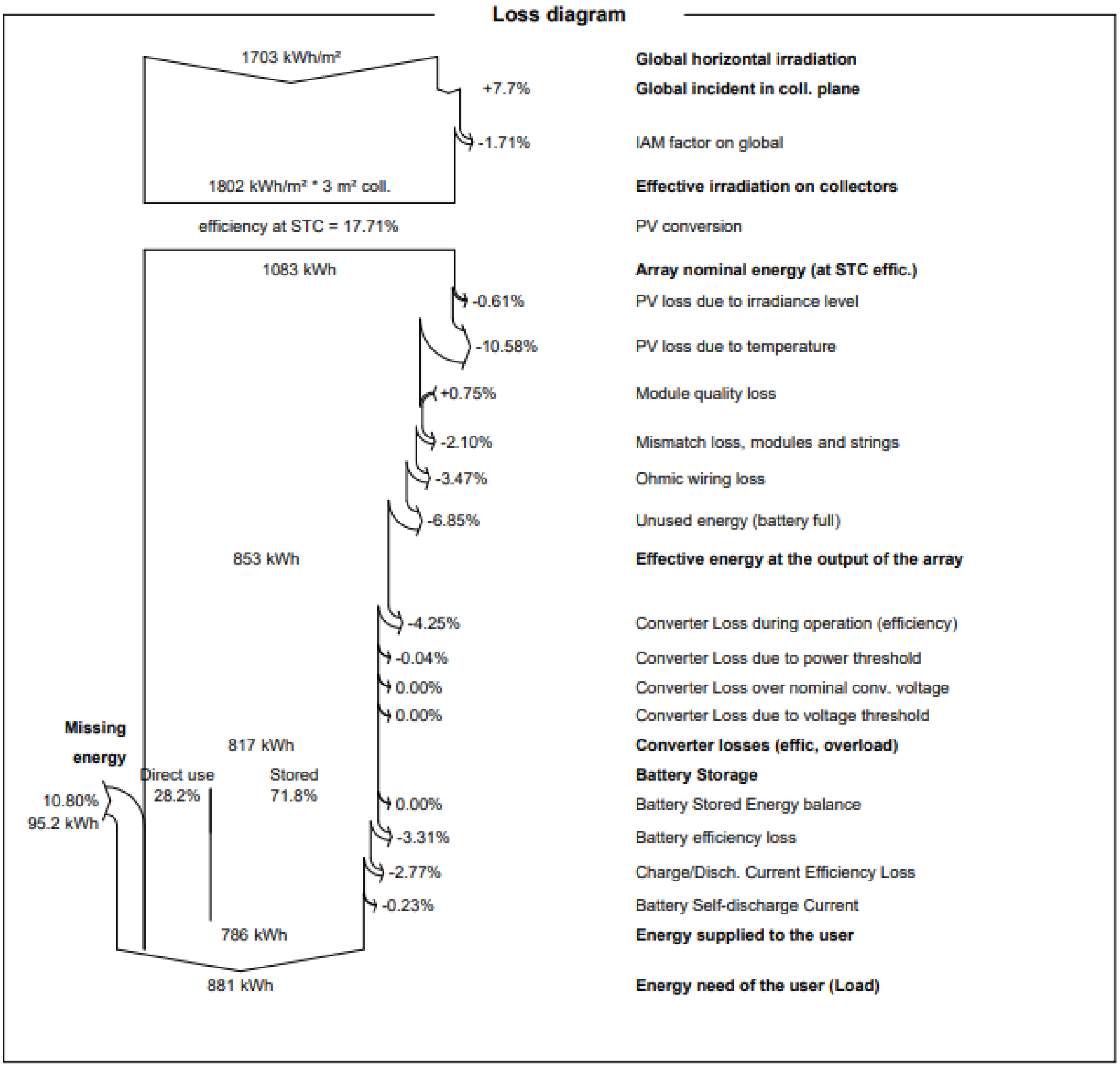


Figure 28: Loss Diagram

Balances and main results over the month:

New simulation variant
Balances and main results

	GlobHor	GlobEff	E_Avail	EUnused	E_Miss	E_User	E_Load	SolFrac
	kWh/m²	kWh/m²	kWh	kWh	kWh	kWh	kWh	ratio
January	125.6	158.8	79.10	8.907	7.44	67.41	74.85	0.901
February	135.7	160.2	78.64	9.885	1.35	66.25	67.61	0.980
March	165.4	176.0	85.11	8.354	1.25	73.60	74.85	0.983
April	178.3	172.8	83.30	9.214	1.23	71.21	72.43	0.983
May	167.0	150.7	73.22	0.490	3.47	71.38	74.85	0.954
June	143.6	126.2	61.73	0.525	13.07	59.37	72.43	0.820
July	109.2	97.7	47.76	1.176	30.75	44.09	74.85	0.589
August	141.5	132.7	64.72	2.373	14.66	60.19	74.85	0.804
September	138.2	138.9	67.54	1.686	9.59	62.84	72.43	0.868
October	136.1	150.8	72.91	4.444	9.23	65.62	74.85	0.877
November	135.9	170.3	83.08	8.088	0.36	72.07	72.43	0.995
December	126.0	166.4	82.41	7.612	2.81	72.04	74.85	0.962
Year	1702.5	1801.7	879.51	62.752	95.22	786.07	881.29	0.892

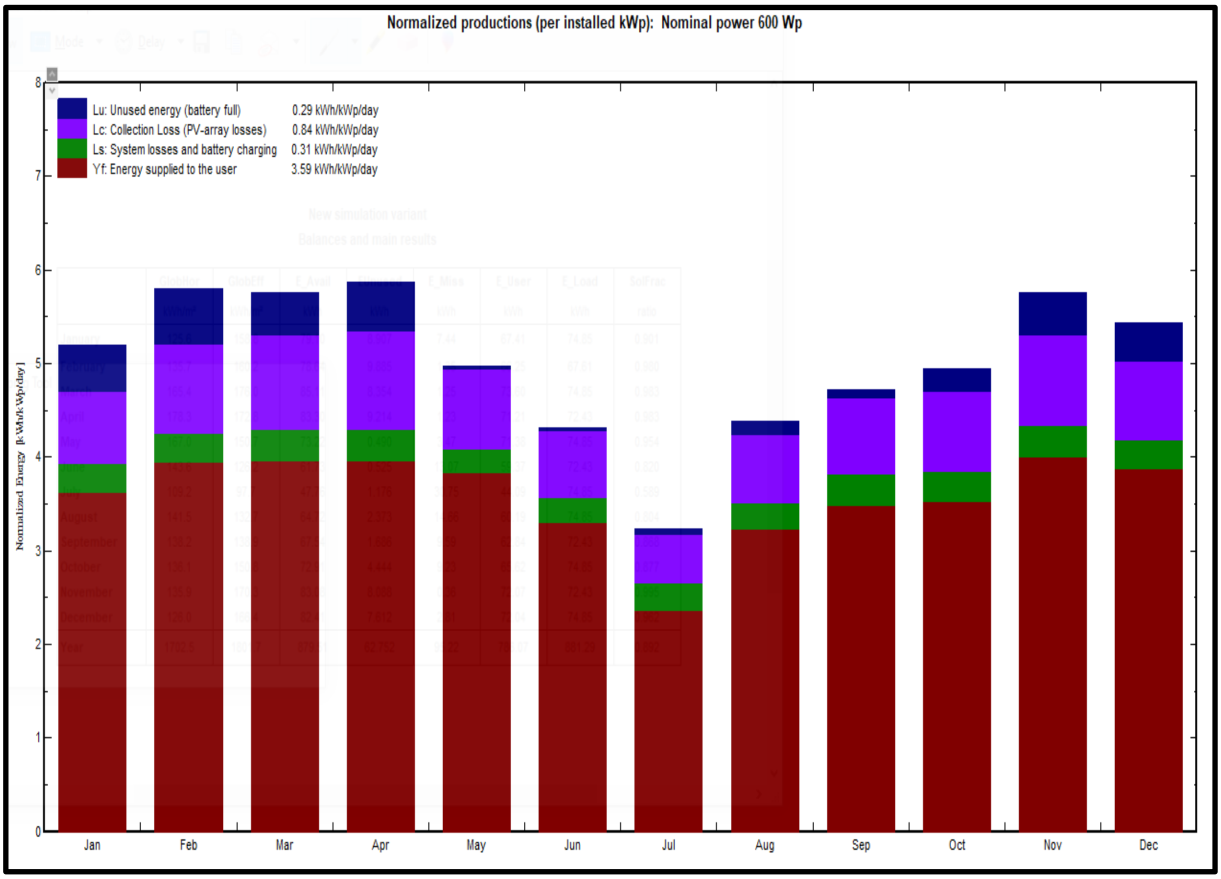


Figure 29: Normalized production and loss factors

This Figure Represents the graph between normalized power production and loss factor which is yield on yearly basis. Here the energy supplied to the user is 71%, collection loss (PV array losses) is 16.6%, system losses and battery charging is 6.1% and the unused energy (battery full) is 5.7%.

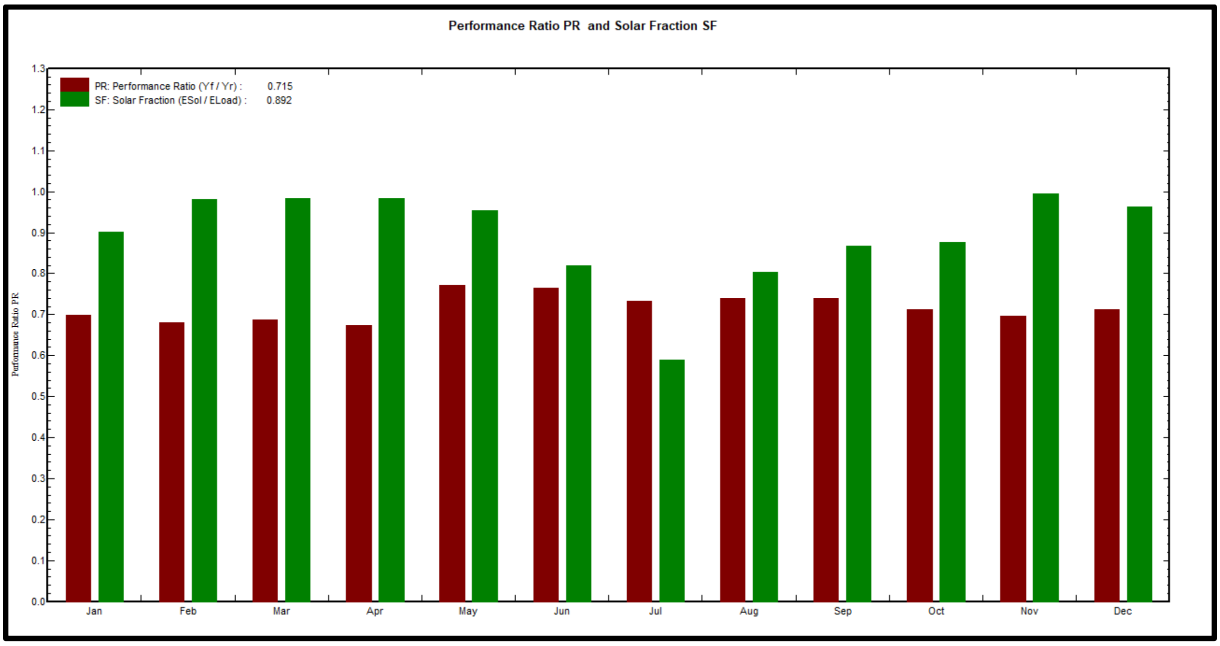


Figure 30 : Performance Ratio and Solar Fraction

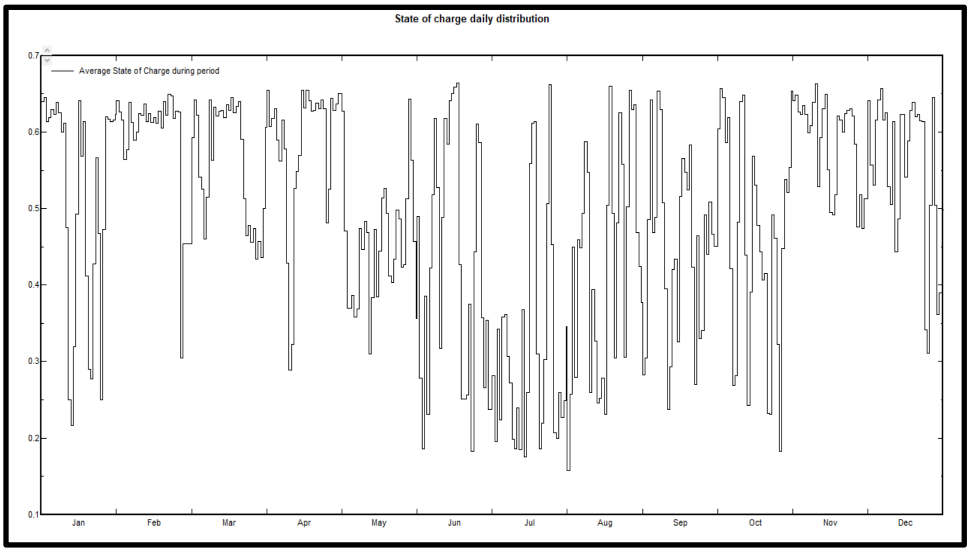
Performance Ratio:

The performance ratio (PR) is a quality factor that measures the quality of a solar PV plant regardless of location. The Performance ratio is expressed as a percentage and reflects the correlation between the PV plant's actual and theoretical energy outputs. According to the regional data, the average Solar Panel Efficiency in Thanchi, Chittagong region is 71%.

Solar Fraction:

The performance ratio (PR) is a quality factor that measures the quality of a solar PV plant regardless of location. The Performance ratio is expressed as a percentage and reflects the correlation between the PV plant's actual and theoretical energy outputs. In that case, our solar fraction is almost on average 0.892, which is almost 89% of the total generated energy around the year.

