



Design and implementation of a small-scale Floating Photovoltaic System in ULAB campus A techno-economic assessment

Submitted by:

Md. Shojal Hossain (ID:193016008)
Arshil Karim Khan (ID:191016010)
Sayed Easin Arafat (ID:172016007)
Rabit Rahian Turjo (ID: 211016003)
Mehedi Hassan Shanto (ID:182016003)

“A project report submitted in partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical and Electronic Engineering”

Supervisor:

Rukhsana Choudhury,
(Lecturer)

Department of Electrical and Electronic Engineering

30 September, 2024

University of Liberal Arts Bangladesh, (ULAB)

688 Beribadh Road, Mohammadpur,

Dhaka -1207, Bangladesh.

ABOUT ULAB EEE

The Board of Accreditation for Engineering and Technical Education (BAETE) under the Institute of Engineers Bangladesh (IEB) bestowed a distinguished accreditation upon the Department of Electrical and Electronic Engineering (EEE) on February 12, 2023. This outstanding result confirms our steadfast dedication to providing excellent instruction and creating capable, professional engineers who are prepared to take on difficulties in the real world. The accreditation process scrutinized the department based on its curriculum, faculty, facilities and performance as a whole in order to guarantee our sustainability at an engineering study level. This accreditation is a reflection of our commitment to delivering the highest-quality education and the outstanding work being done by our faculty, alumni, and staff.

In the modern world, engineering is a never-ending subject, with electrical and electronic engineering producing amazing results. In the undergraduate program, we have four concentrations: 1) Electrical Power; 2) Electronics and VLSI; 3) Communications; and 4) Smart Systems and IoT. The following topics are covered in this section: renewable energy, smart grids, power electronics, telecommunications, machine learning applications for Internet of Things data applications, biomedical signal processing and analysis for IOT applications, such as body sensing networks for m-health infrastructure services for wearable and implantable devices, and smart system engineering, which includes vehicular net warfare architecture supporting lithium-ion power technology trends in the automotive sector. We strongly believe that in order to prepare our graduates for success in a globally competitive economy and to contribute to the achievement of the Sustainable Development Goals (SDGs), we must foster in them a love for lifelong learning, creativity, leadership, ethics, societal awareness, and environmental responsibility. We also place a high value on providing a wide range of extracurricular and co-curricular activities.

I look forward to working in partnership with all parties involved—students, faculty members throughout the globe, alumni, business associates, and governmental organizations—to develop highly qualified engineers who can help create a sustainable society.

DECLARATION

It is hereby declared that,

- The submitted project is our original work while completing the degree at the University of Liberal Arts Bangladesh, (ULAB).
- The project doesn't include any previously published or written content from outside sources, unless properly referenced with complete and precise details.
- The project doesn't include any content that has been approved or turned in for credit toward any other degree or certificate from a college or other organization.
- I have acknowledged all main sources of help.

Student's Full Name & Signature:

1. **Name:** Md. Shojal Hossain **Signature:**
ID: 193016008 **ULAB email:** shojal.hossain.eee@ulab.edu.bd
2. **Name:** Arshil Karim Khan **Signature:**
ID: 191016010 **ULAB email:** arshil.karim.eee@ulab.edu.bd
3. **Name:** Sayed Easin Arafat **Signature:**
ID: 172016007 **ULAB email:** easin.arafat.eee@ulab.edu.bd
4. **Name:** Rabit Rahian Turjo **Signature:**
ID: 211016003 **ULAB email:** rabit.rahian.eee@ulab.edu.bd
5. **Name:** Mehedi Hassan Shanto **Signature:**
ID: 182016003 **ULAB email:** mehedi.hassan.eee@ulab.edu.bd

SUPERVISOR'S CERTIFICATION / APPROVAL

The Final year Capstone Project report titled “Design and Implementation of a small-scale Floating Photovoltaic System in ULAB Campus A techno-economic Assessment” submitted by Md. Shojal Hossain (ID:193016008) EEE, Arshil Karim Khan (ID:191016010) EEE, Sayed Easin Arafat (ID:172016007) EEE, Rabit Rahian Turjo (ID: 211016003) EEE, Mehedi Hassan Shanto (ID:182016003) EEE Fall, 2024 has been accepted as satisfactory in partial fulfillment of the requirement for the degree of B.Sc. in Electrical and Electronic Engineering submitted to the Department of Electrical and Electronic Engineering, University of Liberal Arts Bangladesh, Dhaka on September 30, 2024.

SUPERVISOR:

Rukhsana Choudhury,
(Lecturer)

rukhsana.choudhury@ulab.edu.bd

Department of Electrical and Electronic Engineering

University of Liberal Arts Bangladesh, (ULAB)

688 Beribadh Road, Mohammadpur,

Dhaka -1207, Bangladesh.

Signature

HEAD OF DEPARTMENT:

Prof. Mahbubur Rahman, PhD,

(Professor and Head, Department of Electrical and
Electronic Engineering and Dean, School of Science and Engineering)

mahbubur.rahman@ulab.edu.bd

Department of Electrical and Electronic Engineering

University of Liberal Arts Bangladesh, (ULAB)

688 Beribadh Road, Mohammadpur,

Dhaka -1207, Bangladesh.

Signature

DEDICATION

This thesis work is dedicated to our parents. Also, our honorable teachers Atik Jawad, (Senior Lecturer), Md Liton Hossain, PhD (Assistant Professor) and our supervisor Rukhsana Choudhury, (Lecturer) Department of Electrical and Electronic Engineering and especially our team for his outstanding support throughout our entire Final year Capstone Project.

ACKNOWLEDGEMENT

Firstly, all praise to the Great Allah for whom our Final year Capstone Project has been completed without any major interruption. Secondly, to our previous supervisor Atik Jawad, (Senior Lecturer) sir Bachelor of Science in Electrical and Electronic Engineering (EEE) who since the beginning guided its development. We would like to sincerely thank Md Liton Hossain, PhD (Assistant Professor) for his valuable feedback on our work. Also, suggestions on our work and the subsequent improvements. Finally, we would like to express our sincerest gratitude to our supervisor, Rukhsana Choudhury, (Lecturer) Department of Electrical and Electronic Engineering mam for her kind support and advice in our work. She helped us whenever we needed help and for her ultimate dedication and support to our project and provision of guidance on each stage of project development.

ABSTRACT

In the developing world with increasing use of technology and machines, energy has become a crucial need for daily life. Increased demand in energy is increasing in proportion with modernization. To deal with the demand, generating more energy is needed but keeping the current environmental situation of Bangladesh it is more important to look forward to a sustainable and greener source. Solar photovoltaic (PV) system could be an optimum solution, but occupying land in perspective of Bangladesh is limited. Therefore, an alternative way is much needed, here floating photovoltaic (FPV) is one of the best possible scopes. Since, Bangladesh is a riverine country, it has a vast source of water body and utilizing it would give better efficiency as well [1]. It has documentation about higher operation capability of PV system at lower temperature, which is estimated to be about 10% higher efficiency. Moreover, it is very much important that the concept satisfies with sustainable development goals (SDG) as well. This report includes about the vital SDGs that the system promotes and also evaluated economic outcomes of the project in different method. In addition, possible assessments are evaluated through collected data.

KEYWORDS

Renewable Energy (RE), Photovoltaic (PV), Floating Photovoltaic (FPV), Sustainable Development Goals (SDG), Performance Ratio (PR), Soil Fraction (SF), Payback Period (PBP), Internal Rate of Ratio (IRR), Levelized Cost of Electricity (LCOE), Standard Test of Condition (STC), Dhaka Power Distribution Company Limited (DPDC).

Table of Contents

ABOUT ULAB EEE	i
DECLARATION	ii
SUPERVISOR'S CERTIFICATION / APPROVAL.....	iii
SUPERVISOR:	iii
HEAD OF DEPARTMENT:	iii
DEDICATION	iv
ACKNOWLEDGEMENT	v
ABSTRACT.....	vi
KEYWORDS.....	vi
Table of Contents.....	vii
List of Figures	x
List of Tables	xi
CHAPTER 1	1
INTRODUCTION.....	1
CHAPTER 2	5
LITERATURE REVIEW	5
CHAPTER 3	13
THEORY	13
3.1 Solar Energy:	13
3.2 Radiation:	13
3.3 Nominal Voltage of Array:.....	14
3.4 Battery Nominal Voltage:.....	14
3.5 The panel's nominal power (P_{Nom}):	14
3.6 Normalized production:	14
3.7 PR, or Performance Ratio:.....	15
3.8 The Solar Fraction:	15
3.9 Pmax, or maximum operating power:	15
3.10 Thermodynamic Loss Ratio:	16
3.11 Losses from Incident Angle Modifier (IAM):	16
3.12 Soil Losses or Fraction of Soil:	16
3.13 The Net Present Value (NPV):	16
3.14 Payback Period (PBP):	17

3.15 Internal Rate of Ratio (IRR):	17
3.16 Levelized Cost of Electricity (LCOE):.....	17
CHAPTER 4	18
Methodology.....	18
4.1 Introduction:	18
4.2 Workflow:	18
4.3 Selection of Water Body:	20
4.4 Structural Design.....	20
4.4.1 Tilt angle.....	20
4.4.2 Azimuth angle	21
4.4.3 Albedo	21
4.5 Buoyancy structure creation:.....	21
4.5.1 Placement of solar panels	22
4.5.2 Electrical Components	22
4.6 Software simulation:	22
4.6.1 Meteorological data:.....	24
4.6.2 Orientation of angle.....	26
4.6.3 Solar Panel:	26
4.7 Hardware implementation.....	30
4.7.1 Panel.....	30
4.7.2 Charge controller	32
4.7.3 Battery:.....	34
4.7.4 Inverter:	37
4.7.5 Energy Meter:	38
4.7.6 Switch Board:	39
4.7.7 Load.....	40
4.7.8 Wire Sizing:	41
4.8 Overall System connection:	43
4.9 Economic Parameters:	44
Chapter 5.....	47
Result Analysis	47
5.1 Simulated Result	47
5.1.1 Normalized production	47

5.1.2 Performance ratio and solar fraction.....	48
5.1.3 Losses	50
5.1.4 Balanced and main result.....	53
5.2 Manual result:	56
5.3 Economical outcomes	63
5.3.1 Simulated economic outcomes.....	63
5.3.2 Manual economic outcomes.....	67
5.4 Environmental Impacts	71
5.4.1 Environmental Effect on SDG7 Goals:.....	71
5.5 Project-specific environmental benefits	72
5.6 Limitations and Discussion.....	73
CHAPTER 6	75
CONCLUSION & RECOMMENDATION	75
6.1 Conclusion:.....	75
6.2 Recommendation.....	76
CHAPTER 7	77
CO-PO mapping and breakdown of cost.....	77
7.1 CO-PO mapping	77
7.2 Complex engineering problem solving.....	79
7.3 SWOT analysis	80
7.4 Cost breakdown	81
REFERENCES	82