State of charge daily distribution



The graph above gives the idea about the State of Charge of the Batteries at a particular duration of a day in a year. The state of charge (SOC) of a cell denotes the capacity that is currently available as a function of the rated capacity. The value of the SOC ranges from 0% and 100%. If it is 100%, then the cell is considered to be fully charged. And when The State of charge shows 0%,it indicates that the cell is completely discharged. Since the SOC cannot rise above 50% in real-world applications, the cell is recharged once the SOC hits that level. Similar to this, the maximal SOC starts to drop as a cell ages. Accordingly, a 100% SOC for an old cell would be similar to a 75%–80% SOC for a new cell. From here we can see the average state of charge fluctuates at 30%-60% .It fluctuates more at May-June-July period which is almost 15%-65%. and after October the fluctuation again reduces by 35-65%.

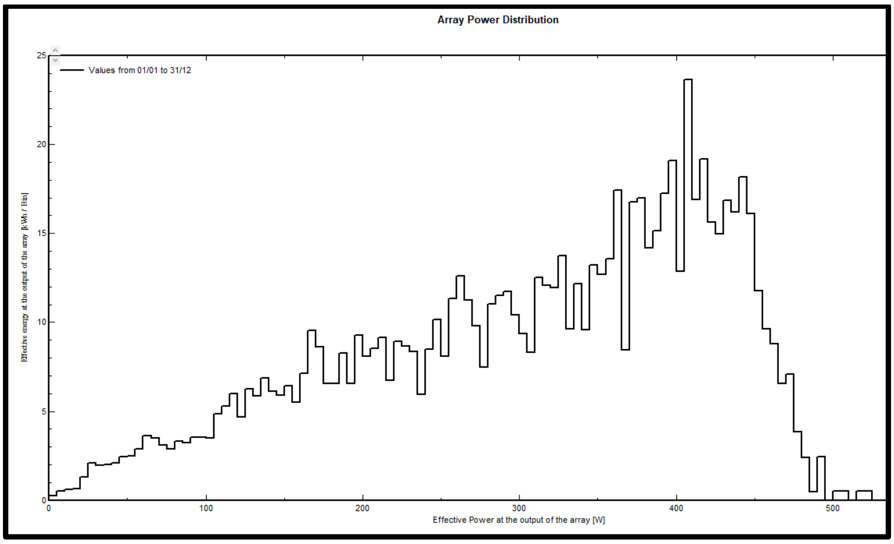


Figure 31: Effective energy at output

This graph provides a scenario of effective energy at the output of the array with a perspective of effective power at the output of the array. And, here we can see at close to 400W effective power it gives the highest effective energy at the output of the array.

2.4 Conclusion

To validate our designs we have done simulations for both of our designs. We have got plenty of numerical and graphical data. These output results coming from individual components as well as from the entire system will help us to choose the optimum design between them. Moreover, we can observe that weather both of our systems need any further optimization or not.

Chapter 3: Use of Modern Engineering and IT Tool. [CO9]

3.1 Introduction

Perfect Selection of Modern Engineering/IT Tools is a prerequisite to develop and test the feasibility of a complex engineering project. During the development phase of the project we had to use different software to study and validate the project. Then we applied some engineering tools in hardware setup.

3.2 Software tools Selection

SOLAR PV AND HYBRID SYSTEM DESIGN TOOLS:

There are several professional software programs accessible to research off-grid hybrid and sustainable energy systems. The general software programs HOMER, RETscreen, and Hybrid2 were created primarily for the technical and financial evaluation of hybrid renewable energy systems. They therefore provide sizable collection of tools that offer resource estimate based on verified data. However, these software packages do not handle changing peak loads and do not cater for the proposal's urban and rural components. On the other hand, resources for designing solar & PV systems that are especially suited for urban applications include Ecotect, PVSyst, Solar Pro, and Sombrero. This is mostly because of the three-dimensional CAD functionality and the capability to take neighboring barriers' impacts into account while performing computations.

In our case study, we have used PVsyst and Homer.

- **Homer:** The National Renewable Energy Laboratory (NREL) created HOMER, a hybrid optimization tool for electric renewables, to be used for simulation, sensitivity analysis, and optimization of hybrid energy technologies. It is beneficial to adjust the sizes of various PV-battery system components while taking into consideration the operational and technological aspects of the system. Additionally, it may offer an economic analysis and system viability report. The software's ability to identify all feasible optimal configurations of a hybrid system that is connected to a wind turbine, solar panel, hydroelectric facility, and distributed generator is its most distinctive feature. It does not, nevertheless, account for nearby structures, trees, and obstructions. Both of our suggested systems were created using Homer. The dimensions and quantity of modules were optimized thanks to its refinement capability.

- **PVsyst:** Some of the energy modelling techniques used by the solar sector to predict the energy harvest of a proposed project site is the PC software program PVsyst V6.64.In addition to the economic analysis, it displays the number of PV modules, cycle life, inverter size, Photovoltaic modules dissipation factor, energy assessment, hourly profile, P-V curve, and peak power point. It offers a large database of well-known rechargeable and PV module manufacturers. Its extensive geographic database can provide accurate details on the solar insolation and solar activity hour of a specific region of a country. The key feature that makes this program intriguing is that it allows a 3D modeling environment and accounts for the shading and blockage effects of nearby objects like bushes, buildings, and other structures, which helps to produce a more realistic outcome. The suggested system was designed using PVSyst 2. It was a solitary off-grid PV installation. Since we weren't able to locate a specified generator for the system, we decided not to execute the design concept 1 at PVsyst.

CAD Design Tools:

- **Fusion360:** The business AUTODESK created the program Fusion360, which is incredibly comprehensive, simple to use, and effective for creating computer-assisted drawings. It is a 3D modeling, CAD, CAM, CAE, and PCB runtime environment for expert product design and production that runs in the cloud. In our venture, we created the entire thing here to see how it may look in the future. As making the final product user-friendly is one of the primary objectives. As a result, we were able to create an accurate representation of the intended device and build every device using our defined specification.

3.3 Hardware tools selection

Selecting the appropriate tool for each function requires tool knowledge, field experience in their safe usage, and adhering to the manufacturer guidelines and instructions for that specific tool. A tool is a handled instrument that assists in the completion of a task. To develop our system we choose different hardware components.

- **PV Panel Selection:** We chose Monocrystalline Photovoltaic Cells to design and demonstrate our system (specification 2V and 20 Watt per cell). We used 12 cells to create a 120 Watt 12V PV module. We connected two cells in parallel to create a 2V 20 Watt panel, and then combined these panels to create a 12V 120 Watt PV module. When designing this PV system, we used cells with an efficiency of about 22.67%.

- **Battery Bank:** We decided on a battery bank, which has a nominal voltage of 12 V. It has a capacity of 7.5Ah for 20HR (10.5V), 6.9Ah for 10HR (10.5V), and 5.4Ah for 1HR (9.60V). This battery is outfitted with high-performance plates and electrolytes to provide more power output for a standard power backup system. This battery features a Heavy Duty Structure with automated construction. It features a design and may provide excellent dependability and stability.

- **Solar Charge Controller:** We incorporated a 10A 12V Intelligent PWM Solar Charge Controller to construct our design. It is a solar power generating system automatic monitoring device that regulates the multi-channel solar cell array to charge the battery and the battery to power the load of the solar inverter. The solar charge controller is the central control component of the photovoltaic power supply system.

- **MT3608 2A Max DC-DC Step Up Booster Power Module:** The MT3608 2A Max DC-DC Step Up Power Module Booster Power Module is a reasonably priced device that can step-up a 2 to 24V input voltage up to a 5 to 28V output at up to 2A. Depending on the input/output voltage settings, this boost converter may output a value in the region of 5.0 to 28V at a constant current of up to 1.5A, with 1A being possible with the majority of configurations. The input voltage has to be less than the output voltage because it is a boost converter. Instead of electrolytic caps, the device can employ bulk low ESR ceramic capacitors, which helps with the compact manufacturing and allays worries about lengthy aging.

- **DC-DC Buck-Boost adjustable step up and down converter XL6009 module:** We picked this auto-buck-boost module because it addresses this issue for 12V devices and can stabilize the output at 12V irrespective of the input voltage, which can range from 5V to 32V. Every random voltage input voltage output may be adjusted, within the range of 5V32V input voltage range and 1.25V35V output voltage spectrum using automated lifting pressure. 4A-capable, 94%-efficient MOSFET switch built-in (lM2577 current is only 3A). 400 KHz switching frequency, decreasing ripple size.
- **5V 600mAh USB Output Charger:** This component outperforms other modules thanks to the usage of overseas high-performance semiconductors. Enter any DC voltage between 0.9 and 5 volts. 5 volts DC output voltage can be steady. A single AA battery can deliver up to 200 and 300 MA of current, while two AA batteries can deliver 500 and 600 MA of current. Supply The temperature range employed in industry is -40°C to +85°C. It has a high efficiency of up to 96% with a USB female connector and is widely available in ultra-compact sizes that may be installed in a number of small gadgets.

- **DC to DC Male & Female Barrel Jack:** We choose DC to Dc barrel Jack which can handle a Voltage of DC12V and Max Working Current 2.5A. This barrel jack has a working temperature of -20 to 65°C and an internal diameter of 2.1mm and an external diameter of 5.5mm.

- **Arduino Uno:** We utilized this dual-inline-package (DIP) ATmega328 AVR microcontroller-based Arduino Uno R3 microcontroller board. It features 20 digital I/O pins. This micro-controller was used to calculate the system capacity, rate of power consumption, and voltage level indicator. Some of those characteristics were also determined using a voltage divider.

- **OLED Display:** This 1.3-inch blue OLED screen module was employed. Using SPI/IIC protocols, the panel module may be connected to any microcontroller. To connect with our Arduino Uno microcontroller, we utilized this I2C display. It has a 128 by 64 resolution. A display board, a display, and a pre-soldered 4-pin male header are all included in the kit. An organic film that is thin and multilayered that is sandwiched between an anode and a cathode makes up an OLED (Organic Light-

Emitting Diode), a self-lighting technology. OLED technology does not necessitate a backlight, in contrary to Display technologies. OLED is thought to be the best technology for the future generations of flat-panel displays and has a great applicability for practically all types of devices. Between both the cathode and the translucent, electrically conductive Indium Tin Oxide anode that make up an OLED's cathode, are organic components (ITO).

- **12 AWG High Quality wires:** For our system, we bought 12 AWG High quality Silicone Rubber Wire Cable which can sustain up to -65 degrees to +200 degrees temperature and handle high ampere current.

3.4 Conclusion

In conclusion we can say that, choosing the right components as the device specific was the most challenging part to build the system. But, after going through a lot of literature review, google demonstration video and manufacturer instruction manual we successfully chose the perfect hardware tools to demonstrate our system and build it from scratch.

Chapter 4: Optimization of Multiple Design and Finding the Optimal Solution. [CO7]

4.1 Introduction

In previous chapters we have shown our two design approaches which are pretty much capable of fulfilling the objectives. But to implement those designs in a practical case and to convince the stakeholders they should be optimized in various ways like efficiency, cost effectiveness, user feasibility etc . In this chapter we will bring some methodologies in order to make both of our systems optimized. Moreover, we will finally choose the best design approach between them.

4.2 Optimization of multiple design approach

Bringing optimization in our project was required because we wanted to make our project reliable and feasible for the stakeholders. Without optimization we can not differentiate between our proposed design and the conventionally used systems properly. So, we focused on some points where we could bring optimization in the most efficient way .We worked with supply management and portability , as these points are very deeply relevant with our project.

4.2.1 System Optimization in terms of supply segment: In the design approach, we proposed to use a 1500 Watt Power Converter to convert the DC power to AC power Supply. There were so many merits for why we chose to use this power converter. But, later while designing the system in hardware, we realized that this power converter has a big demerits which made us rethink and modify our supply segment. For instance, the transistors usage can reduce the circuit efficiency, the usage of switching transistors can cause cross over distortion within the output signal. The converter and conversion losses in the DC nano-grid are comprised of using efficiency curves. The efficiency of DC to AC (Grid-tied inverter) conversion is considered as 89% max with an 11% loss whereas DC to DC conversion is considered as 96% efficient with a 4% loss. As we were working in a power system for a specific group of people, we had to shift the supply segment from inverter to a different level of voltage regulator module. Working with these types of modules help us to reduce the power loss and increase the overall system efficiency.

4.2.2 Optimization based on Portability: As this project was mainly focused on Militaries remote base power demand insurance, we kept Portability as one of the most important requirements. While building the prototype we found out that the carrying PV panel is a big constraint as they usually come with huge weight. That’s why we collected Mono solar child cells. We attached them perfectly to the acrylic sheet and connected multiple panels internally to get our required voltage. During our prototype, we built 120W,12V solar panels. In the regular case, The weight of this panel would have been minimum 7-8kg, but we compacted it into 500 grams which increased portability of our project.

4.3 Identify optimal design approach

Since we proposed two designs in order to fulfill the stake-holders requirement, the best of them has to be chosen based on different criteria. To do that, we focused on some analysis like cost effectiveness, emission rate, optimal use of components etc.

4.3.1 Cost effectiveness

Components	Design Approach 1	Design Approach 2
generator	70$	0
Solar panel	165$	165*3$
Battery	120*2$	120*2$
Inverter	25$	0$
Charge controller	30$	30$
Fuel price(per year)	1000$	0
Capital cost of System(i.e excluding per year fuel cost)	550$	210
Total cost of system	2080$	975$

Table 10: Two-system's cost analysis

Design 2 is much lower in terms of cost than **Design 1.** The hybrid system needs more components and the biggest area of costing comes into fuel. Taking the current world market of oil into account , it's our stakeholders that make this feasible in the long term. The difference is also can be seen in total costing where design approach with hybrid system costs 3x compared to the design approach 2

4.3.2 Emission analysis:

Factor	Quantity(Design1)	Quantity(Design2)
Carbon Dioxide	645	0
Carbon Monoxide	4.03	0
Unburned Hydrocarbons	0.177	0
Particulate Matter	0.0241	0
Sulfur Dioxide	1.58	0
Nitrogen Oxides	3.78	0

Table 11: Emission Analysis

Design 2 emits zero greenhouse gas in nature where **design 1 emits a healthy amoun**t of greenhouse gas

4.3.3 Optimal use of components: Battery

Factor	Design 1	Design 2
Quantity	2	2
Strings in series /parallel	1/1	1/2
Autonomy days	1	1
Average energy cost	0.227$/KWh	0.135$
SOC Highest period/Lowest Period	12th - 18th hour/2Am	12th - 18th hour/2Am
Expected Life	6.47yr	8.21yr
Losses	140KWh/yr	95.2KWh/yr

Table 12: Optimum use of battery

Here both designs perform closely. Both offer similar days without charging capacity. But, our simulation data says design 2's expected life will be more than design 1.Design 2 has lower average energy cost and less losses too. Comparing all of these, we can say **Design 2** is **much optimal** than **design 1** in every aspect of this factor

4.3.4 Optimal use of components: PV Module

Factor	Design 1	Design 2
Number of PV panels	1	2
Levelized cost	0.110 $/KWh	0.0763 $/KWh
Capacity factor	15.4%	18.69%

Table 13: Optimal Use of PV Module

The levelized cost is slightly lower at design 2. **The capacity factor** is the difference between the actual maximum annual energy output of an unit, assuming it runs at its highest recommended capacity every hour of the year, and the yearly average energy production (kWhAC) of an energy producing facility. Capabilities are somewhat improved with better screens and monitoring**.** In this perspective **Design 2** is slightly ahead of **design 1.**

4.3.5 Analysis on weight and area

Factor	Design1	design2
Box Weight	~35kg	~ 27kg
Box Dimension	Not fit inside a carryable box	60cm*36cm*14.5cm

Table 14: Analysis on weight and area

As we will carry PV panels outside of the box, we are not counting them inside box design.Just keeping the solar panel's apart, our target is to compact the system into a box which can be carryable.
Practically Design approach 1 with hybrid sources will require 1*200ah Battery,2 converter, 2 controller and 1 generator apart from the pv panel. But design approach 2 is comparatively straight forward which needs 1*100ah Battery, 1 converter, 1 controller only.
From the 3d design we can see, the design 2 is less weight, more affordable and compact system which makes it more user friendly.

4.4 Performance evaluation of developed solution

The system 2 is the optimal design that we have chosen while starting to move forward in the project completion. So, that was our optimal design for the completion stage. After the completion of the project the test runs and the different case evaluation gave out some performance data which are as follows.

- **Solar Calibration:**

Figure 32 : Solar voltage data at morning time-frame

Time	Voltage(V)	Current(C)
8.00 AM - 9.00 AM	12.7V	4.3
2.00 PM - 3.00 PM	13.2	5.5
11.00 AM -12.00 PM	13.6	6.9
4.00 PM - 5.00 PM	11.4	3.2

Table 15: Solar voltage-current data at different time-frames.

Conclusion

Considering all the factors and comparison it's visible that design approach 2(Solar stand-alone) is well ahead of design approach 1 in terms of cost, emission and battery performance. So, that will be our optimal design for the completion stage. Still, it increased by 2x compared to our assumption parameters which is still user friendly, portable and appealing to the market.

Chapter 5: Completion of Final Design and Validation. [CO8]

5.1 Introduction:

For the completion of the project, we divided the tasks into several categories to make the workflow smooth. We did some literature review and datasheet analysis of the components that we are using followed by the calibration of individual sensors and components used for the system. After that, we moved on to full system integration. We dealt with a lot of systemic and theoretical issues, and we performed a lot of troubleshooting to figure out what the key issues were and come up with practical solutions to support our argument.

5.2 Completion of final design:

The actions that need to be taken to implement the Foldable and portable system have been identified by our team. Then to complete the system we needed to collect resources regarding the hardware components and design the schematic to set up the whole system. A logbook was kept to provide a clearer picture of the development. Since, the final product is comparatively large and needs initial cost, we obtained a prototype design to formulate and test the use case of our stake holders.

5.2.1: Solar PV design:

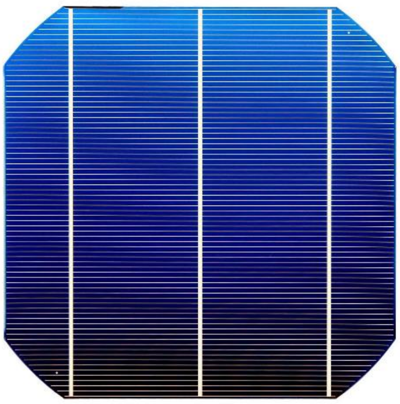


Figure 33: Child cell Rating: 1V-10A(max)

Size:6’’/6”

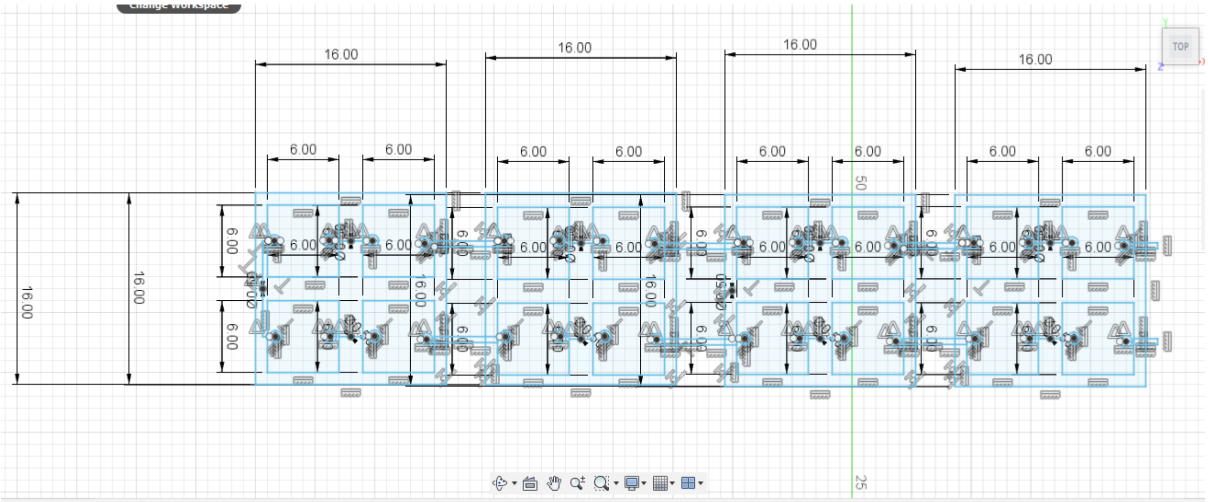


Figure 34 : Solar PV integration

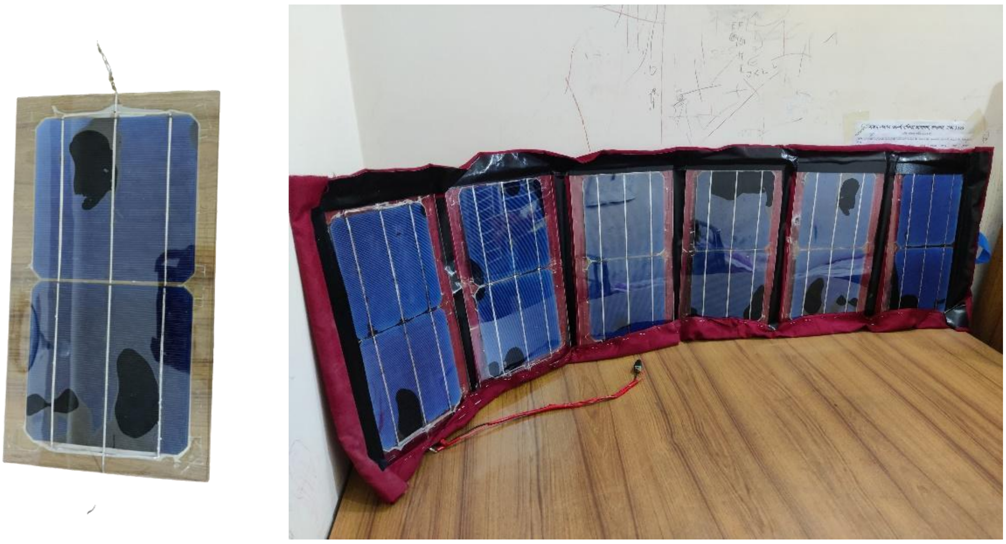


Figure 35: Portable solar panel setup

5.2.2: PCB Design:

FYDP-C ATC-12 MIL COM POW MAN PCB Design

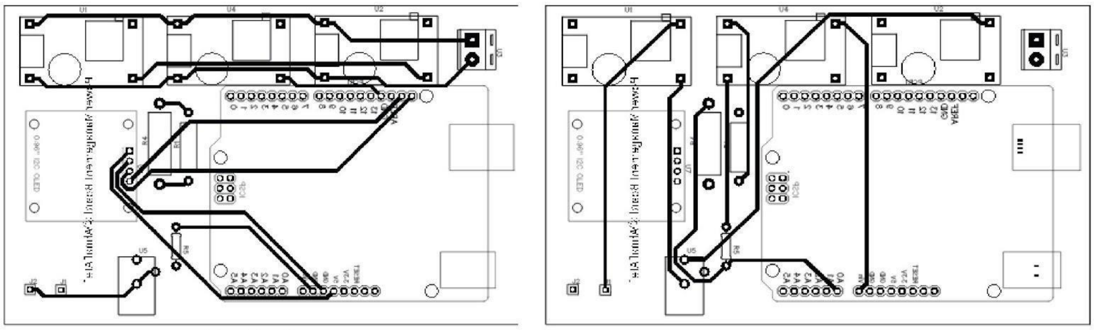


Fig: Top Layer

Fig: Bottom Layer

Figure 36: PCB design

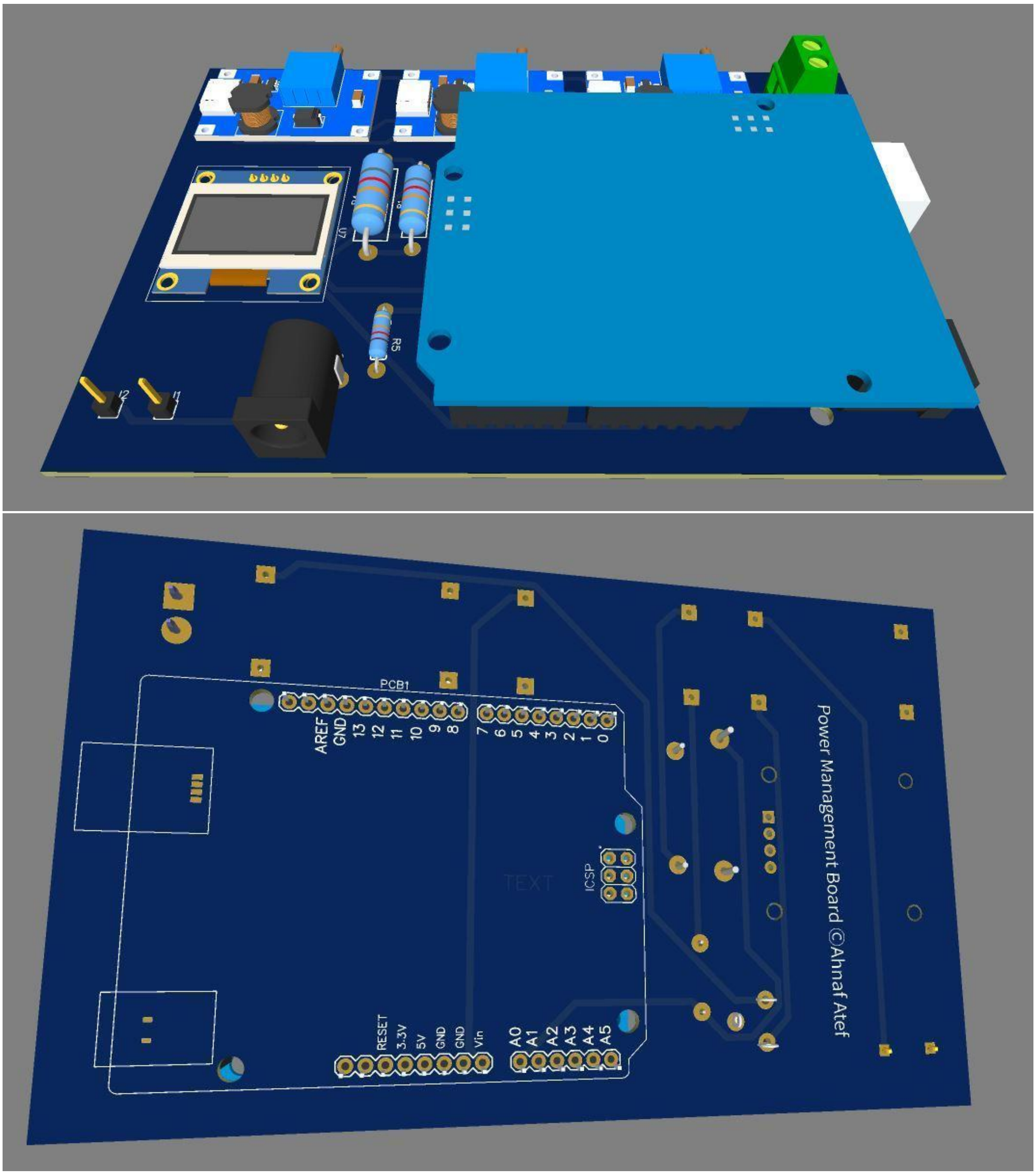


Figure 37: 3D visualization of the PCB

5.2.3: Prototype box design:

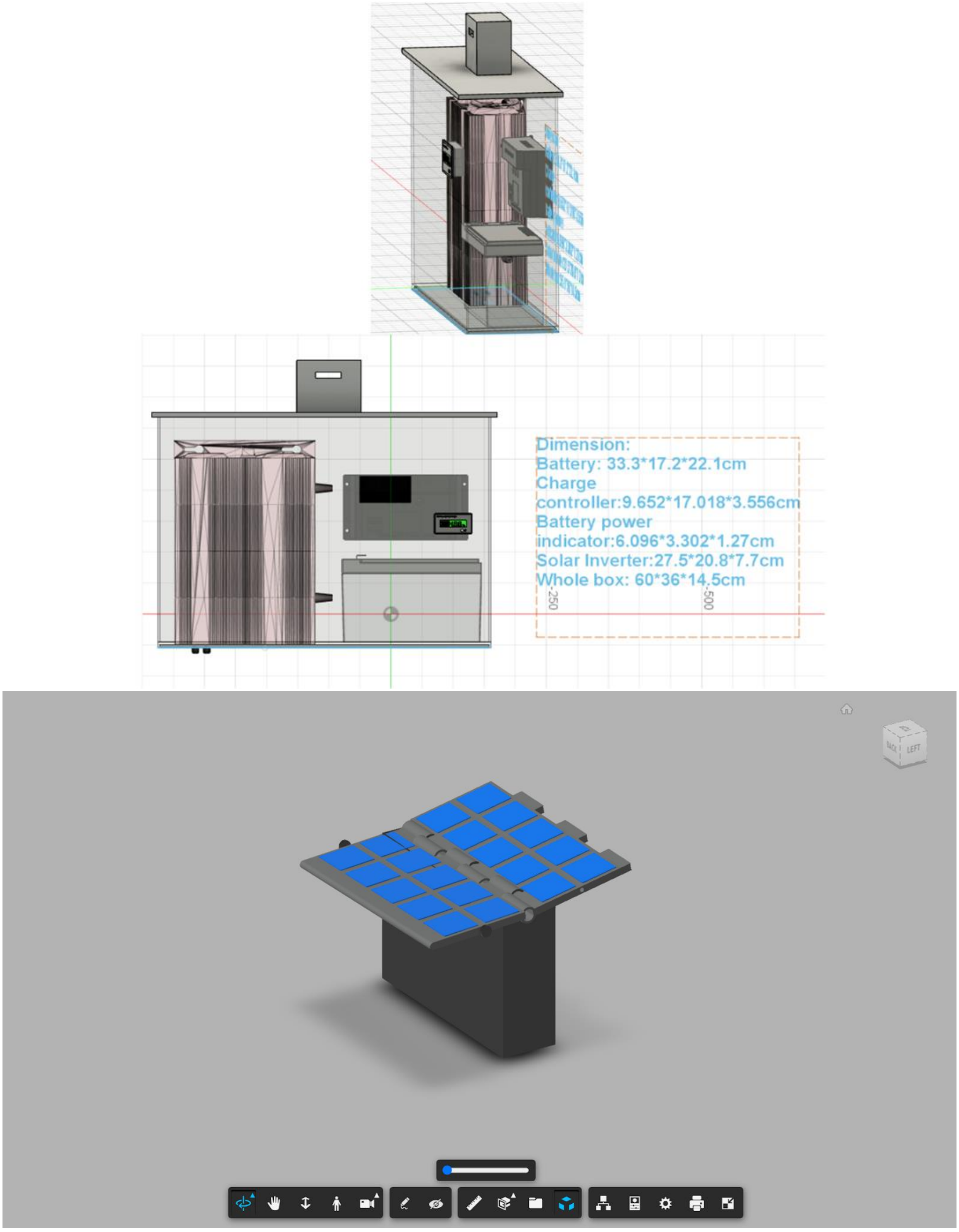


Figure 38: Projected PV Setup design

Figure 39: Prototype design of the system

5.3 Evaluate the solution to meet the desired need:

- **Solar Irradiance:**

Average hourly profiles

Direct normal irradiation [Wh/m^2]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0 - 1												
1 - 2												
2 - 3												
3 - 4												
4 - 5												
5 - 6				26	106	74	30	12				
6 - 7			77	241	234	147	123	112	106	74		
7 - 8	104	243	389	391	336	215	200	199	235	373	360	109
8 - 9	514	548	505	490	417	269	262	280	332	494	590	546
9 - 10	602	640	584	552	470	307	304	336	398	558	677	650
10 - 11	646	696	634	581	494	321	315	358	421	582	723	707
11 - 12	661	712	636	566	487	312	302	345	400	569	726	730
12 - 13	652	694	622	537	443	277	271	320	366	542	710	717
13 - 14	609	654	591	506	395	254	245	280	334	524	670	676
14 - 15	525	593	585	444	340	221	202	239	296	449	570	571
15 - 16	397	405	386	349	281	180	167	193	225	318	363	355
16 - 17	78	203	262	273	228	140	129	142	152	119	24	19
17 - 18		3	50	143	170	108	92	81	24			
18 - 19				1	27	29	17	5				
19 - 20												
20 - 21												
21 - 22												
22 - 23												
23 - 24												

Figure 40: Average hourly profile in a year

The expression "solar irradiance" means the power per unit area (surface power density) acquired first from solar system inside the shape of electromagnetic radiation in the range of wavelength of the detecting apparatus. Watts per square metre (W/m2) is the unit of measurement for solar irradiance in SI. The radiant energy (measured in joules per square metre, or J/m2) released into the environment over a time period is typically reported by integrating solar irradiance through time. The terms solar irradiance, solar irradiance, solar insolation, and insolation are all used to describe this combined solar irradiance. Irradiance can be calculated by measuring it in orbit or at the Planet's surface following air absorbing and scattering. Insolation in space is affected by the Sun's altitude, its cycle, and bridge oscillations. Here, the figure was taken from a website that tracks sun irradiation in Bangladesh over the course of a whole year.

- **Solar Calibration:**

Day 1

Time	Voltage(V)	Current(C)	Time	Voltage(V)	Current(C)
8.00 AM - 9.00 AM	12.7V	4.3	11.00 AM - 12.00 PM	13.6	6.9
2.00 PM - 3.00 PM	13.2	5.5	4.00 PM - 5.00 PM	11.4	3.2

Day 2

Time	Voltage(V)	Current(C)	Time	Voltage(V)	Current(C)
7.00 AM - 8.00 AM	12.5V	4.2	12.00 PM -1.00 PM	13.4	6.7
1.00 PM - 2.00 PM	13.4	5.6	3.00 PM - 4.00 PM	11.2	3.1

Day 3

Time	Voltage(V)	Current(C)	Time	Voltage(V)	Current(C)
8.00 AM - 9.00 AM	12.9V	4.5	11.00 AM - 12.00 PM	13.8	7.1

2.00 PM - 3.00 PM	13.1	5.4	4.00 PM - 5.00 PM	11.7	3.4

Day 4

Time	Voltage(V)	Current(C)	Time	Voltage(V)	Current(C)
9.00 AM - 10.00 AM	12.5V	3.9	11.00 AM - 12.00 PM	13.2	6.4
3.00 PM - 4.00 PM	13.1	5.6	4.00 PM - 5.00 PM	10.6	2.9

Day 5

Time	Voltage(V)	Current(C)	Time	Voltage(V)	Current(C)
9.00 AM - 10.00 AM	12.3V	4.2	11.00 AM - 12.00 PM	13.5	6.9
3.00 PM - 4.00 PM	13.5	5.9	4.00 PM - 5.00 PM	10.8	3.2

Day 6

Time	Voltage(V)	Current(C)	Time	Voltage(V)	Current(C)
8.00 AM - 9.00 AM	12.5V	4.4	10.00 AM - 11.00 AM	13.8	6.4
3.00 PM - 4.00 PM	13.7	6.2	4.00 PM - 5.00 PM	10.9	3.1

Table 16, 17, 18, 19 : Solar calibration

The voltage and current for each section of the day were obtained from the table above. For testing purposes and real-time simulation, we simulate the test mostly in the morning, when we have slightly higher voltage and current than the nominal voltage of our system; during the midday and afternoon phases, we have relatively greater voltage and current than the morning phase. Furthermore, when we tested our system at night, we found that the voltage and current were typically lower than the nominal value. We do all of these days tests throughout the winter season, primarily in December.

Demand analysis:

Day 1:

Battery	**Charging time**	**Output Current**	**Battery**	**Charging time**	**Output Current**
0-56%	8.00 AM - 9.00 AM	4.3	0-92%	11.00 AM -12.00 PM	6.9
0-73%	2.00 PM - 3.00 PM	5.5	0-42%	4.00 PM - 5.00 PM	3.2

Day 2:

Battery	**Charging time**	**Output Current**	**Battery**	**Charging time**	**Output Current**
0-53%	7.00 AM - 8.00 AM	4.2	0-87%	12.00 PM -1.00 PM	6.7
0-75%	1.00 PM - 2.00 PM	5.6	0-40%	3.00 PM - 4.00 PM	3.1

Day 3:

Battery	**Charging time**	**Output Current**	**Battery**	**Charging time**	**Output Current**
0-61%	8.00 AM - 9.00 AM	4.5	0-95%	11.00 AM -12.00 PM	7.1
0-72%	2.00 PM - 3.00 PM	5.4	0-46%	4.00 PM - 5.00 PM	3.4

Day 4:

Battery	Charging time	Output Current	Battery	Charging time	Output Current
0-52%	9.00 AM - 10.00 AM	3.9	0-81%	11.00 AM -12.00 PM	6.4
0-77%	3.00 PM - 4.00 PM	5.6	0-38%	4.00 PM - 5.00 PM	2.9

Day 5:

Battery	Charging time	Output Current	Battery	Charging time	Output Current
0-58%	9.00 AM - 10.00 AM	4.2	0-88%	11.00 AM -12.00 PM	6.9
0-80%	3.00 PM - 4.00 PM	5.9	0-43%	4.00 PM - 5.00 PM	3.2

Day 6:

Battery	Charging time	Output Current	Battery	Charging time	Output Current
0-64%	8.00 AM - 9.00 AM	4.4	0-86%	10.00 AM -11.00 AM	6.4
0-84%	3.00 PM - 4.00 PM	6.2	0-42%	4.00 PM - 5.00 PM	3.1

Table 20, 21, 22, 23 : Battery Charging Time

We can see from the table above that by simulating the system for various segments of the day, we obtained the charging current and charging rate of the battery. We can also see that charging a 7.5Ah battery performed best between midday and afternoon. We charged our battery at an average pace of 60% in the morning and 39% in the evening. These simulations and table clearly show that we received the greatest results during the midday and afternoon hours, when the irradiance was higher than during other times of the day.

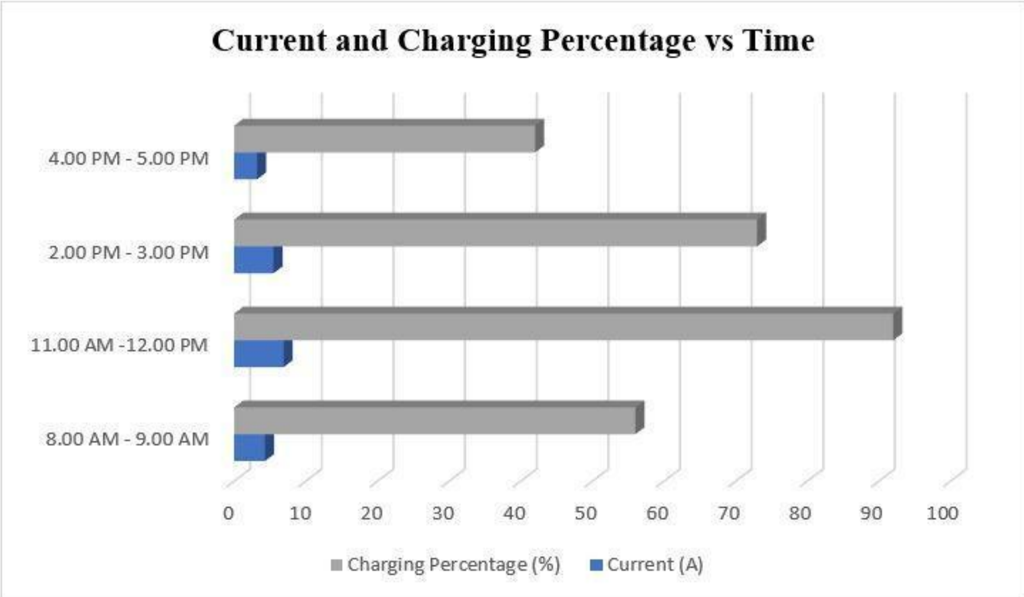


Figure 41 : Average Current and charging percentage vs time

So, we can see that from the acquired data it's giving viable data from our generation side(PV to controller) and load side(Battery to load) which meets our requirements. In peak sun period it almost charged up the battery by 100%. This is the result of a prototype case and it's a scalable project. As per our software data analysis we can see the specification will increase linearly according to the requirements.

5.4 Conclusion:

We split the tasks into different categories for the portable and foldable energy generation system's completion in order to facilitate a seamless workflow. Before integrating individual system components, we reviewed some relevant literature and examined the datasheets of the components we are implementing. Then, we advanced to complete system integration.

As a result, we may infer that the system we want to construct meets all of the requirements we established earlier. From the research till the development, the high integrity of the system was always the main priority as this project is related to military protocol. Any indiscipline may cause huge hazard and loss of important lives, which will ruin the core objective of this particular project. So, multiple tests have been done on the system to evaluate the system integrity and the characteristics and in which condition it works best.

Chapter 6: Impact Analysis and Project Sustainability. [CO3, CO4]

6.1 Introduction

Project sustainability is a method that is becoming more and more popular for managing projects, programs, organizations, businesses, people, as well as other institutions that need effective and efficient production, marketing, shipping, and the delivery of products and services. In general, from strategy development throughout planning process, conceptualizing, design, evaluation, funding, implementation, monitoring, and evaluation, specific metrics and standards should be developed.