List of Figures

Figure 1.1: Energy demand in the reference and alternative scenario [1].....	1
Figure 4.1: Methodology Flowchart of Floating Photovoltaic System plant.	19
Figure 4.2: The selection area and water body collected from google earth.	20
Figure 4.3: The buoyancy structure with drums.	21
Figure 4.4: PVsyst software.	23
Figure 4.5: Step by step diagram of software simulation.....	24
Figure 4.6: Tilt angle and azimuth angle.....	26
Figure 4.7: The selection of panel and controller.....	28
Figure 4.8: Layout of the system in PVsyst software.	30
Figure 4.9: PV panel with angle.	32
Figure 4.10: PWM charge controller.....	33
Figure 4.11: Battery.....	36
Figure 4.12: Power inverter.....	37
Figure 4.13: Energy meter.	39
Figure 4.14: Switch board	39
Figure 4.15: Single line diagram of distribution designed by Autocad.....	40
Figure 4.16: Two led lights at load.	40
Figure 4.17: The Overall connection diagram of the system.	43
Figure 5.18: Monthly normalized production with losses.....	47
Figure 5.19: Performance ratio and solar fraction	48
Figure 5.20: Daily input output diagram.	49
Figure 5.21: Array power distribution.....	49
Figure 5.22: Array temp vs Effective irradiance.....	50
Figure 5.23: Loss diagram of the system in PVsyst software.....	52
Figure 5.24: System production in 4 months in PVsyst.....	54
Figure 5.25: Performance Ratio and Solar fraction in 4 months from PVsyst.	55
Figure 5.26: Performance ratio for the panel.....	57
Figure 5.27: Performance ratio.....	59
Figure 5.28: Performance ratio for panel in 4 months.	61
Figure 5.29: Performance Ratio in 4 months.....	62
Figure 5.30: The main economic results in PVsyst.	64
Figure 5.31: Yearly Cashflow.....	65
Figure 5.32: Cumulative Cashflow.	66
Figure 5.33: Income Allocation.	67
Figure 5.34: Software performance Ratio.	74
Figure 5.35: Hardware performance ratio.	74

List of Tables

Table 4.1: Meteorological data	25
Table 4.2: Location of the site	26
Table 4.3: Specifications of PV panel in the software.	27
Table 4.4: Consumption.	27
Table 4.5: The specifications of MPPT charge controller.....	29
Table 4.6: The specifications of Battery in PVcyst.	29
Table 4.7: PV panel specifications	31
Table 4.8: Charge controller specifications.	33
Table 4.9: The battery specifications.....	35
Table 4.10: Inverter Specifications.....	37
Table 4.11: Specifications of the energy meter.....	38
Table 4.12: Specifications of led light collected from company.	41
Table 4.13: Wire specifications.	42
Table 4.14: Project life periods by sector[39].....	44
Table 4.15: Simulated parameters rating.	45
Table 4.16: Financial Summery	45
Table 4.17: Economic parameters for software and manual.....	46
Table 5.1: The all losses from PVsyst.....	51
Table 5.2: Balance and main result of the system.	53
Table 5.3: System production, array loss and system loss in 4 months.	54
Table 5.4: Performance Ratio and Solar Fraction in 4 months from PVsyst.	55
Table 5.5: For 16 days PV Panel, DC Energy supply to battery (Watt) & Performance Ratio:	56
Table 5.6: For 16 days Inverter, AC Energy supply to an Inverter (Watt) & Performance Ratio for Inverter data: ..	57
Table 5.7: For 16 days Per-day Useable Load (Watt), Load Useable Time (H) & Energy Consume (Wh) data:	59
Table 5.8: For 4 months PV Panel, DC Energy supply to battery (Watt) & Performance Ratio data.	60
Table 5.9: For 4 months Inverter, AC Energy supply to an Inverter (Watt) & Performance Ratio data:	62
Table 5.10: For 4 months Useable Load (Watt), Load Useable Time (H) & Energy Consume (wh) data:	63
Table 5.11: The output parameters of financial factors.	64
Table 5.12: Detailed economic result.....	65
Table 7.1 Project features addressing course and program outcomes.....	77
Table 7.2: Project features addressing complex engineering problem solving requirements.	79
Table 7.3: SWOT analysis.	80
Table 7.4: Breakdown of costs of the project.	81

CHAPTER 1

INTRODUCTION

Our world's population growth, urbanization, and technological developments have all contributed to a steady increase in the energy demand throughout time. The rate of increase in the world's energy consumption over 2020 is expected to reach almost 50% by 2050[2]. Any country's economic development depends on the energy sector's expansion. When conventional (non-renewable) resources run out of energy, renewable energy sources become accessible. Hydropower, geothermal energy, wind, solar energy, biogas, and ocean waves are a few types of renewable energy. They are abundant, highly environmentally friendly, and usually pollution-free. Floating photovoltaic offers a number of benefits over solar panels erected on land. FPA is consequently more efficient than a PV system installed on land. By reflecting light onto the water and darkening its surface, FPV prevents water from evaporating. The natural irrigation cooling system lowers the temperature of the PV panels from a cooling perspective. Due to its ability to stop algae from developing and providing photosynthesis, it may also result in improved water quality. It turns underutilized, converting non-revenue-generating water surfaces into solar power plants for businesses while protecting irreplaceable land for use in mining, agriculture, tourism, and other land-incentive sectors [3].

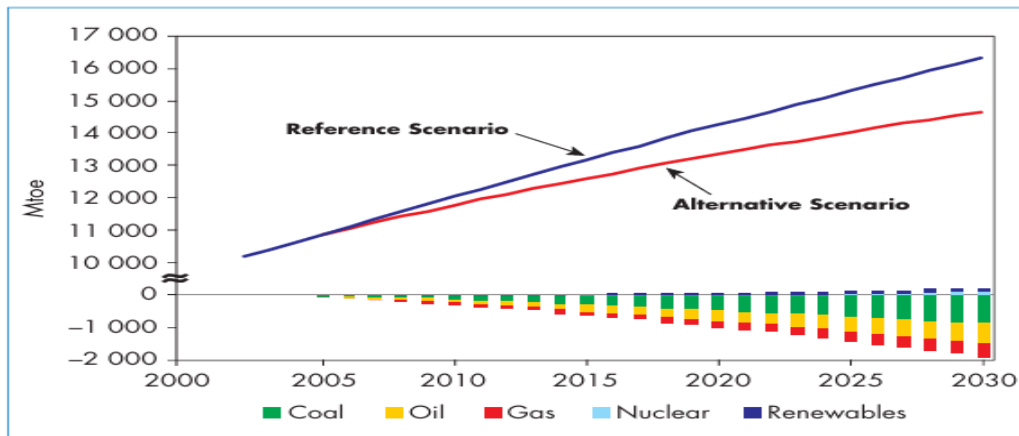


Figure 1.1: Energy demand in the reference and alternative scenario [1].

Figure 1.1 shows that the energy demand of power increasing and to cope up the demand its reliable on renewable energy increasing in significant way day by day which is clear to see the

linearity of the renewable energy line in the plot. In 2018, the first 998 KW solar installation was constructed in Belgium, a country in Europe. A 17 MW FPV system was constructed in France in 2019. With the assistance of forty firms, the Netherlands plans to establish a 2 GW FPV infrastructure by 2023. The country started building a 1.85 MW FPV system in 2018. With a 6.36 MW capacity, the first project in the UK was built in 2016. More and more European countries, like Sweden, Portugal, Spain, Italy, and so on, are establishing solar power facilities. Two FPV projects in California constructed storm water storage reservoirs and wastewater treatment ponds in 2017 and 2018, respectively, with a total capacity of 31.5 kW and 252 kW. The 8.9 MW installation by New Jersey Resources Corporation (NJR) Clean Energy Ventures in Millburn, New Jersey, is now the largest FPV project in the US. However, many nations still have a low number of FPV installations. Globally, 2 GW of FPV installations were constructed in 2020, and by 2025, 7–11 GW are expected to be added. FPV is a great choice for countries where there isn't much land available for solar installation. It has also positively impacted the economy and the cost of a generation because it doesn't require land to be installed. Because of the natural cooling impact of being near water and the effects of water reflection, which enhances irradiance levels, the FPV plant will also become more efficient. Situated in the heart of Dhaka, the capital city of Bangladesh, Hatirjheel Lake has been the subject of a feasibility research study by the EEE department of the Green University of Bangladesh. The analysis is centered on the PV power potentiality, per unit tariff, and CO₂ emission reduction and includes geological, technological, ecological, and economic issues [3]. Solar system financing is being driven by investors due to the fast progress of technology and growing confidence in the economy. The "new king of electricity supply" according to the International Energy Agency's World Energy Outlook 2020 is solar photovoltaic (PV), which should be produced at a rate of 500 Gwp per year [4]. There are several advantages when comparing floating photovoltaic (FPV) to land-based solar panels. It prevents evaporation of water by reflecting light back into the water, and its integrated irrigation cooling system lowers panel temperature. Additionally, FPV improves the quality of the water by stopping algae from growing and photosynthesizing. It secures land for mining, agriculture, tourism, and other sectors by transforming unused water surfaces into solar power plants for commercial use [5]. In 2018, Belgium constructed its first 998 KW photovoltaic (FPV) facility. In 2019, France constructed a 17 MW system, and by 2023, the Netherlands intends to have 2 GW of FPV infrastructure in place. In 2016, FPV's first facility in the UK was constructed [6]-[7]. The floating

solar power project spans 63.6 acres and uses silty clay soil to anchor solar islands. Helical anchors support the float portions, allowing them to withstand hydrodynamic stresses and seasonal water level variations. Setting up a floating plant costs more than an attached one. The features of the body of water, logistics, and reservoir placement all affect the project's cost. The majority of the money is used to secure floating power plants for enduring dependability. The entire anchoring expenses for the China shallow water Anhui project came to about \$10 USD per kW. The floating power plant, which employs local labor and industrial facilities, intends to keep anchoring costs to 30 USD/kW or below. The cost of floating solar farms is expected to be between 0.85 and 1.20 USD/Wp, assuming that primary plastic components are produced locally [8]-[7]. Maintaining pre-existing infrastructure, such as the requirement for a grid connection, might make the construction of floating solar farms less expensive. Since coal-powered power plants have a higher carbon footprint than photovoltaic solar electricity, with an average CO₂e/GWh of 1000 t CO₂ e/GWh, co-benefits might arise in the event of coal mine flooding. In order to lessen water evaporation—a significant problem in the Middle East and North Africa—many nations are implementing floating solar farms. Because of extended droughts and heat waves brought on by climate change, open water reservoir evaporation is predicted to rise. These countries may reduce greenhouse gas emissions, boost renewable energy sources, and reduce water evaporation by putting floating solar farms on lake surfaces. The United Arab Emirates (UAE) is looking for China's creative solution to address environmental issues, such as water scarcity, which has resulted in more productive solar farms. One of the most attractive aspects of floating power plants in arid environments is their ability to reduce water evaporation through design choices made on the floats supporting the PV modules and island. It is possible for the floating power plants to reduce water evaporation from covered regions by up to 80% [7]-[9]. Carbon use is increasing as the world's energy demand grows, causing environmental degradation. Sustainable Development Goal 7 stipulates that by 2030, "everyone should have access to modern, affordable, reliable, and sustainable energy." According to research on renewable energy sources, by 2050, renewable energy may account for more than half of Asia's electricity. Sustainable energy solutions rely on the development of photovoltaic (PV) devices powered by solar radiation. Researchers advocate incorporating solar-powered plants into floating photovoltaic (FPV) systems. FPV systems create more energy from solar panels by reflecting sunlight off the water's surface. Additionally, FPV solar systems conserve water and enhance water quality by lowering evaporation losses. Research

conducted on huge bodies of water, like Egypt's Lake Nasser, suggests that 61.71% less water evaporation may occur if floating solar plants were installed on 50% of the accessible surface. Small-scale FPV plants, however, may provide a more affordable and sustainable means of achieving SDG7 objectives. Urban water features such as small lakes, canals, and ponds provide a feasible substitute for FPV deployment without necessitating previous land acquisition. These facilities provide clean, renewable energy while making the most use of available land. Particularly in isolated locations, small-scale FPV plants provide resilience and energy supply by locally generating and storing electricity. With an emphasis on rooftop solar, research has examined potential integration strategies for renewable energy sources on college campuses. On the other hand, not much thought has been given to the potential effects of small-scale FPV installations on campuses. It is necessary to do more research that takes into account social and environmental concerns as well as a thorough comparison with RSS on campus [2]-[10]. Moreover, Bangladesh is a riverine country. As a result, land is limited, and there are numerous rivers, ponds, canals, reservoirs, and other bodies of water across the nation. These can be used to generate electricity as floating photovoltaic (FPV) systems. An FPV system creates energy while simultaneously reducing severe water evaporation. Furthermore, water quality is preserved by limiting algal development. After all, this approach is more environmentally friendly and meets SDG targets. The capstone project, "Design and implementation of a small-scale floating photovoltaic system on the ULAB campus: A techno-economic assessment," emerges as a beacon of innovation and progress, focusing on the evaluation of the impact of off-grid floating photovoltaic (FPV) systems at the ULAB University Permanent Campus. This endeavor not only aligns with the global commitment to advancing Sustainable Development Goals (SDGs) but also serves as a testament to our collective responsibility in steering towards a greener and more economically viable energy landscape [10]. Our project recognizes the interconnectedness of economic and environmental knowledge needed to make informed decisions that propel us toward a future defined by renewable energy and economic prosperity.

CHAPTER 2

LITERATURE REVIEW

The study examines the increasing need for renewable energy sources, namely in Indonesia, where the government aims for a 21 percent contribution of modern renewables to primary energy generation by 2050 and 23 percent by 2025. It highlights the advantages of solar photovoltaic (PV) systems, especially floating PV, which mitigates the spatial limitations of terrestrial installations. The study emphasizes the benefits of floating photovoltaic, notably enhanced power generation efficiency due to the cooling effect of water, which helps sustain consistent cell temperatures. This work includes a simulation that contrasts floating photovoltaic systems with ground-based installations, focusing on factors such as operational efficiency, conversion efficiency, and capacity factor. Research indicates that floating photovoltaic systems outperform terrestrial installations, exhibiting a capacity factor that is 1.53% superior and a conversion efficiency that is 0.79% greater. To validate the simulation outcomes, the study assesses various environmental parameters influencing photovoltaic output, including temperature, wind speed, and solar irradiation. The literature study underscores the potential of floating photovoltaic systems as a viable solution for generating renewable energy in space-constrained regions [11].

The literature emphasizes the growing global energy demand and the detrimental impact of carbon use on the environment. To attain Sustainable Development Goal 7 (SDG7), which mandates universal access to cheap and sustainable energy by 2030, research is being undertaken on renewable energy sources, especially photovoltaic (PV) systems. The geographical constraints linked to conventional PV installations have prompted the emergence of FPV systems as a potentially feasible alternative. Research indicates that FPV systems may enhance energy production by reflecting sunlight off water surfaces. They may also provide additional benefits such as enhanced water quality and improved water conservation. The study indicates a significant disparity in the feasibility and impacts of small-scale FPV systems, particularly inside academic environments, despite the emphasis on large-scale FPV installations. Most prior studies have not addressed the capacity of small-scale FPV plants to meet energy requirements at educational facilities. Previous research has mostly concentrated on the financial viability of large-scale FPV systems, with less emphasis on smaller-scale projects. This study aims to address the existing

vacuum in the literature by providing a comprehensive economic and environmental evaluation of small-scale floating photovoltaic systems in Bangladesh. Social Acceptance: Research has shown the importance of understanding public sentiment towards FPV installations. The findings of this study's surveys indicate that individuals have a favorable perception of FPV systems, implying their potential effective implementation on college campuses [12].

The paper provides a comprehensive electrical modelling of a photovoltaic (PV) and battery energy storage system (BESS) integrated mini-grid, taking into account practical load profiles. The authors perform a techno-economic and environmental analysis for the western coastal regions of Bangladesh. This research emphasizes the viability and advantages of a floating PV (FPV) powered mini-grid system for remote coastal areas of Bangladesh. With different amounts of desired voltage, current, and power, the simulation results show a strong link. According to the analysis, the generation facility's ideal Cost of Energy (COE) is 18.29 US cents, which is in line with the present pricing. The proposed mini-grid system is projected to reduce carbon dioxide (CO₂) emissions by 228 metric tons annually for households and 466.56 metric tons for electric vehicle (EV) scooters. Additionally, the use of MATLAB/Simulink and HOMER Pro software for electrical characteristics and techno-economic modeling, respectively, is highlighted in the paper [13].

The popularity of floating photovoltaic (FPV) systems has increased, especially in countries like China, South Korea, and Japan where FPV is regarded as a feasible alternative for the deployment of solar energy. With a capacity of about 1 MW, Singapore established the largest floating photovoltaic (FPV) testbed in the world in 2016 to look at the technical, financial, and environmental viability of FPV systems on inland freshwater lakes. Eight distinct systems, comprising various configurations of PV modules, inverters, and floating structures, make up the testbed. This variation makes it possible to get vital data regarding the dependability and effectiveness of FPV systems. The study compares the operating parameters of floating photovoltaic (FPV) systems on water with conventional rooftop installations using extensive field measurement data. It highlights how FPV enhances performance by reducing module temperatures and augmenting energy generation. The study underscores the need of establishing best practices to mitigate possible issues associated with photovoltaic deployment on water, notwithstanding the benefits of floating photovoltaic systems. This literature analysis underscores the growing

significance of FPV technologies and the ongoing endeavors to enhance their performance and application [14].

This study emphasizes floating photovoltaic (FPV) technology as a viable advance in renewable energy, considering land constraints and environmental benefits. It highlights prior research, including Kim's work on flexible thin-film solar systems and their cost-effectiveness relative to offshore wind energy. Lin's study emphasizes the significance of tilt angles on energy output, examining the use of decommissioned floating production storage and offloading (FPSO) units as platforms for floating photovoltaic (FPV) systems. Patil and Yousuf, who presented a chronology of FPV ideas and technology, emphasizing both research and commercial applications, are included in the literature review. The document highlights the restricted technical information accessible because of the private characteristics of FPV designs, which obstructs thorough study. It cites works on hydrodynamics, aerodynamics, and structural analysis of FPV systems, showing a need for performance optimization. The assessment closes with a discussion on the issues associated with floating solar systems, namely the need for efficient mooring designs and the influence of external conditions like as wind and waves [15].

The article discusses the burgeoning domain of renewable energy sources, specifically highlighting solar energy, recognized for its sustainability and accessibility. It underscores the efficiency and eco-friendliness of photovoltaic (PV) systems as the predominant application of solar energy. The substantial land requirement for solar photovoltaic installations presents a significant challenge that can be mitigated by utilizing large bodies of water for floating solar systems. Research indicates that due to the cooling effect of water, floating solar panels can generate increased electricity while inhibiting algae proliferation and minimizing water evaporation, all of which are advantageous to the aquatic ecosystem. The research, which compares the installed capacity of floating photovoltaic systems worldwide, argues that this technology can enhance economic feasibility in regions with plentiful water bodies and mitigate land scarcity challenges. It necessitates further exploration into the impacts of saltwater on photovoltaic structures, anchoring systems, and the development of flexible thin-film technologies capable of withstanding harsh environments. This literature review summarizes the main concepts and findings about floating solar power plants as mentioned in the research [16].

The article discusses the design and implementation of a Floating Photovoltaic (FPV) power plant, highlighting the advantages of this technology regarding energy generating potential and spatial efficiency. The authors recognize collaborative research efforts and express appreciation for the financial and technical assistance received from University Malaysia Pahang and the Malaysian Technical Cooperation Program. They provide insights into environmental factors critical for assessing the feasibility of solar energy projects, including Bangladesh's monthly wind speed and solar radiation. The authors conduct a comprehensive analysis of the site's geography and soil composition, which are vital for the construction of the FPV plant. The benefit of reducing transmission losses and costs highlights the proximity to the Mogbazar grid substation. The project cost estimation encompasses various elements, including civil work, engineering consultations, and environmental expenses, which are essential for budgeting and project planning. Overall, the literature review demonstrates a thorough approach to comprehending the technical, environmental, and economic dimensions of FPV systems, providing significant insights into the renewable energy [17].

The article addresses the increasing use of solar photovoltaic (PV) electricity, particularly in remote areas of developing countries without access to national electrical networks. It underscores the need of optimizing energy production via the adjustment of the tilt angle of photovoltaic modules, influenced by factors such as temperature and solar radiation. The research models an independent solar power system at three different tilt angles using PVsyst software: optimum year average, optimal summer months, and optimal winter months. The findings indicate that although the tilt angle for optimal yearly average solar radiation generates the most energy output (2190 kWh), it is not the most efficient regarding load probability loss. The setup yielding optimal performance in the warmer months had a 3.3% drop in load probability. This resulted from its optimal tilt angle. The findings suggest that the choice of tilt angle should not just rely on energy production, since more energy output may lead to greater energy wastage. This study advises solar power designers to reassess their choice of the optimal tilt angle to enhance overall system performance [18].

The report underscores the increasing significance of photovoltaic (PV) power systems in the global energy portfolio, accentuating its advantages such as minimal maintenance costs, renewable energy sources, and environmentally benign characteristics. It discusses the critical factors

influencing photovoltaic system design, including microclimate, sun irradiation, and geographic location. Bauchi has three primary microclimatic seasons that influence solar energy availability. The article delineates the solar array, battery bank, charge controller, inverter, and protective devices constituting a standalone photovoltaic system, accompanied with a systematic methodology for their design and specification. A practical case study is presented, focusing on a typical residence in Bauchi, Nigeria, with standard energy requirements. The delineated design procedures may be implemented using this case study as an example. The report advocates for governmental assistance in local photovoltaic component manufacture and financial support for system installation to reduce expenses and enhance access to renewable energy. This literature review encapsulates the main concepts and findings of the study, providing a comprehensive overview of the design and implementation of independent solar systems [19].