6.2 Assess the impact of solution

Impact	Impact Details
Environmental	1) Rate of Carbon emission will be zero
	2) No toxic waste will release
	3) No sound pollution
Social	1) Being grid independent, it will reduce pressure on power supply from local gird
	2) Health of local people won't be affected due to zero carbon emission.
	3) Local people will not face sound pollution problem
Legal	Laws and regulations regarding RE development have limited enforcement. Implementing our system in such important sector will aware authority to come up with laws having proper enforcement
Political	In practice, the arrangements relating to RE development and strategy execution in Bangladesh are viewed as isolated exercises as there are more than one authority that deal with this issue which is a problem. If our system is implemented in this important sector, government will allocate a single authority to monitor performance and development in RE sector.
Cultural	Our system doesn't affect any culture and norm in the society
Economic	1) Less dependency on fossil fuel will reduce the amount of fuel to be imported from abroad.
	2) Since it is grid independent , no extra charge won't be bared for power consumption from local grid.
	3) The equipements are reusable depending on their lifetime. So, these equipments could be used in other operations in future.
	4)There are many base camps throughout the country and to implement this system in all the camps , more production will be required . So companies will need enough human resources which will create job opportunities.
Financial	Since government allocates a good percentage of budget (nearly 8%)for this sector.So, there is an assurity of getting financial support to implement this system
Safety	If anyhow enemies disrupt power supply from local grid , it will not affcet
	No risk of communication break with the main camp

Table 24 : Impact analysis

6.3 Evaluate the sustainability

Sustainability evaluation through SWOT analysis:

A SWOT analysis is designed to provide a practical, fact-based, and data-driven evaluation of the advantages and disadvantages of a venture or sector of the service economy. Qualities, Limitations, Competencies, and Risks are abbreviated as SWOT. It is a technique for strategic planning that project managers use to help them assess the advantages and disadvantages of their initiatives in addition to investigate and weigh any future risks and opportunities. In our study, we sought to identify the advantages, disadvantages, possibilities, and risks.

Strengths	Weaknesses
1)Introducing renewable sources	1) System based on photovoltaic module may face difficulties in rough weather
2) The system doesn't release any toxic waste	2)It is not an indoor system
3)Reducing the dependency on Fossil Fuel	3)Renewable energy sources have less efficiency in production of electricity
4)Less health risk	4)Take more space and land than usual
5) No need for extra maintenance facility	5)Lower number of production house keep the price higher for renewable energy sources
6)Carbon emission rate is very low	
7) The system is grid independent	
9) The equipment's uses in the system are reusable in future operations.	
10) Globally accepted and defending climate change as well as global warming.	

Opportunities	Threats
1)If this system works successfully ,It can be implemented in larger camps	1) Since the system won’t need strong maintenance, damage can occur by any unexpected means.
2) Fossil fuels are limited and the future industry needs to depend on renewable energy.	2)Solar intensity decreasing and atmospheric level demolishing
3) A huge amount of fossil fuel usage will be reduced and the government won't need to import fossil fuel as much as before.	3) The main competitors are the fossil fuel industry and they won’t let renewable energy sources get the throne of the electricity generation sector.
4) High efficiency renewable sources will accelerate the production of electricity and meet the demand in near future.	
5) Manufacturers need more production of RE equipment which will need more human resources and that will create job opportunities.	
6) High efficiency and low weight storage will keep this system much closer to the user.	

Table 25: SWOT analysis

Quantitative analysis of sustainability

Based on the above discussed **"Constraints" & "Comparative Analysis" and group brainstorming** we have quantified some criteria for sustainability analysis.

Criteria	Approach 1		Approach 2		Weights
	Rating(5)	Score	Rating(5)	Score	
Environment friendly	3	0.75	5	1.25	25%
Fuel Independency	2.5	0.5	5	1	20%
Cost Effectiveness	2	0.3	3	0.45	15%
Durabality	2.7	0.405	3.5	0.525	15%
Portability	2	0.3	3	0.45	15%
Ease of Use	3	0.3	4	0.4	10%
Total Score	**2.555**		**4.075**		

Table 26 : Quantitative analysis of sustainability

6.4 Conclusion

Project sustainability management (PSM), which is now gaining root in project management, is altering the dynamics of how many different projects are implemented. Economic sustainability is the capacity to meet environmental demands from people and commerce without compromising the atmosphere's ability to support subsequent generations.

Chapter 7: Engineering Project Management. [CO11, CO14]

7.1 Introduction

Project management is the process of overseeing a project from conception to completion while using the essential expertise and understanding to keep it on track with all pertinent requirements, under budget, and on schedule.

7.2 Define, plan and manage engineering project

7.2.1 Defining Project Management

Engineers who achieve results must carefully plan their approach and communicate it to their engineering team. It comprises determining the project's goals and milestones while also developing alternative strategies for various scenarios. Each and every technical team that ignores this phase runs the risk of experiencing the labor of several dozen, if not hundreds, of workers disrupted by the unforeseen. Because engineering is a challenging and dynamic industry, project leaders in this sector must be adaptable and educated about all current quality requirements. This includes both broad managing skills and technology practices relevant to the current work.
Engineering project directors must have extensive understanding of project management. Cooperation, risk evaluation, stakeholder involvement, procurement, production standards, continual learning, planning, pricing, and project description are among the skills that the Project Management Institute defines as being part of this. In able to issue orders and comments, the engineering project manager must, at the very least, have a fundamental understanding of the intricate job being done.
As a result, we made every effort to follow them from our end. Our teamwork was excellent, and everyone was committed from the beginning.
As we use high-quality materials to keep our project standard, we also examine our risk.
Finally, we made every effort to keep the cost of our project within reason.

7.2.2 Project management in planning in proposal preparing phase

In our Final Year Design Project, we started with finding the complex engineering problem through brainstorming. We selected a particular area of interest for us and sequentially we interviewed our stakeholders. Interviewing our stakeholders, we came to know their issues and identified the problem statement from their speech. The problem that they are facing is about meeting power needs in their communication sector while camping remotely. Generally, these remote camps contain 8-10 members, which are often called a squad. Identifying their problem we started our initial research on the problem statement that we sorted out and did extensive literature review. After this stage, we again interviewed our stakeholders and came to know their total requirement and accordingly the specification of their communication sector devices. After that, we set the objective of our project and propose two Multiple Design Approaches based on Hybrid Energy Generation system and Renewable Energy Generation System.

After completing the design approach field, we jump into the design specification part and sort out the overall system design through multiple block diagrams. We again did literature review in the design approaches and found out the constraints and overcame those with logical proposals. After that, we calculate the overall budget of our project, determine the expected outcomes & impacts, sustainability analysis, applicable codes and standards, ethical consideration, risk management, safety considerations. Also, we determined how our problem statement is a complex engineering problem based on some different parameters.

Gantt Chart for phase 1

Before start working on preparing project proposal and planning we made a gantt chart for the entire phase to approach in a disciplined and sequential manner to avoid any sort of mismanagement in this journey.

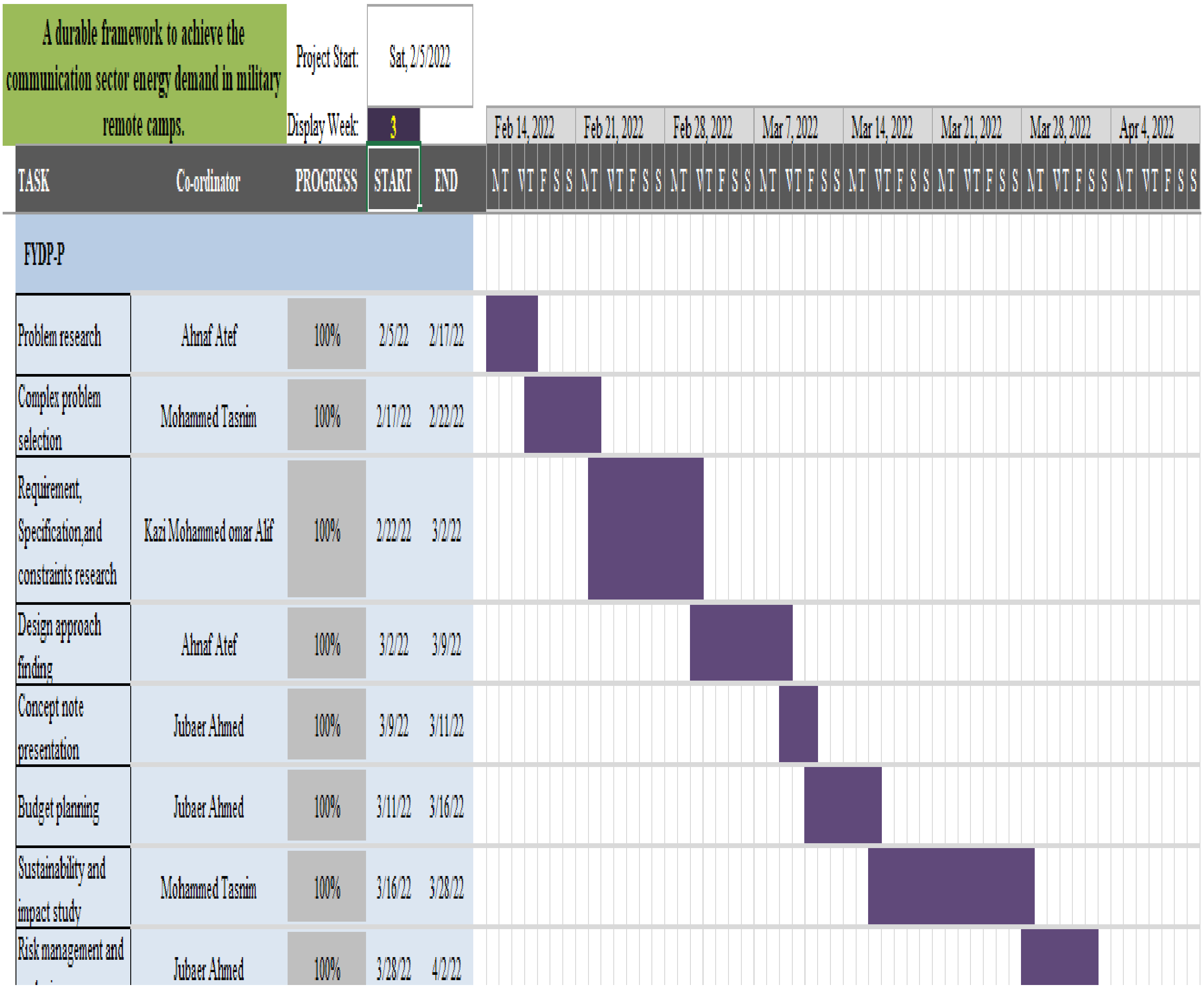


Figure 42 : Gantt chart for phase 1

Flow diagram of planning

Throughout the proposal preparation phase we tried to approach in a formative manner so that we could introduce satisfying designs based on our proposal. The following flow diagram represents our approach:

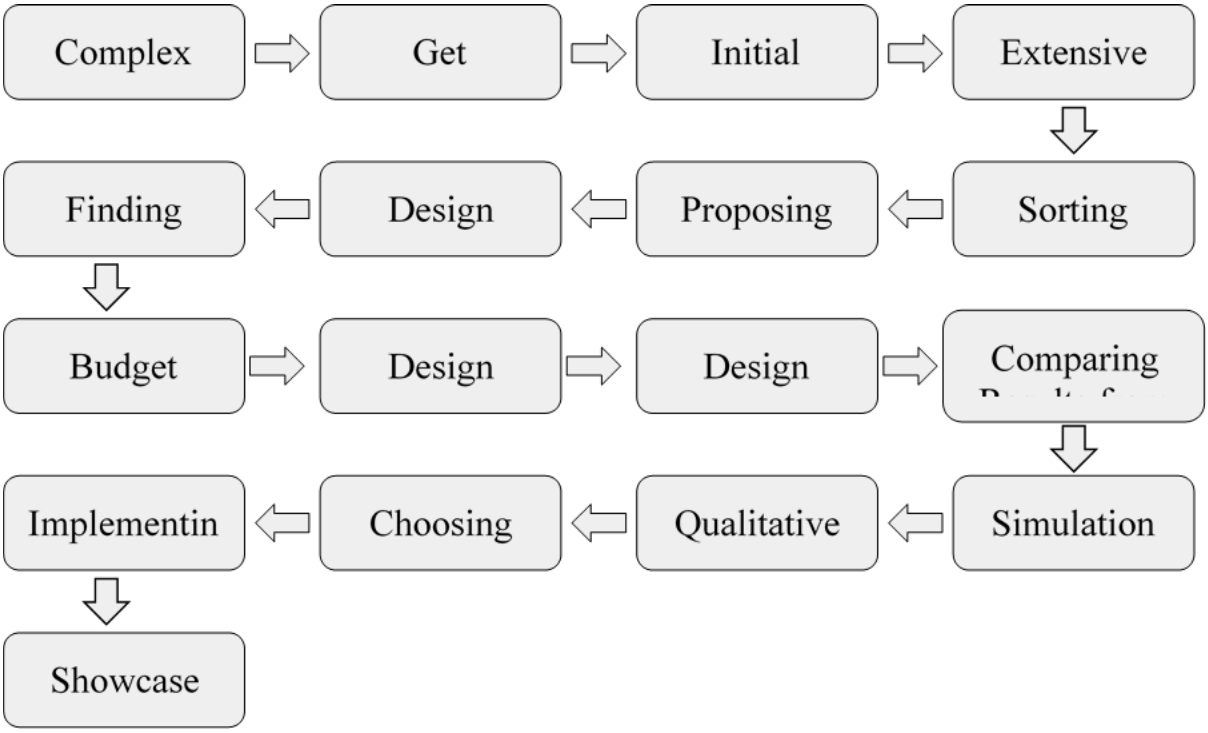


Figure 43 : Project Planning Flow chart in phase 1

7.2.2 Project management in design & development phase

In a similar manner we proceeded for the design phase and made our road map. As it was a design and development phase we had to search for the most relevant and reliable software for simulation. After simulation, we had to look into the optimization process to make our system more sustainable. Then after different analyses like energy loss, cost effectiveness, and sustainability we selected our final design.