The increasing demand for power significantly affects the ecology and land availability. Floating photovoltaic (FPV) systems have emerged as a prominent solution to address these difficulties, seeing significant growth. A primary reason for this is the recorded evidence that floating PV modules function at lower temperatures than ground-mounted PV modules. The efficacy of photovoltaic (PV) modules diminishes at elevated temperatures, as shown by research indicating that well-cooled PVs have efficiencies that are 10% greater. The increase in energy yields attributed to various factors ranges from 0.11% to 31.29%, clearly indicating a deficiency in the potential gains of FPV. The performance characteristics are analyzed both individually and systematically using the laws of physics, without the construction of any prototypes or models. Effects resulting from wind, water, temperature, and tilt angles are considered. The primary cause for the cooling of FPV is wind convection, resulting in an efficiency improvement that is suboptimal, ranging from about 0.5% to 3% [1].

As the need for electrical energy escalates, several alternatives are being persistently explored that would serve as more sustainable resources and minimize damage to the planet. The report indicates that floating photovoltaic are growing at an annual rate of 100%, demonstrating greater reliability and reduced maintenance costs. This led to a reduction in costs and extensive use of solar technology, as this research examined its implementation in the maritime environment. FPVs are mostly placed on lakes, ponds, or reservoirs. Recent study has concentrated on installations in offshore regions with maximum wave heights of 2 to 3 meters. Enhancing adaptability to this

concept would diminish the reliance on fossil fuels and other energy sources to avert severe climatic alterations, as shown by current literature on climate change attributable to non-renewable energy utilization. This work examines mathematical and numerical methodologies regarding the design of research for environmental loads and the response of floating photovoltaic (FPV) systems being placed at sea. The review was conducted in accordance with the requisite standards and suggestions to inform the study and examine the principal components and criteria for the assessment. It also included the latest sophisticated evaluation of waves, ocean currents, and wind. It also includes the mooring computation, accounting for wave motions and the losses incurred owing to wave-induced movements. There are increased opportunities to anticipate research that will enhance the safety of applications in maritime settings, since it encompasses on-site testing and field studies related to environmental pressures [20].

It is well established that using renewable energy (RE) resources is essential for mitigating climate change. The article highlights that the Caribbean and Puerto Rico are behind in the production of enough renewable energy. An analysis has been conducted to examine the energy transition route, indicating that by 2050, Puerto Rico and the Caribbean would achieve 100% power supply from renewable sources. To achieve the objective, islands are constrained by accessible land, resulting in the emergence of offshore floating photovoltaics. This signifies a substantial advantage for Puerto Rico in achieving 100% renewable energy, since the levelized cost of electricity (LCOE) is projected to decrease to 47.4€/MWh from 100€/MWh by 2050. Furthermore, in all electricity sectors, the LCOE would decrease to 53€/MWh from 79€/MWh. As of July 2023, 81% of the power supply was produced by photovoltaic (PV) systems, with a capacity of 33.4 GW, of which 17.5 GW was generated by floating photovoltaic (FPV) systems, despite spatial constraints. If area constraints can be managed, costs would decrease by 2.7%. The objective of the Caribbean initiative for 100% renewable energy, spanning from 2020 to 2050, entails electricity output ranging from 110 to 667 TWh, with photovoltaic sources contributing 92% of the total, up from 2%. Furthermore, the photovoltaic capacity ranges from 1 to 332 GW, with 19% produced by prosumers and 81% from utility-scale sources, of which 38% will be derived from offshore floating photovoltaic systems. Should the plan's implementation be flawless, the LCOE will decrease from 100€/MWh to 31.9€/MWh. Consequently, it would introduce a striking transformation in the Caribbean and Puerto Rico [21].

The research examines 40 years of maximum wind speed and wave height data to evaluate possible implications for solar photovoltaic. The data are categorized into five distinct classifications. Subsequently, the disparate data were integrated into geographic information systems (GIS) visualization, resulting in the creation of a wind-wave map. The mapping indicates that the equatorial areas exhibit more tranquilly, characterized by the absence of strong winds and significant waves. The most appropriate places are identified as the Indonesian archipelago and the Gulf of Guinea along the western coast of equatorial Africa. Comprehensive examination of the data obtained from this assessment indicates that such areas may be used for long-term planning and larger-scale implementation of FPVs. Preliminary calculations suggest that the devices might produce around one million terawatt-hours annually in places that never see waves exceeding 6 meters and winds higher than 15 meters per second. The research provides a clear understanding of the utilization and applications of FPV on a wider offshore scale, which can effectively meet energy demand with significant potential [22].

This article fully examines the reliance on renewable energy, namely photovoltaic systems, to address the need of decarbonization and transition away from fossil fuel use. Floating photovoltaic are an exemplary introduction to technology. There are limits in understanding about FPV, since it is a novel technology concerning both technical performance and environmental implications. However, it may be used by application in both inland waters (freshwater photovoltaic) and offshore environments (marine photovoltaic). It is essential to acquire information via study prior to large-scale implementation. The study examined the technical efficacy and ecological consequences of FPV systems in certain areas. It is essential to assess technical performance by comparing energy outputs, cell temperature, and wind speed of land-based photovoltaic (LBPV) systems, specifically for both freshwater and offshore photovoltaic situations. Assess the environmental implications of FPV on water quality, ecology, and meteorological conditions. Previous research has been done based on assumptions and models that are not precise. To validate with precise data or enhance the assumptions, follow-up evaluations were conducted to assess the technical performance and environmental implications of freshwater FPV systems. Despite the infeasibility of offshore FPV, findings were included based on incomplete interviews. Follow-up assessments indicated that the technical efficacy of freshwater FPV systems surpassed that of terrestrial systems. However, it faced a hurdle in mitigating the severity caused by reduced sunlight underneath floating platforms, which may result in diminished algal development. Moreover, it

results in a reduction in oxygen levels, creating a detrimental environment for aquatic organisms and fish. Offshore FPV systems guarantee design dependability and are economically viable in the future. If successful, it would give more output than terrestrial systems and would not impact the ecosystem, unlike freshwater systems. Moreover, it would be advantageous for extensive implementations. Both freshwater and offshore systems may contribute to the objectives and sustainability; nevertheless, further technology improvements are necessary to improve outcome technology improvement necessary to improve outcome [23].

CHAPTER 3

THEORY

3.1 Solar Energy:

This is the solar system's energy (photovoltaic or solar thermal system) provides. The total energy demand is the total quantity of energy required by the system, such as for heating, electricity, etc.

3.2 Radiation:

The quantity of solar energy received on a particular surface during a predetermined time is called radiation. The amount of solar energy that can be produced at a particular place depends on its radiation, which immediately affects the capacity of solar panels to produce energy. Watts per square meter (W/m^2) and kilowatt-hours per square meter (kWh/m^2) are two common measures used to express energy per unit area. Higher irradiation often results in the production of more power in solar energy systems. For instance:

Higher irradiation often results in the production of more power in solar energy systems. For instance:

A place with a $5 \text{ kWh}/\text{m}^2/\text{day}$ average GHI indicates that 5 kWh of solar energy is projected onto each square meter of surface daily.

Solar Energy Irradiation Types:

- i. **GHI, or global horizontal radiation:** The total quantity of solar radiation received per unit area on a horizontal surface during a specific period is known as horizontal global radiation (GHI). It is often stated in $\text{kWh}/\text{m}^2/\text{day}$. It's among the most crucial indicators for assessing the solar potential of a particular area.
- ii. **DNI, or direct average radiation:** The quantity of solar energy received per unit area when the surface or solar panel is pointed straight towards the sun and is perpendicular to the sun's beams. DNI excludes diffuse radiation and only includes direct sunshine
- iii. **DHI, or diffuse horizontal radiation:** The amount of solar energy that has reached the Earth's surface from all directions after being dispersed by the atmosphere. DHI only considers the diffuse portion of solar energy, leaving out direct sunlight.

3.3 Nominal Voltage of Array:

The planned or rated voltage of the whole photovoltaic array—a collection of linked solar panels—is called the array nominal voltage. This number is often used to match the input voltage range of the system's charge controller or inverter.

3.4 Battery Nominal Voltage:

The nominal voltage is the typical operating voltage a battery intends to operate at. It shows the battery's estimated average voltage throughout the discharge cycle.

Solar batteries may have nominal voltages of 12V, 24V, or 48V, depending on the system's needs. For instance, a 12V battery's nominal voltage is specified at 12V for design reasons, although it may vary between 10.5V and 14.5V throughout discharge and charging cycles. Matching the nominal voltage of batteries with other system components, such as charge controllers and inverters, is crucial to ensuring compatibility and best performance.

3.5 The panel's nominal power (P_{Nom}):

The maximum power output of a solar panel under Standard Test Conditions (STC) is known as nominal power, also known as rated power or nameplate capacity. STC conditions include the following:

- Light intensity: 1000 W/m²
- Temperature of the module: 25°C
- 1.5 air masses

The standard for measuring a panel's ability to produce energy is its nominal power, measured in watts (w) or kilowatts (kW). For instance, a panel with a 300 W rating would have a nominal power of 300 w under typical test circumstances.

3.6 Normalized production:

Normalized production, which is often adjusted to specific parameters (such as temperature, irradiance, etc.), describes the actual energy output of a solar power system according to its rated capacity. Normalizing the energy output to a standard measure, usually kWh/kWp (kilowatt-hours per kilowatt-peak), helps compare the performance of various systems, independent of their size.

METHOD: $\text{Installed Capacity (kWp)} / \text{Actual Energy Output (kWh)}$ equals Normalized Production. It enables to evaluate the effectiveness of a solar system over a specific time frame.

3.7 PR, or Performance Ratio:

The performance ratio (PR) is a critical metric for evaluating a solar power system's efficiency. It compares energy production under real and ideal circumstances. It considers losses from shade, temperature changes, and inefficient inverters. PR stands for "actual energy output, theoretical Power Production ratio.

Usually, the PR value falls between 70% and 90%, or 0.7 and 0.9. A PR of 1.0 would mean that the system is operating at 100% efficiency, which is very uncommon in real-world settings because of things like dirt, temperature losses, and other issues.

3.8 The Solar Fraction:

The percentage of a system's total energy demand that is satisfied by solar energy is expressed as the Solar Fraction (SF); a metric used in solar energy systems. It estimates the proportion of energy requirements met by solar energy as opposed to other energy sources (such as fossil fuels or grid electricity).

$\text{Energy Provided by Solar Energy} / \text{Total Energy Demand}$ equals the Solar Fraction (SF). When the solar percentage is one, or 100%, solar energy satisfies all of the energy demand. But it's just in ideal case.

When the solar percentage is 0.5, or 50%, it indicates that half of the energy required is supplied by solar power, and conventional sources supply the other half. No energy is derived from the sun when the solar percentage is zero.

3.9 Pmax, or maximum operating power:

The maximum electrical power a solar panel or array can generate under ideal circumstances is the maximum Operating Power or Pmax. Standard Test Conditions (STC) are often used to quantify an air mass of 1.5, a module temperature of 25°C, and an irradiance of 1000 W/m². This is expressed in watts (W) and is also known as the panel's nominal or peak power.

3.10 Thermodynamic Loss Ratio:

The Thermal Loss Factor explains the decrease in solar panel efficiency brought on by elevated temperatures. As temperatures rise, solar panel efficiency decreases. This factor, which typically shows how much performance decreases with each degree above a reference point (generally 25°C), is given as a percentage per degree Celsius. For instance, the panel's output will drop by 0.4% for each degree Celsius over 25°C if the heat loss ratio is -0.4%/°C.

3.11 Losses from Incident Angle Modifier (IAM):

The decrease in solar panel production caused by the angle at which sunlight strikes the panel is known as an IAM Loss. When the angle of incidence—formed by the incoming light and the perpendicular to the surface—increases, more sunlight is reflected off the panel, and less is absorbed by it. IAM losses become noticeable when the sun is lower in the sky during the early morning, late afternoon, and winter. An IAM curve for the panel material and design is typically used to compute these losses.

3.12 Soil Losses or Fraction of Soil:

The term "soiling fraction" describes the decrease in solar panel efficiency brought on by dust, debris, bird droppings, or other particles building up on the panel's surface. Soiling decreases the quantity of sunlight that reaches the photovoltaic cells, lowering the amount of energy produced.

The proportion of soiling losses is often stated and is contingent upon the surrounding environmental factors, such as heavy soiling in arid regions or locations prone to frequent pollution. Soiling losses may be reduced with regular cleaning or self-cleaning coatings.

3.13 The Net Present Value (NPV):

The Net Present Value (NPV) of an investment is the future cash inflows subtracted by the future cash outflows, assessed over a specified duration. Net Present Value is very important Calculation for evaluating economics. The equation of NPV is [34]

$$NPV = \sum_i^N \frac{C_i}{(1+r)^i} - TIC$$

Where C_i is the net cash flow in the year i , r is the discount rate TIC means total investment cost. If $NPV > 0$. Then we can say that means the project is profitable.

3.14 Payback Period (PBP):

Usually regarded as the period needed to achieve a break-even point or refund the original investment amount, the payback period is the length needed to recoup an investment. The leftover money after this payback time ends will create profits. The equation is [34]

$$PBP = \frac{\text{Initial Investment}}{\text{Cash flow per year}}$$

3.15 Internal Rate of Ratio (IRR):

This term stands for "internal rate of return." The return on investment (ROI) is determined while other factors are considered. Investment profitability may be calculated similarly to the accounting rate of return (ARR). An internal rate of return (IRR) of one or greater improves the likelihood that an investment or project will provide value to your business. When evaluating possible investments, it is typically suggested to prioritize the one with the highest internal rate of return (IRR), assuming that all projects have similar expenditures. The IRR equation [34]

$$IRR = \sum_{n=1}^N \frac{Ci}{(1 + IRR)^i}$$

3.16 Levelized Cost of Electricity (LCOE):

The total cost of energy produced over a system's operating lifespan is termed the levelized cost of energy (LCOE). A decreased LCOE indicates improved economic efficiency. The word LCOE may be defined as[1].

$$\sum_{n=1}^N \frac{Qn \times LCOE}{(1+d)^n} = \sum_{n=1}^N \frac{Cn}{(1+d)^n} \quad \sum_{n=1}^N \frac{Qn \times LCOE}{(1+d)^n} = \sum_{n=1}^N \frac{Cn}{(1+d)^n}$$

Given an annual project cost of C_n and a discount rate of d , we get Q_n , where Q represents the amount of power the system will provide to the grid in year n , and N denotes the study period [1].

CHAPTER 4

Methodology

4.1 Introduction:

In this particular section, an overview of the methodological framework will guide the review procedure that includes the workflow, selection of water body, structural design and data collection and analysis. Through the following frameworks, the review will justify a complete comprehensive and unbiased analysis of the existing literature review on floating PV systems, thus providing a valuable resource for further research and large-scale implementations.

4.2 Workflow:

A conceptual model of a small-scale off grid floating photovoltaic system has been developed in this project. This section provides a specific exaggeration of the methodology of the system. There is a flowchart for the clarity and convenience showed below in figure 4.2

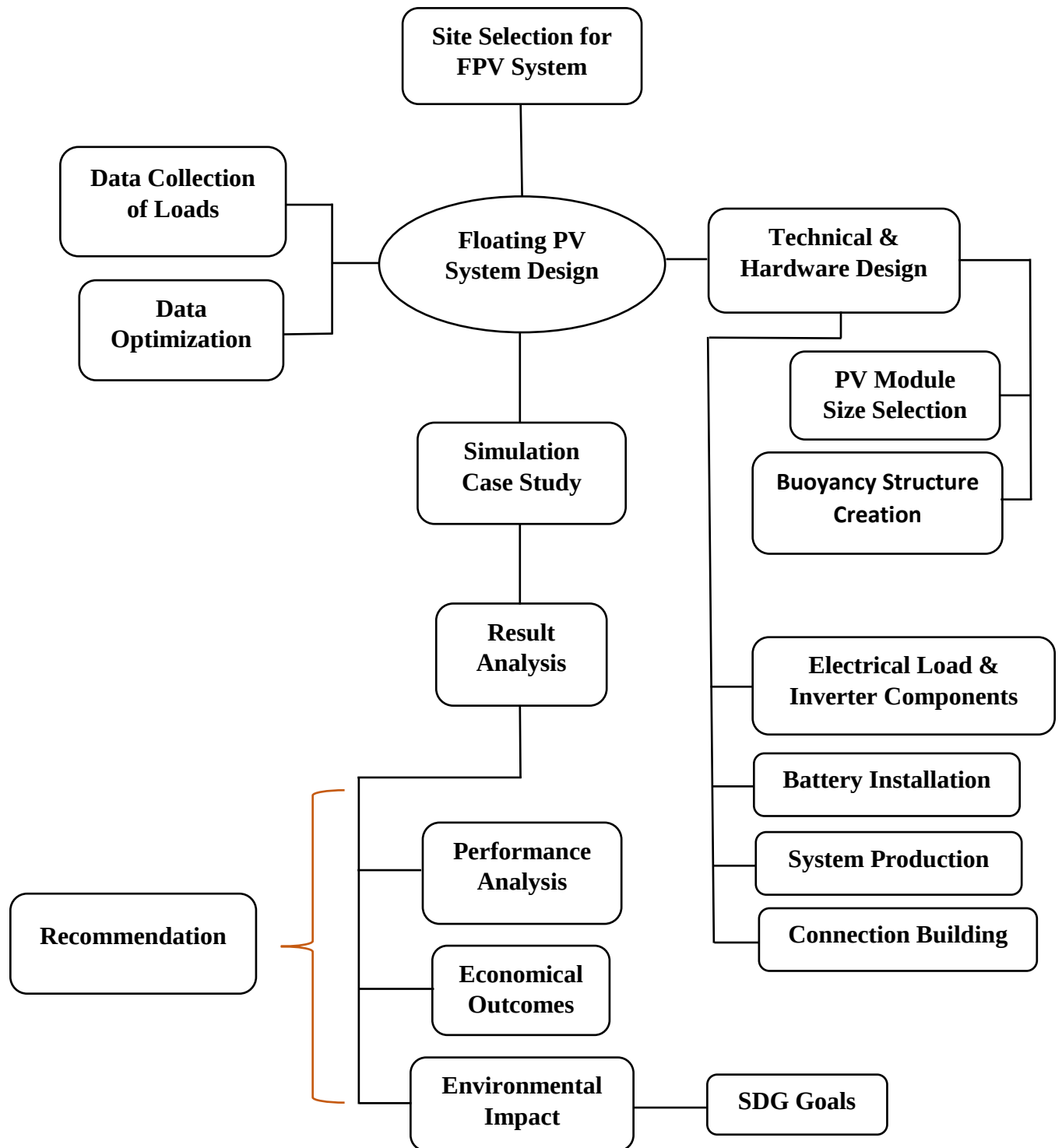


Figure 4.1: Methodology Flowchart of Floating Photovoltaic System plant.

4.3 Selection of Water Body:

The countries in the world have remarkable potential in solar energy Bangladesh is one of them. The selected area for this project (Latitude 23.76°, Longitude 90.35°) situated in university campus in Mohammadpur, Dhaka. Solar radiation in the chosen area is an important factor to consider for improved performance [24]. The selection area and water body are shown below in the figure 4.2



Figure 4.2: The selection area and water body collected from google earth.

The selection area is considered for this project on the basis of these point

1. The selection area is free from tide, flood and other hazards.
2. The area has not been affected by shading and situate near the office of security.
3. The water body is quite large enough for the solar and produces enough energy [24].

4.4 Structural Design

For making the structure of this project these are the things that are being considered.

4.4.1 Tilt angle

Basically, tilt angle is an angle between solar and the sun where panels are mounted to face the sun. This angle varies among the places and with the systems. In this project tilt angle has been set 11° according to the research journal [24]. In this angle the plate will get maximum irradiation.

4.4.2 Azimuth angle

The solar azimuth angle (z) is the angle that results from the sun's rays projecting onto a line that is orientated either due north or south. It's an angle measured in a horizontal plane. The azimuth angle has been set for this project 0° [18]. For getting maximum sunlight, avoiding shading and geographical consideration this angle has been taken.

4.4.3 Albedo

Generally, albedo means the fraction of sunlight that the surface reflects. FPV may not benefit from high reflection from water surfaces, as the overall albedo is low. The albedo rate is normally 5 to 7% on water [25].

4.5 Buoyancy structure creation:

Pontoon is used for the buoyancy of Floating Photovoltaic Systems. These pontoons are not available in Bangladesh as well as these are cost. For this reason, drums are used for the floating purpose in this project. They set up a fixed structure with a given tilt and azimuth angle with steel and solar plates on the drums. These drums made the project cost efficient than using the pontoons. The structure is given below in the figure 4.3 the drums with a 200-liter capacity.



Figure 4.3: The buoyancy structure with drums.

The floating structure can be categorized in three types:

1. The ‘free standing’ types where the panels are in higher position from the water surface.
2. A ‘small footprint’ type coverage on a small water surface.
3. A ‘large footprint’ type coverage on a large water surface [25].

1 and 2 types have been used for this project to float on the water.

4.5.1 Placement of solar panels

PV modules: A PV module or panel is a collection of PV cells. A single PV cell produces insufficient voltage, making it inconvenient. To achieve a higher voltage, more cells are connected in series. The series linking of cells creates a unit referred to as a PV module [26].

4.5.2 Electrical Components

By the number of journals and research paper studying the many electrical components has been gathered for the project. These are

1. 12-volt, 9Ah lithium-ion phosphate battery
2. A charge controller (PWM) type
3. 6 AWG GI wires
4. Single phase non grid power inverter of 1000watt
5. An energy meter.
6. Led bulbs

There are being used two types of set up for this project

- i. Software
- ii. Manual

4.6 Software simulation:

The PVsyst software has been used for the project. This is very helpful and famous soft tools for photovoltaic system. There are some other soft tools i.e., Helioscope, Homer pro but among these PVsyst is handier and easier to use. For the software simulation PVsyst 7.4 has been used.