Gantt chart for design phase

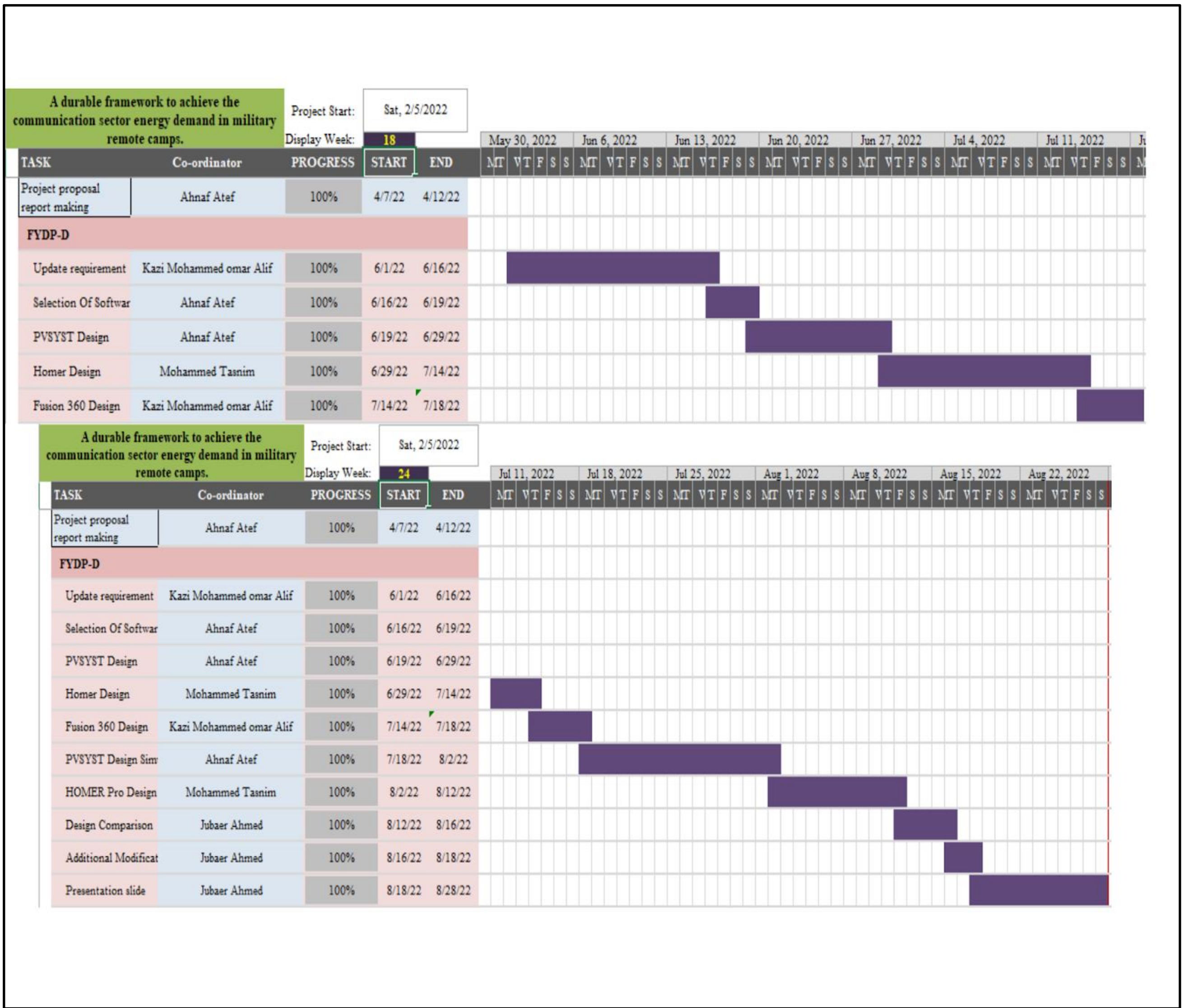


Figure 44 : Gantt chart for design phase

Flow diagram for design phase

Same as the previous phase we tried to approach in a sequential manner in this phase. It was quite a sensitive phase as we had to simulate both the design approach and select the best one between them and it required a technical analysis with a large amount of data.

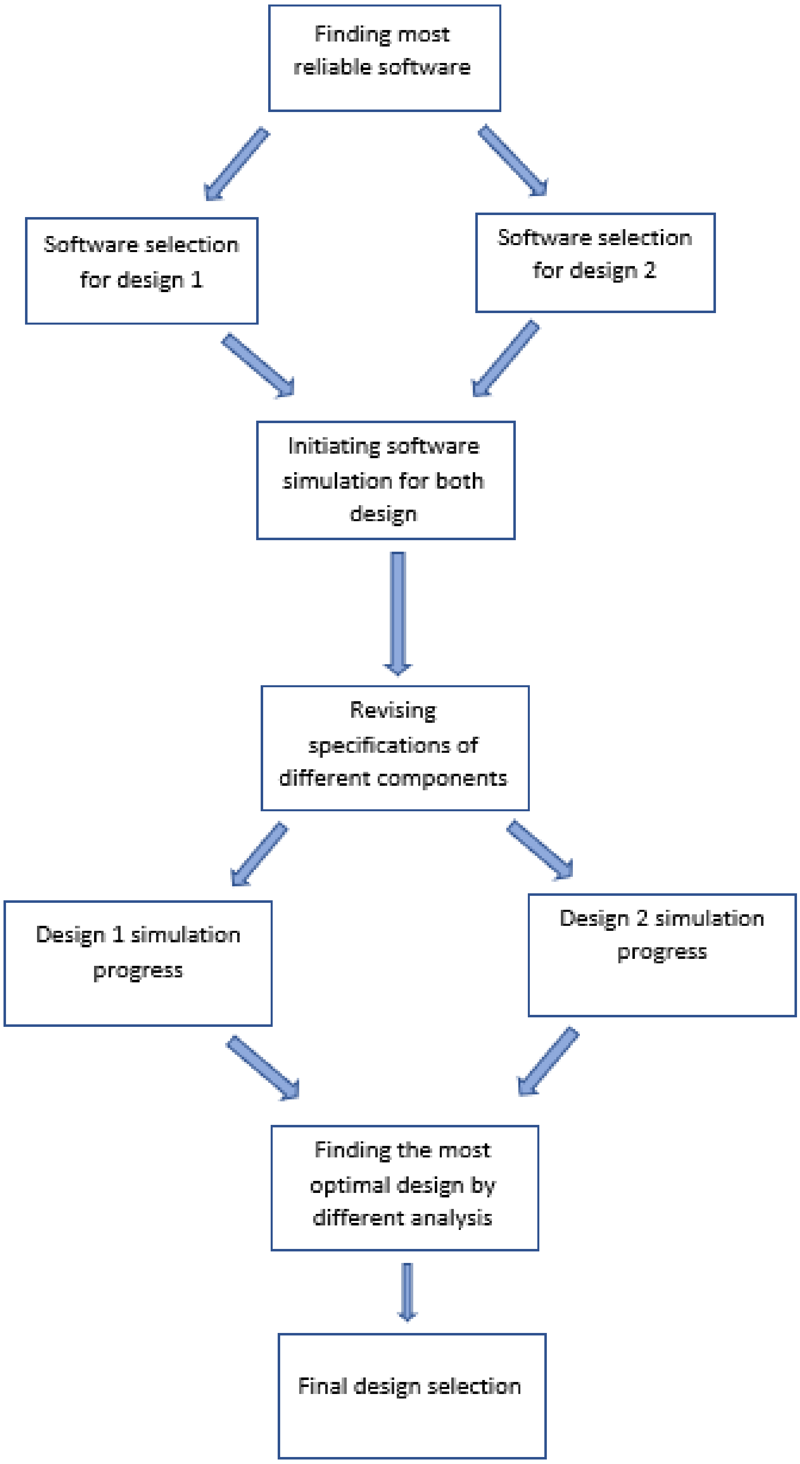


Figure 45: Flow diagram of design phase

7.2.2 Project management in completion and execution phase

This is the final phase of our project where our project was physically developed and executed. This phase was full of activities with different hardware tools of proper configuration. To validate our final design we always had to make a continuous check with the practical result and the simulation result. Moreover, we had to develop our physical project with different optimization methods. Obviously, there were difficulties in getting the desired output but ultimately it was managed by different troubleshooting approach.

Gantt chart for FYDP-C

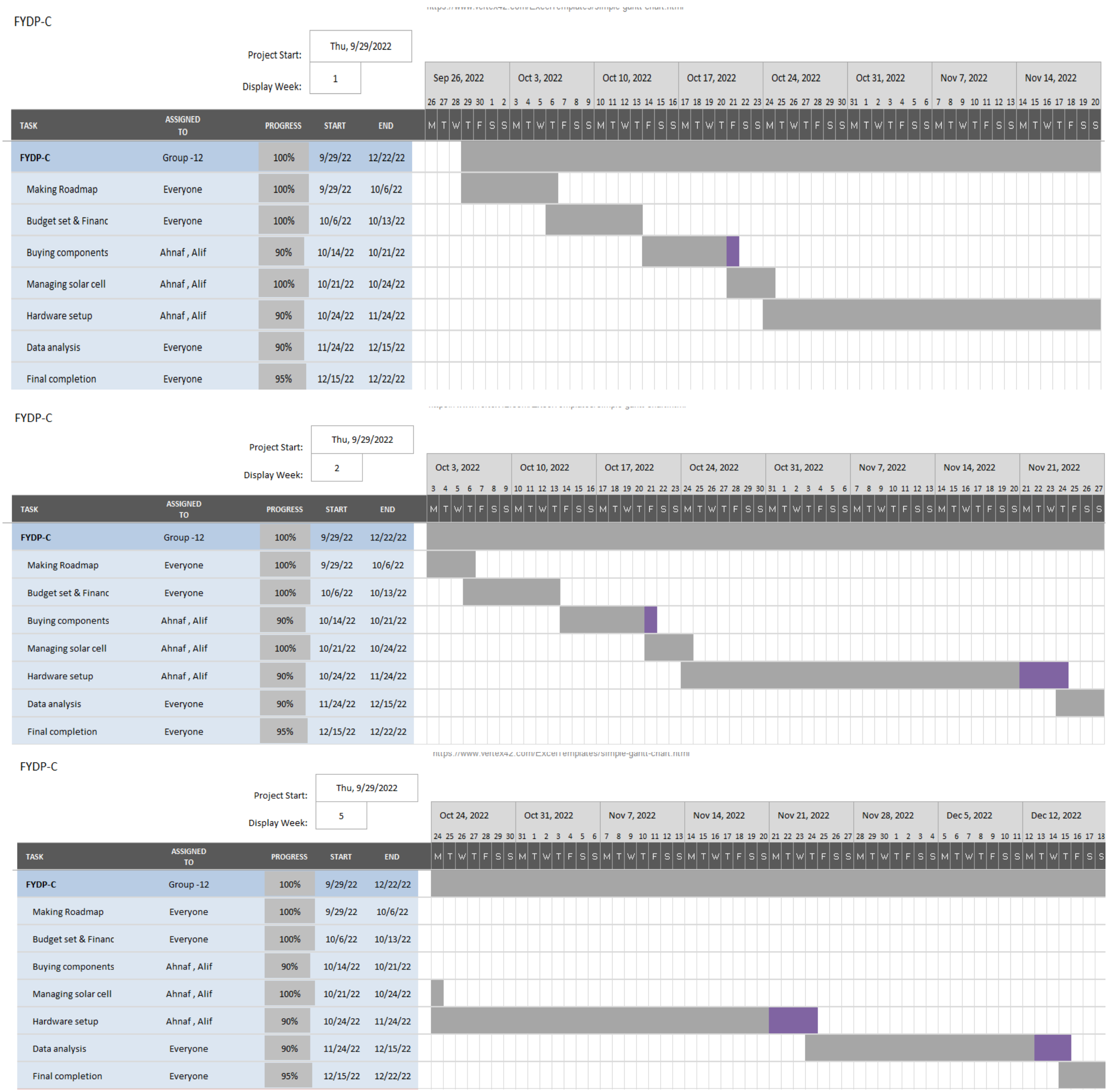


Figure 46 : Gantt Chart of D phase

Flow diagram for project completion and execution phase

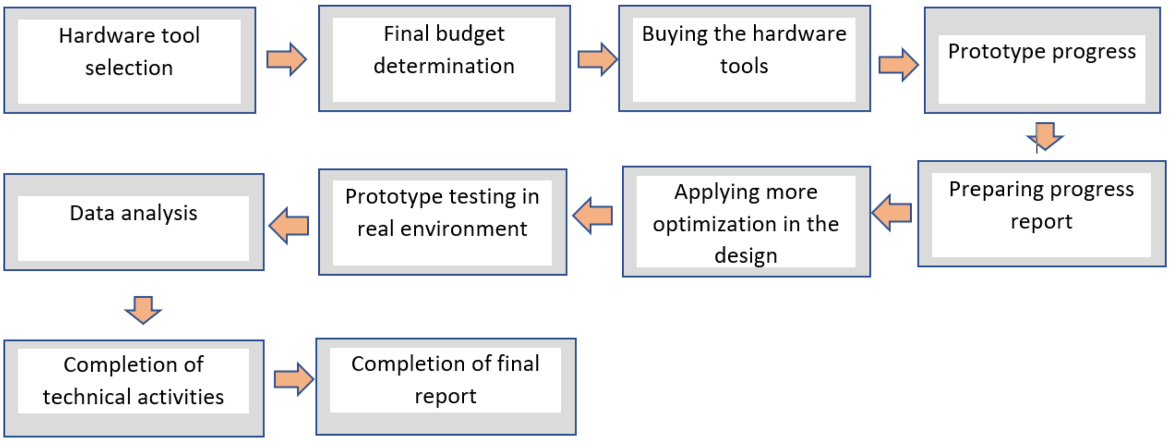


Figure 47: Flow diagram of project completion and execution phase

According to the above shown flow diagram, we started our project with hardware tools selection with appropriate rating which are commercially available. Then according to the selected models of tools, we prepared the budget list. After the collection of from every member, we went for buying the tools. After collecting the tools, hardware setup was initiated. When the hardware setup was done, we went for testing our prototype in a real environment. Then, we took various data from the output. The hardware setup and writing the final report was being done simultaneously. Thus, we completed our final project completion phase.