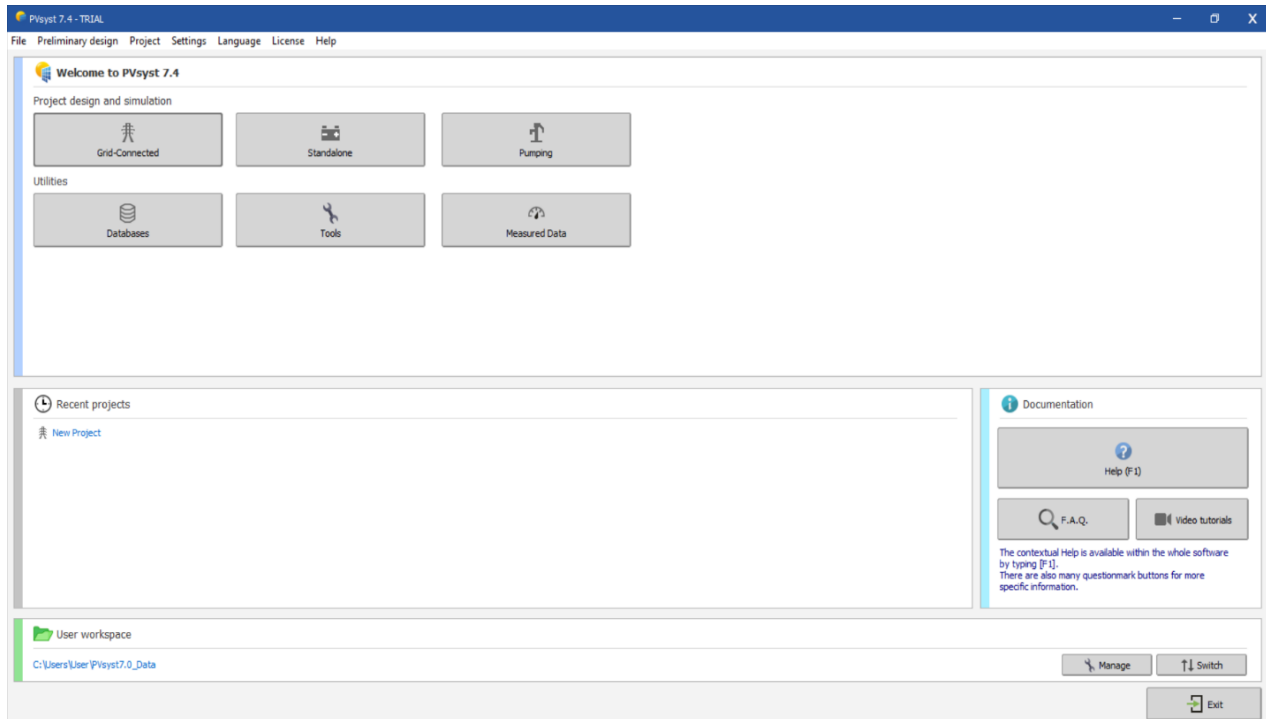


Figure 4.4: PVsyst software.

Figure 4.4 depicts the first page of the software. There three types design can be done by this software greed connected, stand alone and pumping. As this project is without grid connected, this project has been implemented in stand-alone system. For implementing this project this flow diagram is followed step by step in figure 4.5.

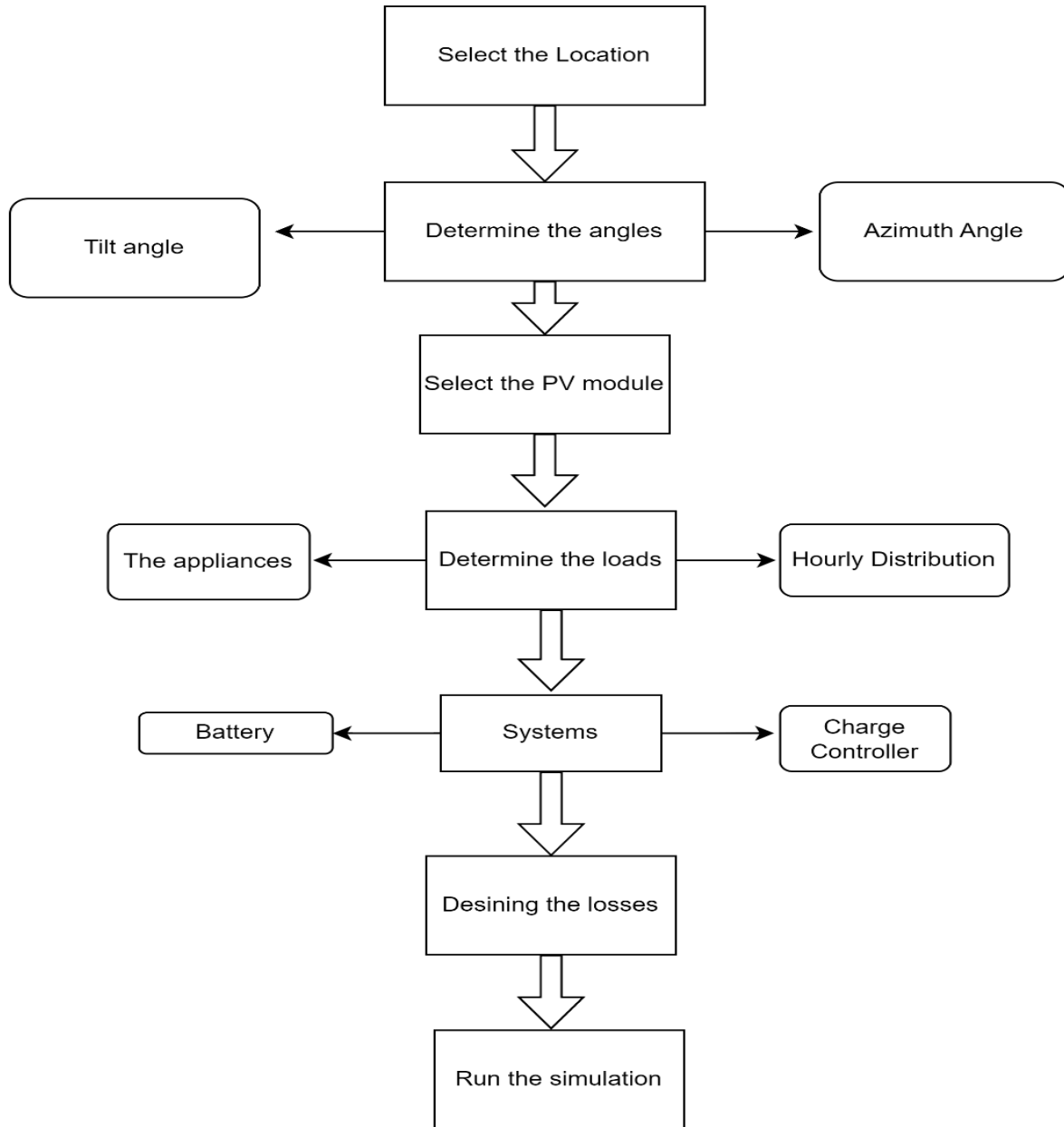


Figure 4.5: Step by step diagram of software simulation

4.6.1 Meteorological data:

First of all, had to choose the site where this system had been set up. This software easily gives meteorological information of the site through internet from NASA website. Selected areas meteorological data is determined by software which is shown in below table 4.1 indicates the yearly meteorological data of the location.

Table 4.1: Meteorological data.

	Global Horizontal irradiation (kWh/m ²)	Diffuse Horizontal irradiation (kWh/m ²)	Ambient temperature (°C)
January	104.9	61.9	17.03
February	113.0	63.6	20.96
March	155.2	79.5	25.76
April	157.8	90.9	27.74
May	159.3	100.2	28.41
June	133.3	91.0	28.15
July	127.0	82.0	28.54
August	135.2	95.2	28.69
September	125.9	74.5	28.01
October	119	70.9	27.15
November	108.3	58.7	23.02
December	97.8	61.0	18.88
Year	1536.7	929.3	25.21

4.6.2 Orientation of angle

The figure shows the PVsyst software front page. There are showing the tilt angle and azimuth angle which could easily input for the season. The summer season took for the simulation in this project. Here is shown in the figure 4.6

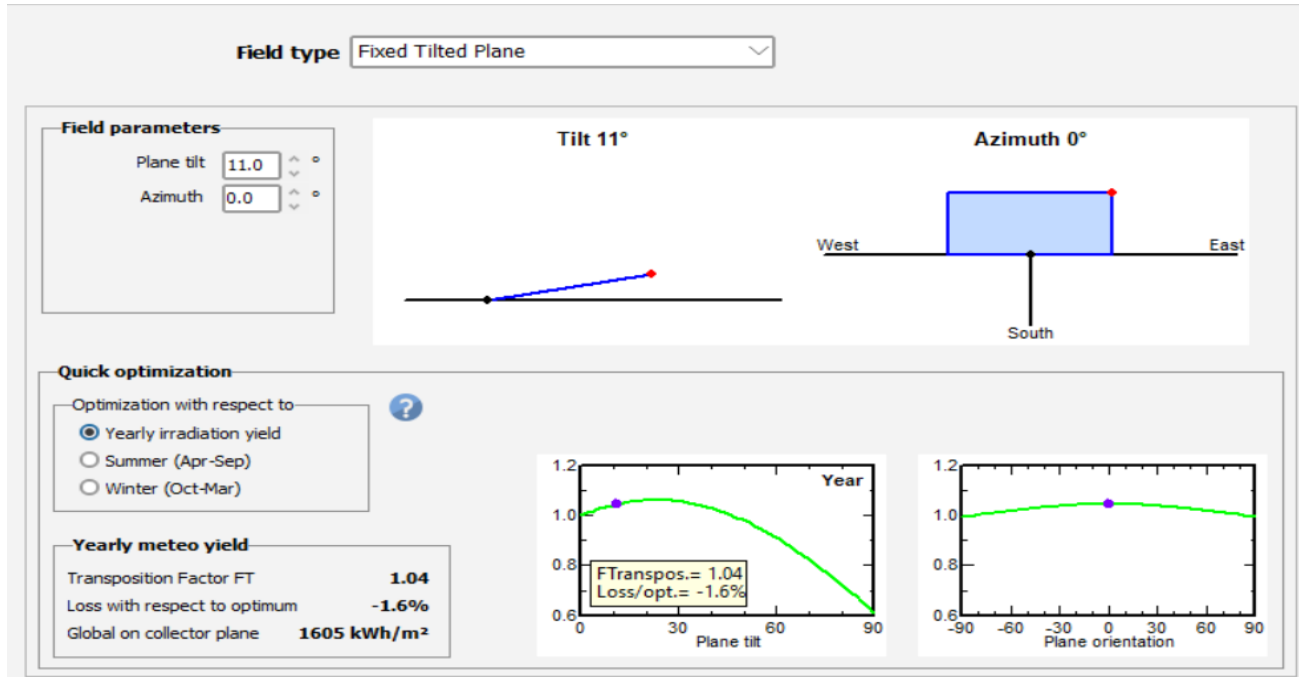


Figure 4.6: Tilt angle and azimuth angle.

Table 4.2: Location of the site

Parameters	Albedo	Latitude	Longitude	Altitude
Value	0.20	23.76	90.35	6

In the figure 7 field parameter of tilt and azimuth angle has been taken also chosen the optimization yearly. The location's geographical site and albedo given in the table 4.2 above.

4.6.3 Solar Panel:

In the software 65 watt of 12v ratings panel was used for the project. There are many solar panels in the list of the software that can be selected based on power output, qualities, robustness etc. The specification of the panel given below in the table 4.3

Table 4.3: Specifications of PV panel in the software.

PV panel	System type	Collector Orientations		Used model	Module PV	Manufacture	Number of PV modules	Total field Power (STC)	Total area of modules
	Stand-alone system	Tilt 11°	Azimuth 0°	All modules	Si-mono ZT6SS, 65 Watt solar	Zytech Solar	1(1-Mod. In Series), No. Strings (between 1 and 1)	65 Wp	1m ²

4.6.4 Loads and needs

The PV syst suggests for the adequate quantity of panel, battery, and charge controller for the system. As this is a stand-alone system there is no inverter in this system in software. But in hardware set up there has been used inverter that will be shown in hardware section. In the PV system the load demand must be assigned so that it can avoid oversizing. The daily consumption given in the **table 4.4** accordingly. Total daily energy needs 540wh.

Table 4.4: Consumption.

Number	Appliance	Power	Daily Use	Daily Energy
2	LED	5 w/lamp	24.0 h/day	240 Wh
10	Mobile charging port	15 w/lamp	2.0 h/day	300 Wh
Total Daily Energy				540 Wh/day
Monthly Energy				16.2 kWh/month

Av. daily needs kWh/day Enter accepted PLOL % Requested autonomy day(s) Battery (user) voltage V Suggested capacity Ah Suggested PV power Wp (nom.)

Storage PV Array Back-Up Simplified sketch

Sub-array name and Orientation
Name Tilt °
Orient.. **Fixed Tilted Plane** Azimuth °

Pre-sizing Help
☐ No sizing Enter planned power kWp
 ... or available area m²

Select the PV module
All modules Sort modules ☒ Power ☐ Technology
Zytech Solar 65 Wp 12V Si-mono ZT 65S Until 2013
Sizing voltages : Vmpp (60°C) **12.3 V**
Voc (-10°C) **20.3 V**

Select the control mode and the controller
☒ Universal controller MPPT power converter
Operating mode
☐ Direct coupling
☒ MPPT converter
☐ DC-DC converter
Max. Charging - Discharging current
MPPT 1000 W 12 V 6 A 13 A Universal controller with MPPT conve
The operating parameters of the universal controller will automatically be adjusted according to the properties of the system.

PV Array design
Number of modules and strings
Mod. in series should be:
Nb. strings ☒ No constraint ☐ between 1 and 1
Nb. modules **1** Area **1 m²**

Operating conditions:
Vmpp (60°C) 12 V
Vmpp (20°C) 15 V
Voc (-10°C) 20 V
Plane irradiance **1000 W/m²**
Imp (60°C) 4.6 A
Isc (60°C) 5.0 A
Isc (at STC) 5.0 A
Max. operating power (at max. irrad and 50°C) **59 W**
Array nom. Power (STC) 65 Wp

Figure 4.7: The selection of panel and controller.

Figure 4.7 depicts the selection of the components in PVsyst.

4.6.5 Charge controller:

There are commonly two types of charge controller used PWM and MPPT type. In the software implementation there is used MPPT type charge controller because of in PVsyst software there is no PWM type controller in the list. The best thing of the software is it can choose suitable parameters of component based on demand. Above in the figure 8 there is shown the chosen charge controller selection. The charge controller's whole description given below at table 4.5

Table 4.5: The specifications of MPPT charge controller.

MPPT Charge controller	
Max, charging current	6.0 A acc. To STC
Max, discharging current	13.3 A acc. To load
Max, back-up current	13.3 A genset
Converter nom, power	52 W
Max efficiency	97%

4.6.6 Battery:

In the PVsyst software there can be select battery easily from the lists. The software can choose the right parameters or ratings on the basis of demands of the loads and manage the nominal voltage with array. The assumption of battery temperature 20°C. It's very important to choose correct rating of battery. Here are the details of chosen battery in PVsyst in the table 4.6

Table 4.6: The specifications of Battery in PVsyst.

Parameter	Battery pack voltage	Global Capacity	Stored energy (80% DOB)	Total weight	Nb, cycles at 80% DOD	Total stored energy during the battery life	Correction coefficient	Reference Temperature
Value	12V	24 Ah	0.2 kwh	10kg	485	112 kwh	-5.0 mv/C*	20

The Synoptic Diagram of the project given below in figure 4.8

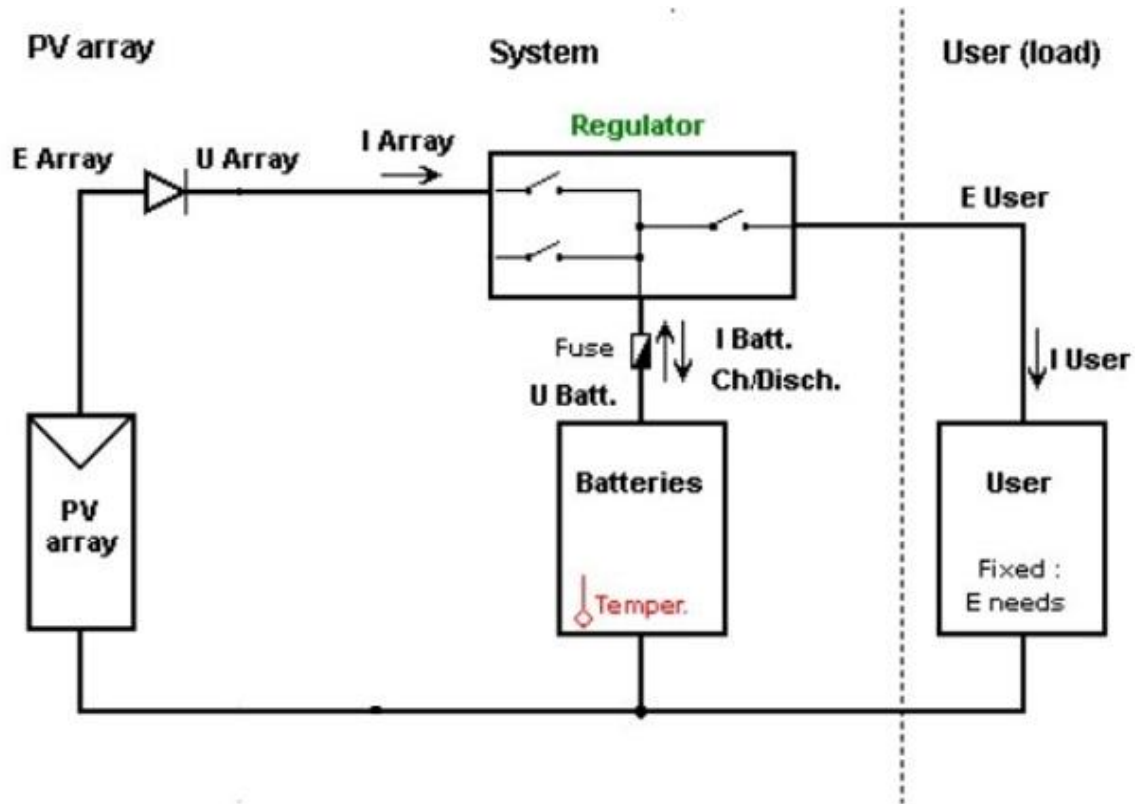


Figure 4.8: Layout of the system in PVsyst software.

4.7 Hardware implementation

For the implementation of this project there had been used many components. The details of components used in the project given below

4.7.1 Panel

The mono facial panel has been chosen for the project. As the system is on the water so the albedo rating is less than the ground. The reflection rate is less than soil in water so mono facial solar is suitable for the project. Table 4.7 represents the specifications of the PV array of the hardware project.

Table 4.7: PV panel specifications

Specifications	Remarks
Model	MONO-65W
Rated Maximum Power	65W
Tolerance	±3
Voltage at Maximum Power VMPP	18.36 V
Current at Maximum Power IMPP	3.54 A
Open Circuit Voltage VOC	21.67 V
Short Circuit Current ISC	3.75 A
Power Tolerance Positive	+ 10 %
Maximum System Voltage	1000 V
Weight	4.6 kg
Cell Type	Monocrystalline
Cell Count	36
Glass Type	Tempered, High Transmittance
Glass Thickness	3.2 mm
Frame Type	Anodized Aluminum Alloy
Junction Box Protection Class	IP65



Figure 4.9: PV panel with angle.

Figure 4.9 depicts panel with the fixed angle of hardware project of the system.

4.7.2 Charge controller

In stand-alone applications commonly use two types of charge controllers: PWM and MPPT. PWM controllers are less expensive than MPPT controllers and feature a simpler operating system, which improves battery life. It is only functional when the voltage of the battery and the load are the same. Meanwhile, MPPT charge controllers improve power transmission by matching the charging voltage to the battery's voltage state of charge, resulting in a 30% more efficient charging procedure [27]. It is standard procedure to make sure the charge controller can tolerate the product of the array's total short circuit current when sizing a controller device. The following equation [28] has been used for determine the charge controller

$$I_{cc} = I_{sc}^M \times N_{pm} \times F_{safe}$$

Where I_{sc}^M = the module's chosen short circuit current.

PWM (pulse width modulation) type Solar Charge Controller has been used for this project.

Table 4.8: Charge controller specifications.

Specifications	Remarks
Model	Solar Charge Controller
Rated Charge Current	10A
System Voltage	12/24V DC AUTO
Max. PV open circuit voltage	50V (24V System) 25V (12V System)
Max. PV input power	120W when your battery is 12V;240W when your battery is 24V

In the table 4.8 shows the specifications of the charge controller used in the project.



Figure 4.10: PWM charge controller.

PWM charge controller is shown above in figure 4.10.

4.7.3 Battery:

The choice and functionality of a battery in a photovoltaic system are influenced by various factors. Car batteries ought not to be used if there is a better solution available. PV batteries are built and function differently to deliver electricity for extended periods of time while recharging gradually [29]. Due to the remote and inaccessible character of the site, this criterion is usually crucial for remote electrification projects, where the shipping of goods, including batteries, takes longer. Even when the battery is not being used or has no load, it must be regularly charged if its self-discharge rate is high in order to maximize its energy output and lifespan [26]. The typical self-discharged rate of the batteries

1. Lead Acid batteries—4 to 6 % per month
2. Nickel Cadmium batteries—15 to 20 % per month
3. Nickel Metal Hydride batteries—30 % per month and
4. Lithium-Ion batteries—2 to 3 % per month

Lithium-Ion battery took for the project. The calculation of the battery capacity follows the equation [3] below depend on load

$$\text{Battery capacity (Ah)} = \frac{\text{Required Energy (Wh)} \times \text{Days of autonomy}}{\text{Battery Voltage} \times \text{DOD}}$$

Here DOD is batteries depth of discharge. The battery's DOD is 85% of this project which means 85% can be used of total ratings.