7.3 Evaluate project progress

We used to make progress in our progress through **group discussions, attending the meeting with ATC panel and following the Gantt Chart at each phase**. Group discussion was very much frequent in order to keep the track of each member's progress. Furthermore, various troubleshooting issues were discussed on those discussions. Most importantly, we attended several meetings with our ATC panel to make them know our working progress. Whenever we faced any difficulties we asked for suggestions from them and we were guided in a decisive approach. They also ensured our project validity by checking each and every approach and evaluating those. Furthermore we always tried to maintain the Gant Chart which were developed before the starting of each phase in order to keep the track strong and efficient. In order to reserve the proof we prepared log book in each of our project phase. Those logbooks represent the division of project work responsibilities among all the group members discussed in the group meetings as well as ATC meetings through out an entire phase.

7.4 Conclusion

Practically all initiatives will certainly encounter difficulties at a certain time, thus engineering project leaders must be prepared to tackle these issues head-on and provide workable solutions. For instance, an engineering program manager can run into technical data inconsistencies that could possibly impede the success or development of a project. To bring the project back on track, the engineering project coordinator must address the underlying causes of these errors and apply problem-solving techniques. Moreover our ATC members guided us from time to time so that project goes smoothly & accordingly.

Chapter 8: Economical Analysis. [CO12]

8.1 Introduction

Economic analysis is the process of weighing benefits and expenses to determine if an initiative, business venture, occasion, or other situation is viable. In plenty of other senses, it requires figuring out, assessing, and contrasting expenses and advantages. There are also other additional important notions as well. The assessment procedure is an essential step in the judgment call process since it helps with the best resource distribution and usage. For instance, macroeconomic analysis concentrates on GDP, unemployment, and inflation, whereas techno economic analysis (TEA) looks at the economic strength of a manufacturing environment. Microeconomic research attempts to define how individuals and corporations work in a specific economy.

8.2 Economic analysis

Here is our project budget part:

Device	Price Range	Quantity	Total Average Price,$
Photo Voltaic Module 120 W	35$	1	35$
Battery Size (12V-7.5Ah)	13$	1	13$
Solar Charge Controller	4$	1	4$
DC-DC Step Up Booster Power Module- Mt3608	1.2$	2	2.4$
DC-DC adjustable step up and down converter- XL6009 module	1.3$	2	2.6$
5V 600mAh USB Output Charger	1$	2	2$
DC to DC Male & Female Barrel Jack	0.5$	4	2$
OLED Display	4$	1	4$
12 AWG High-Quality wires	5$		5$
System box	10$	1	20$
Total			~90$

Table 30: Economic analysis

To create our project, we studied the market prices of all accessible possibilities and then determined which component would be the most useful not only technically but also financially. We looked in stores and on online websites to make it more cost effective for our stakeholders, so that this prototype can give the projection about the whole project.
Our initial approach for the system was to use pv modules that are available in the market. But due to high price and less portability features we decided to go with module manufacturing from child cell which made this project cost effective and portable friendly. Further, we planned to use an inverter, however this was more expensive and created power losses. As a result, we removed it and decided to go for full dc supply insurance.

8.2 Cost benefit analysis

A cost-benefit analysis compares the expected or estimated costs and benefits (or opportunities) connected with a project choice to evaluate whether it makes business sense. Previously we have discussed the overall cost of our project. In some crucial aspects we can compare our project's overall cost with the conventional methods.

Conventional System		**Optimized System**	
Factors	**Cost**	**Factors**	**Cost**
PV Panel Cost	450-500$	PV Panel Cost	100-150$
Fuel Cost	11$/day	Fuel Cost	0$
Inverter cost	25$	Inverter cost	0$
Generator cost	70$	Generator cost	0$

Table 31: Cost benefit analysis

The components that we have chosen are the most cost efficient and effective when compared to the other alternatives, and the projected installation cost of the entire project is nearly 750$ which is almost 1/3rd of the conventional approach.
Firstly, our optimized system removes the dependency from conventional energy sources. That's how it omits almost 1000$ of fuel cost from a military remote camp every year. Moreover the capital cost of the system is also half that of conventional systems.
To conclude, our stakeholders may not think taking conventional systems ahead of our developed system as a product like the one we've developed and finalized would provide them a far higher return on their investment.

8.3 Evaluate economic and financial aspects

Since this project will reduce typical fossil fuel costs and we are using solar power, a lot of money will be saved on military procurement. We are a developing nation, so saving money from this site might help us provide financial assistance to different sectors, or we can use this money to develop our military by buying new products to upgrade our systems. Also, none of the materials we used are very expensive, and they are also easy to use. Hence, once this project goes public, it will be affordable for all aspects of the population. Our project does not cost more than $90, and we are using solar, which will be beneficial in the long run as all of the economic powerhouse countries move into this sector. So it will be crucial for our economy if we use these products on a mass scale, which will only help us by lowering our military budget.

8.4 Conclusion

Evaluating or studying subjects or situations from an expert's point of view is the process of economic analysis. The examination of financial systems is called economic analysis. It might also be a study of an organization or a production method. The analysis seeks to ascertain how efficiently the economy, or some aspect of it, is functioning. An economic examination of a business primarily considers how profitable it is. Economic assessments take into account the potential costs that individuals or businesses incur. They quantify the financial gains a project will bring to the city's economy or neighborhood that is why economic analysis is important.
The entire anticipated cost of carrying out each project activity throughout the duration of the project's stages is the project budget. It is important for getting project approval, making sure finances are available on time, and evaluating performance since it aids in defining spending expectations. We calculated the costs for both design options, and we concluded by recommending the one that is most cost-effective for the project. Our total average price will be 400-500$, which is definitely lower than any typical mechanism available on market. Also it will reduce overall cost military budget & possible use in tourist hiking.

Chapter 9: Ethics and Professional Responsibilities

9.1 Introduction

Only satisfying the stakeholder's requirements without considering the relevant ethics and professional responsibilities is not a fair approach while completing a project . We also had to maintain some ethics and professional responsibilities at different stages of the development of our project.

9.2 Identify ethical issues and professional responsibilities

From the project planning stage to project development we tried to maintain the ethical issues and professional responsibilities. While preparing the project proposal our concern was to ensure the safety of our targeted group and other associated groups in terms of their health, economy, personal data etc. Then at developing phase we ensured the proper use of applicable standards and the most reliable and relevant software for simulation. Moreover, running and testing the system under the practical environment was also ensured.

9.3 Apply ethical issues and professional responsibilities

Here are the things we applied:

- **The research method used for designing:**
  The method we are using completely fits with the purpose of the research. We have made a significant literature review and followed IEEE standards and codes accordingly. Thus, It doesn't have any risks associated with the research method.

- **Confidentiality:**
  We generally know that military documents are confidential. Still, we got some open source documents and got some data from there. As our main stakeholders are the army, we need to talk with them in different phases of our project. But, we are bound to keep confidentiality of all information provided by them. we won't share or give access to any information related to them or provided by them under any circumstances. Further, we will keep the anonymity of the participants too.

- **Software selection:**

  During software selection we chose those softwares which are popular for renewable energy based simulation. So that we can ensure the reliability of the stakeholders and evaluation team on our design. Moreover, the softwares we used generates results by considering different regional data, environmental data and efficiency of every component . Then the result we get shows some difference with the theoretical result.

Instead of getting some differences we considered those software results, because we want our design to be fully applicable for a practical environment and properly used by the stakeholders.

- **<u>Fairness in picking up the best design</u>**
  We tried our best to choose the most optimum design for our targeted stakeholders. We did not intend to go for the design which was easy to build. Rather, our concern was to provide such a design which will be sustainable in terms of all relevant criteria.

- **<u>Running and testing the system in a pure real environment without hampering any social norm</u>**

  To run and test our system in a practical environment we choose one of our friend's rooftop. We did not go for any other places owned by other people or group which could lead us to take permission from them. But we avoided that to ensure the proper testing without any difficulty and hurting anyone's privacy .

9.4 Conclusion

In order to public safety & project confidentially we didn't make any compromise. We tried our best to fulfill all the safety concerns. So we followed IEEE standards.Also, we tried to be fair as much as possible.

Chapter 10: Conclusion and Future Work.

10.1 Project summary/Conclusion

In conclusion, we developed this project for military small villages and distant outposts that have unique energy supply and management issues. Due to the significance of military operations and the dangers posed by disruptive events, they require reliable energy supply and robust infrastructure. Conventional energy alternatives have associated logistical costs and risks since they often call for an extensive distribution system. The difficulties associated with energy security, affordability, and affordability are all connected with the harm that energy usage does to the ecology and the impacts of global climate change.

In addition to the previously mentioned concept, communication is a crucial component of efficient Command & Control. The effectiveness of every military mission entails keeping consistent and dependable connection. And for that, the main camp's logistical assistance and constant power supply are necessary. The majority of the electricity used and spent by the military goes toward communication devices. We learned through speaking with several military officers that Bangladesh's army now relies heavily on local assistance to maintain a continuous supply of electricity for their telecommunications sector. They occasionally transport power bank batteries with a meager power backup alternative. So keeping all these in mind we created this project to solve all this obstacle.

10.2 Future work

The precise subset of outcomes or aspects that make up a project are referred to as its future work. The project's criteria provide the basis for these milestones. The work required to achieve a good, service, or outcome with the desired features and functionalities is carried out by the project's future.

At this point, it may look like our project is only for a small military base camp, but it has huge potential on a larger scale too. For example, during UN missions where the military must travel to remote and difficult locations in Africa or other countries where the enemy may be waiting for our soldiers, this is the best time and place to use this project or device. Furthermore, this can be used for surveillance in remote areas of the UN mission. Hikers and travelers can also take those to difficult places whenever they go because they need to charge their phones, cameras, and other electronic devices from time to time.

- Large Scale use in military Base camps
- Essential device For hikers
- Use in Remote Island
- Use in UN mission

Chapter 11: Identification of Complex Engineering Problems and Activities.

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

P1	Depth of knowledge required
P2	Range of conflicting requirements
P3	Depth of analysis required
P4	Familiarity of issues
P5	Extent of applicable codes
P6	Extent of stakeholder involvement and needs
P7	Interdependence

Table 32: Attributes of complex engineering problem

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

P1: Knowledge Depth:

We accumulated a few publications and thoroughly reviewed them. We learnt about our project's requirements and specifics. Then we looked into the most vital part of this phase: software simulation. One of the important tasks was selecting the most appropriate softwares for our design approaches. To do that we had to go for deep analysis about all relevant software related to our design. Then we picked up those softwares by which we could generate results through all analytically required input parameters.

P2: Range of conflicting requirements:

Interviewing our stakeholders and from our extensive literature review, we found that our project has a wide range of conflicting requirements in our project-planning phase.For example, our stakeholders' demand was for the smaller size with more generation power. But, from literature review and brainstorming, we found out that the highest efficient photovoltaic cell that is available in the market is 22-27% efficient. But, the work is an ongoing process to increase the efficiency of solar cells in the laboratory. Now at this phase of design development we tried to meet this requirement as much as we can. We proposed a highly efficient solar panel model and a box type carriable system in our design. Also, they had a requirement to hide their renewable source from their enemy. As, a bit of solar ray reflects from the photovoltaic module. But, there is no Camo available in the market to overcome their requirements in this regard.

P3: Depth of analysis required:
While working on software simulation we had to go through a good number of analytical terminologies related to different input and output parameters. First we had to know about those

terminologies and then input the numerical values as input parameters and observe the output results.

P4: Familiarity of the issue:

Meeting the energy demand is the real challenge for the Military. Each year, they make a huge budget on the energy sector. Our objective is to reduce their fossil fuel consumption, lower their energy budget, and reduce the impact in the global climate. From our literature review, we came to know that this problem is a global problem and faced by most of the countries Military. As a result, a bulk amount of research is going on to solve this problem. Our stakeholder is also demanding such a system that can reduce their dependence on their traditional energy generation system in remote camps.

P5: Extent of applicable codes:

The project on which we will be working in the design implementation phase includes a number of components, modules, and other aspects. In the project proposal stage, we analyzed all applicable codes, rules, and constraints imposed by the authorities of the many organizations participating in our project. If any further analysis required related to our design we will also look into it. As a consequence, to avoid any potential conflicts with the necessary codes, we will employ appropriate components.

P6: Extent of stakeholder involvement:

The primary purpose of our project is to meet the energy demand in the Military communication sector at remote camps. We've been considering adding more features to our project, but we'll need a lot of help from the stakeholders to do so.

P7: Interdependence:

Project interdependence is a relationship among activities or projects where the development of one project may influence the development of another, or their occurrence in a certain order may drastically change the trajectory of the portfolio. Dependencies may be thought of as every deliverable, procedure, task, technology, or product produced by any initiative, team, or resource. Each and every element of our strategy is reasonably interdependent with the others.

11.3 Identify the attribute of complex engineering activities (EA)

A1: Range of resources

A2: Level of interaction

A4: Consequences for society and the environment

A5: Familiarity

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

A1: Range of resources

From the project proposal stage to the project design stage we required a sufficient number of facts and analytical knowledge related to our project which drove us to go through various research papers, publications, and journals. These papers provided us with a wide range of options for how we may create our project, and we came up with two design approaches from which we would choose the optimal one to build it

A2: Level of interaction:

The level of interactive activity in this project is regarded as important. As a consequence, we visited in person with some of the stakeholders and took information about the project from our consumers.

A4: Consequences for society and the environment:

Our project has a wide range of consequences for society and the environment. In our design approach, we tried to make the system as environment friendly as well as noise pollution free. Our system will use less fossil fuel or no fossil fuel depending on the design and have a great positive impact on Global Climate Change. Also, it will meet the demand required by our stakeholders

A5: Familiarity:

Our project is very familiar with the existing energy generation system. But, in terms of the Military Communication Sector, this system is a new addition. Because, in present days they use the traditional energy generation system in their remote camp, which is not a sustainable option. So, we tried to come up with a system which is sustainable, compact and less harmful for the environment.

Attributes of Complex Engineering Problems (EP)

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

Attributes of Complex Engineering Activities (EA)

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

Table 33 & 34 : Attributes of complex engineering activities

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Appendix

Logbook of FYDP -P

Date/Time/Place	Attendee	Summary of Meeting Minutes	Responsible	Comment by ATC
12.02.2022(ATC Meeting 1)	1. Alif 2. Ahnaf 3. Tasnim 4. Jubaer	1. How to find problem statement 2. All necessary CO's 3. Literature review system	Task1: everyone Task2: everyone Task3: Everyone	N/A as it was an introductory meeting.
15.02.2022(Group meeting 1)	1. Alif 2. Ahnaf 3. Tasnim 4. Jubaer	1. Share Ideas 2. Gather information 3. Identify a possible problem	Task1: everyone Task2: everyone Task3: Ahnaf	
20.02.2022(ATC Meeting 2)	1. Alif 2. Ahnaf 3. Tasnim 4. Jubaer	1. Need to finalize the title. 2. Need to finalize the problem statement. 3. Need to prepare a draft concept note	Task1: Ahnaf Task2: Ahnaf Task3: Everyone	Task1: Partially completed. Need more specific title Task2: partially completed. More literature review recommended Task3: partially completed
21.02.2022 (Stakeholder meeting)	1. Alif 2. Ahnaf 3. Tasnim 4. Jubaer	1. in depth discussion on their energy source and Problems		
22.02.2022 (Group meeting 2)	1. Alif 2. Ahnaf 3. Tasnim 4. Jubaer	1. Gathering ideas from feedback 2. Literature Review collection	Task1: everyone Task2: everyone	
25.02.2022(ATC Meeting 3)	1. Alif 2. Ahnaf 3. Tasnim 4. Jubaer	1. Shortening topic name 2. Finding functional and nonfunctional requirements 3. Work on constraints	Task1: Ahnaf Task2: Alif Task3: Jubaer and Rupok	Task1: completed Task2: partially completed. Wattage requirements required. Task3: partially completed. Constraints overcoming formula
26.02.2022(Stakeholder meeting 2)	1. Alif 2. Ahnaf 3. Tasnim 4. Jubaer	1. discussion on Requirement and specification	Task1: Alif	
27.02.2022(Group meeting 3)	1. Alif 2. Ahnaf 3. Tasnim 4. Jubaer	1. Work Distribution 2. Progress Planning	Task1: Ahnaf Task2: Jubaer	
03.03.2022(Group meeting 4)	1. Alif 2. Ahnaf 3. Tasnim 4. Jubaer	1. shared our collected papers with group mates. 2. Specification and requirement completion	Task1: everyone Task2: Alif	
06.03.2022(Group meeting 5)	1. Alif 2. Ahnaf 3. Tasnim 4. Jubaer	1. design approach and constraints discussion. 2. discussion on concept note	Task 1: Tasnim & Ahnaf Task2: everyone	
07.03.2022(Group meeting 6)	1. Alif 2. Ahnaf 3. Tasnim 4. Jubaer	1. Discussion on concept note report and ppt making	Task1: everyone	

08.03.2022(ATC Meeting 4)	1. Alif 2. Ahnaf 3. Tasnim 4. Jubaer	1. Concept note showcase and mock progress presentation	Task1: everyone	Task1: completed.
19.03.2022 (Group meeting 7)	1. Alif 2. Ahnaf 3. Tasnim 4. Jubaer	1. Discussion on presentation feedbacks 2. Work on design methodology and specification	Task2: everyone	
20.03.2022(ATC Meeting 5)	1. Alif 2. Ahnaf 3. Tasnim 4. Jubaer	1. Discussion on Progress presentation feedbacks 2. Different design approach suggestion		
22.03.2022(Stakeholder meeting 3)	1. Alif 2. Ahnaf 3. Tasnim 4. Jubaer	1. Discussion on communication sector problems at remote base camps		
27.03.2022(Group meeting 8)	1. Alif 2. Ahnaf 3. Tasnim 4. Jubaer	1. Budget, 2. Impact and standard codes discussion	Task1: Jubaer Task2: Tasnim	
31.03.2022 (ATC Meeting 6)	1. Alif 2. Ahnaf 3. Tasnim 4. Jubaer	1. Design approach presenting 2. Sustainability discussion	Task1: everyone Task2: Tasnim	Task1: partially completed. Hybrid system recommended. Conventional system discarded Task2: Partially completed. Sustainability matxics recommended
05.04.2021(Group meeting 9)	1. Alif 2. Ahnaf 3. Tasnim 4. Jubaer	1. Sustainability analysis 2. Risk management analysis	Task1: Tasnim Task2: Jubaer	
11.04.2022(ATC Meeting 6)	1. Alif 2. Ahnaf	1. Design approach correction 2. System device assessment	Task1: everyone	Task1: completed
14.04.2021(Group meeting 10)	1. Alif 2. Ahnaf 3. Tasnim 4. Jubaer	1. Final draft making	Task1: everyone	
21.04.2022(ATC Meeting 7)	1. Alif 2. Ahnaf	1. Draft submission	Task1: everyone	Task1: Partially completed. Recommended to complete the draft by 24th April

Table 27: Logbook of FYDP P

Logbook of FYDP -D

Date/Time/Pl ace	Attendee	Summary of Meeting Minutes	Responsible	Comment by ATC
02.06.2022(A TC Meeting 1)	1. Alif 2. Ahnaf 3. Tasnim 4. Jubaer	1) Evaluation Of previous 'Project Concept Note' Literature review about system design	Task1: everyone Task2: everyone	N/A as it was a previous semester review & present semester plan meeting.
13.06.2022 (Group meeting 1)	1. Alif 2. Ahnaf 3. Tasnim 4. Jubaer	Share Design plan Find Simulation Software	Task1: everyone Task2: everyone	
20.06.2022(A TC Meeting 2)	1. Alif 2. Ahnaf 3. Tasnim 4. Jubaer	Find Software Homer	Task1: Rupak,Ahnaf	Design System
27.06.2022 (Stakeholder meeting)	1. Alif 2. Ahnaf 3. Tasnim 4. Jubaer	Give Stakeholder update		
04.07.2022 (Group meeting 2)	1. Alif 2. Ahnaf 3. Tasnim 4. Jubaer	Simulate Design 1	Task1: everyone	
11.07.2022 (ATC Meeting 3)	1. Alif 2. Ahnaf 3. Tasnim 4. Jubaer	Show Simulation Design 1	Task1: Rupiah,Ahnaf	Task1: completed
18.07.2022 (Stakeholder meeting 2)	1. Alif 2. Ahnaf 3. Tasnim 4. Jubaer	discussion on Requirement and specification	Task1: Alif	
25.07.2022 (Group meeting 3)	1. Alif 2. Ahnaf 3. Tasnim 4. Jubaer	Homer Update Progress Planning	Task1: Ahnaf Task2: Jubaer	
01.08.2022 (Group meeting 4)	1. Alif 2. Ahnaf 3. Tasnim 4. Jubaer	shared our collected papers with group mates.	Task1: everyone	

03.08.2022(Group meeting 5)	**1. Alif 2. Ahnaf 3. Tasnim 4. Jubaer**	**1)design approach 1 and constraints discussion.**	**Task 1: Jubaer & Alif**	
05.08.2022(Group meeting 6)	**1. Alif 2. Ahnaf 3. Tasnim 4. Jubaer**	**Discussion on concept note report**	**Task1: everyone**	
08.08.2022(A TC Meeting 4)	**1. Alif 2. Ahnaf 3. Tasnim 4. Jubaer**	**Software 2 : PVSYST Selection**	**Task1: Jubaer,Alif**	**Task1: completed.**
10.08.2022 (Group meeting 7)	**1. Alif 2. Ahnaf 3. Tasnim 4. Jubaer**	**Tutorials & some paper review on Desgn2**	**Task1: everyone**	
11.08.2022(A TC Meeting 5)	**1. Alif 2. Ahnaf 3. Tasnim 4. Jubaer**	**Simulation of PVSYST**		**Graph details important**
22.03.2022(Stakeholder meeting 3)	**1. Alif 2. Ahnaf 3. Tasnim 4. Jubaer**	**Discussion on communication sector problems at remote base camps**		
27.03.2022(Group meeting 8)	**1. Alif 2. Ahnaf 3. Tasnim 4. Jubaer**	**Budget, Impact and standard codes discussion**	**Task1: Jubaer Task2: Tasnim**	
18.08.2022 (ATC Meeting 6)	**1. Alif 2. Ahnaf 3. Tasnim 4. Jubaer**	**Update Both Design**	**Task1: everyone**	**Find OPTIMAL one**
05.04.2021(Group meeting 9)	**1. Alif 2. Ahnaf 3. Tasnim 4. Jubaer**	**Sustainability analysis Risk management analysis**	**Task1: Tasnim Task2: Jubaer**	
25.04.2022(A TC Meeting 6)	**1. Alif 2. Ahnaf**	**Compare Design**	**Task1: everyone**	**Task1: completed**

28.08.2021(Group meeting 10)	1. Alif 2. Ahnaf 3. Tasnim 4. Jubaer	Final report making	Task1: everyone	
31.08.2022(A TC Meeting 7)	1. Alif 2. Ahnaf	Report Show	Task1: everyone	Wishes us luck!

Logbook of FYDP-C

Date/Time/Place	Attendee	Summary of Meeting	Responsible	Comment by ATC
29.09.2022 (Group meeting)	1.Ahnaf Atef 2.Kazi Omar 3.Jubaer 4.Md.Tasnim	1)Need to be clear about COs and POs to be covered by FYDP-C 2) Need to set the roadmap of final project implementation in C phase	Task 1: Everyone Task2 :Every one	N/A
5 .10.2022 (group meeting)	1.Ahnaf Atef 2.Kazi Omar 3.Jubaer 4.Md.Tasnim	1) Budget determination for final design	Task to : Kazi Omar	N/A
6. 10.2022 (group meeting)	1.Ahnaf Atef 2.Kazi Omar 3.Jubaer 4.Md.Tasnim	1) Need to Manage solar cell 2) Need to initiate writing report	Task 1 : Kazi Omar , Ahnaf Task 2 : Md.Tasnim ,Jubaer	N/A
27.10.2022 (Group meeting)	1.Ahnaf Atef 2.Kazi Omar 3.Jubaer 4.Md.Tasnim	1) Need to prepare updates for ATC meeting	Task to : everyone	

1.11.2022 **(ATC meeting)**	**1.Ahnaf Atef** **2.Kazi Omar** **3.Jubaer** **4.Md.Tasnim**	**1) Need to make more progress in the developing system** **2)Need to make optimization in the system**	**Task to : Everyone**	**Previous tasks were completed**
2.11.2022 **(Group meeting)**	**1.Ahnaf Atef** **2.Kazi Omar** **3.Jubaer** **4.Md.Tasnim**	**1) Need to prepare updates for progress presentation**	**Task to : Everyone**	**N/A**
3.11.2022 **(Group meeting)**	**1.Ahnaf Atef** **2.Kazi Omar** **3.Jubaer** **4.Md.Tasnim**	**1) Need to work on the feedback came from judge panel in Progress presentation**	**Task to : Everyone**	**N/A**
14.11.2022 **(ATC meeting)**	**1.Ahnaf Atef** **2.Kazi Omar** **3.Jubaer** **4.Md.Tasnim**	**1) Need to work on cell calibration** **2)Need to prepare a complete layout** **3) Need to bring progress in report writing**	**Task 1&2 : Kazi Omar , Ahnaf**	**Previous tasks were partially completed**
15.11.2022 **(Group meeting)**	**1.Ahnaf Atef** **2.Kazi Omar** **3.Jubaer** **4.Md.Tasnim**	**1) Budget Update**	**Task to : Kazi Omar**	**N/A**

29.11.2022 **(ATC meeting)**	**1.Ahnaf Atef** **2.Kazi Omar** **3.Jubaer** **4.Md.Tasnim**	**1) Need to work on power and load management if possible**	**Task 1: Kazi Omar, Ahnaf** **Task 2: Md. Tasnim ,Jubaer**	**Previous tasks were completed**
		2) Need to bring progress in report writing		
8.12.2022 **(Group meeting)**	**1.Ahnaf Atef** **2.Kazi Omar** **3.Jubaer** **4.Md.Tasnim**	**1) Chapters of report were divided for each member**	**Task to : everyone**	**N/A**
10.12.2022 **(Group meeting)**	**1.Ahnaf Atef** **2.Kazi Omar** **3.Jubaer** **4.Md.Tasnim**	**1) Need to bring updates on topics covered during FYDP P& D phase .**	**Task to: everyone**	**N/A**
14.12.2022 **(Group meeting)**	**1.Ahnaf Atef** **2.Kazi Omar** **3.Jubaer** **4.Md.Tasnim**	**1) To prepare updated documents for final presentation**	**Task to: everyone**	**N/A**
20.12.2022 **(ATC meeting)**	**1.Ahnaf Atef** **2.Kazi Omar**	**1)To prepare final report**	**Task to : everyone**	**Previous tasks were completed**

Table 28&29 : Logbook of FYDP D &C