Total energy consumption = $2 \times 5 \times 12 = 120 \text{Wh}$ (daily)

Battery capacity required = $120 \times 30 = 3600 \text{Wh}$ (month)

When two light in load

$$\begin{aligned} \text{Battery capacity (Ah)} &= \frac{\text{Required Energy (Wh)}}{\text{Battery Voltage} \times \text{DOD}} \\ &= \frac{120}{12 \times 0.85} \\ &= 11.765 \text{Ah} \end{aligned}$$

In the table 4.9 below there is specifications of chosen battery for this project

Table 4.9: The battery specifications.

Specifications	Remarks
Nominal Voltage	12 volts
Nominal Capacity	9 Ah (Amp-hours)
Chemistry	Sealed Lead-Acid (SLA), AGM (Absorbent Glass Mat) or Gel
Terminal Type	F1 or F2 spade terminals (sometimes T2)
Dimensions	- Length: ~151 mm (5.94 inches) - Width: ~65 mm (2.56 inches) - Height: ~94 mm (3.70 inches) - Total Height (with terminals): ~100 mm (3.94 inches)
Weight	~2.4 to 3 kg (5.3 to 6.6 lbs)
Max Discharge Current	Varies, typically around 135 Amps (5 seconds)
Internal Resistance	~20-30 milliohms
Operating Temperature	- Discharge: -15°C to 50°C (5°F to 122°F) - Charge: 0°C to 40°C (32°F to 104°F) - Storage: -15°C to 40°C (5°F to 104°F)

Cycle Life:	Typically 200-300 cycles at 50% discharge depth
Charging Voltage	- Standby use: 13.5-13.8V - Cycle use: 14.4-15.0V
Self-Discharge	3% per month at 20°C (68°F)

Nominal Voltage means the output of the battery when it fully charged. Here in the table nominal voltage 12v indicates that when the battery will get fully charged its output voltages rating will be 12v. In figure 4.11 showing the battery of the project in hardware implementation.



Figure 4.11: Battery

4.7.4 Inverter:

An electrical device that changes direct current (DC) into alternating current (AC) is called an inverter. The input voltage of the inverter needs to match the voltage of the batteries [19]. There are several procedures for figuring out inverter ratings [30].

- Determine total power of appliance.
- The ratings of the inverter must be greater than 20-25% total power of AC appliance.

Basically, Capacity of inverter $\geq 1.2 \times$ total AC appliance power [30].

The inverter's specifications of the project given below in the table 4.10.

Table 4.10: Inverter Specifications.

Specifications	Shell material	Body Color	Peak-power	Continuous Output power	Input voltage	Output voltage	Conversion efficiency
Remarks	Aluminum alloy	Black	1000W Resistive Load	850W Resistive Load	DC 12V	AC 220V	Greater than 90%



Figure 4.12: Power inverter

Here the figure 4.12 above depicts the power inverter of the project.

4.7.5 Energy Meter:

The meter that calculates how much energy an electric load uses is called an energy meter. The entire power that the load uses and consumes at any one time is known as the energy. It is used to monitor power consumption in both residential and commercial AC circuits.

In this project a single-phase energy meter has been used.

A single-phase double-neutral missing tamper-proof kilowatt-hour (kWh) meter is a type of energy meter designed to accurately measure electrical energy consumption while preventing tampering, especially in environments where power theft is a concern. These meters are commonly used by utilities for billing purposes and to ensure the integrity of energy measurement.

Table 4.11: Specifications of the energy meter.

Category	Specifications
Meter Type	Single-phase, two-wire (L-N), tamper-proof electronic meter
Voltage Rating	230V AC $\pm 20\%$
Frequency	50 Hz $\pm 5\%$
Current Rating	5/30A, 5/60A, 10/60A (Basic); up to 60A or 100A (Max)
Temperature Range	-10°C to +55°C
Energy Measurement	Active energy (kWh), Reactive energy (kVARh, optional)
Starting Current	0.4% of base current
Backup	Non-volatile memory (data stored during power failure)
Memory Capacity	Stores data up to 12 months
Load Profile Recording	Yes, records consumption at set intervals (e.g., 30 min)
Power Consumption	Voltage Circuit: $\leq 1.5W$; Current Circuit: $\leq 2.5VA$

Table 4.11 indicates the whole specifications of selected energy meter for the project. In the figure 4.13 is shown the energy meter which is used in the project.

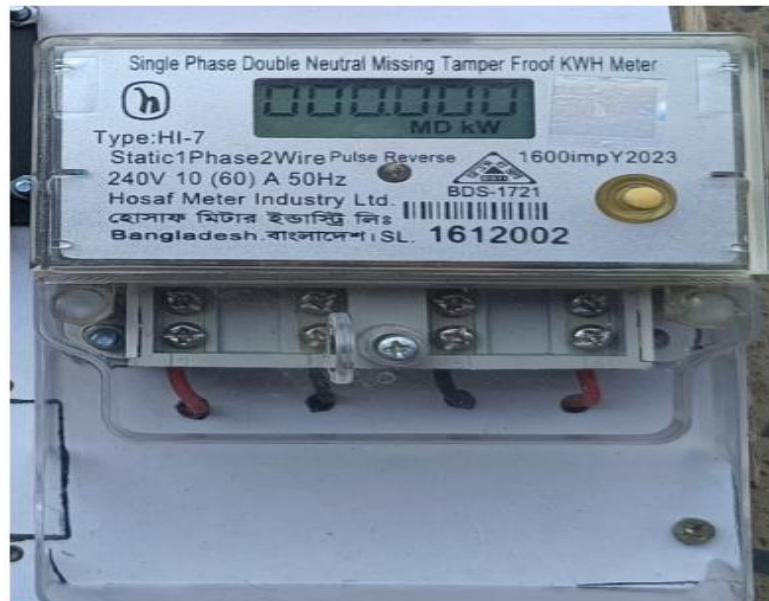


Figure 4.13: Energy meter.

4.7.6 Switch Board:

Switch board basically use for on/off purpose of loads. A switchboard is an electrical device that distributes and controls the electrical power. There is being also used a switch board with two switches and a charging pot depicts in figure 4.14. The output AC current of inverter flow towards energy meter then from the energy meter it flows to the switchboard. There is single line diagram of distribution shown in figure 4.15.



Figure 4.14: Switch board

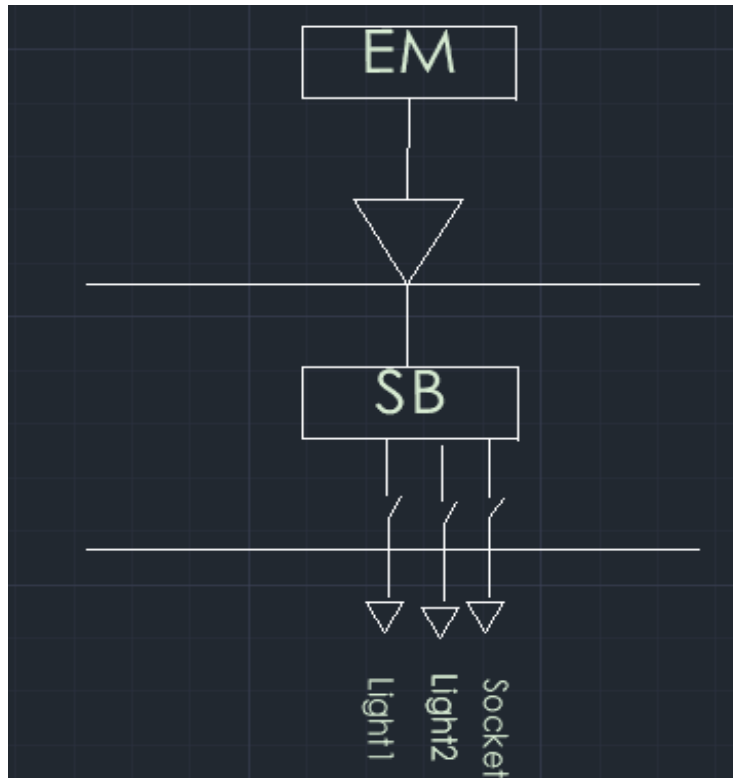


Figure 4.15: Single line diagram of distribution designed by Autocad.

4.7.7 Load

In the load there are two LED lights of 5watt and an energy meter. The information of energy meter has been given above already.



Figure 4.16: Two led lights at load.

There two led blue and red are shown in figure 4.16 and the descriptions of the led given in table 4.12.

Table 4.12: Specifications of led light collected from company.

Specifications	Remarks
Power Consumption	5 watts
Input Voltage	Usually, 85-265 volts AC
Luminous Flux	Approximately 400-500 lumens (varies by manufacturer)
Color Temperature	Available in different options
Beam Angle	Typically, 120 degrees
Lifespan	Approximately 15,000 to 25,000 hours
Efficiency	80-100 lumens per watt
Base Type	E27 or B22
Material	Aluminum heat sink and plastic housing

4.7.8 Wire Sizing:

Cable sizing between panel and battery is calculated by some steps. These are [30]

- Calculate the maximum DC system voltage by this equation [30]

Maximum DC system Voltage = Maximum number of modules per string $\times V_{oc}$ $\times$ Temperature correction factor.

- Calculate the maximum DC current

The maximum DC current = $1.25 \times I_{sc}$

Where I_{sc} = Short circuit current given in panels specifications.

- Determine the conductor's maximum DC current carrying capacity.

Maximum dc current carried by the conductor = $1.25 \times$ Maximum DC current

$$= 1.25 \times I_{sc}$$

- Percentage Cable loss

Generally, the cross-sectional area and cable length calculations about 2-3% voltage drop is considered [30].

The cross-sectional area [30] $A = \frac{pI}{Vd} \times 2$

Where p = the resistivity of copper wire which is $1.724 \times 10^{-8} \Omega m$

Vd = Maximum voltage drop

l = length of the cable

I = the maximum current carried by the cable.

6 AWG GI wire has been selected for the project. Here is the full description of the wire in the table 4.13 below

Table 4.13: Wire specifications.

Parameter	Values
Model	6 AWG GI wire
Wire Gauge	6 AWG
Diameter	Approximately 4.115 mm (0.162 inches)
Material	Galvanized Iron (GI)
Finish	Zinc-coated for corrosion resistance
Current Rating	Typically used for applications requiring up to 50-65 amps, depending on insulation and installation conditions.
Weight	Approximately 0.395 kg/m (0.265 lbs/ft)
Tensile Strength	Generally, ranges around 350-400 MPa (megapascals)
Applications	Commonly used in electrical wiring, grounding, and fencing.

4.8 Overall System connection:

The basic connection of the system will be systematically connected, initiating with connecting the solar panel to the charge controller in the PV port input. Here, the charge controller will be used so that we can protect our appliances from unwanted fluctuating charge from the panels. The charge controller will send the constant rate of DC voltage to provide a stable voltage to our appliances. From the charge controller the output will be connected to a battery and which will be connected parallel to a non-grid inverter. Once the connection will set with the inverter, the supply will be successfully inverted into AC power supply. Afterwards, energy meter will be connected to obtain a long-term reading. Once it will connect, the bulbs will be connected directly to the switch board for output. After completion of implementing, loads will be applied to take readings in kilo-watts in time intervals of daily, weekly and monthly basis. Figure 4.17 depicts the components connection of this system created by power point.

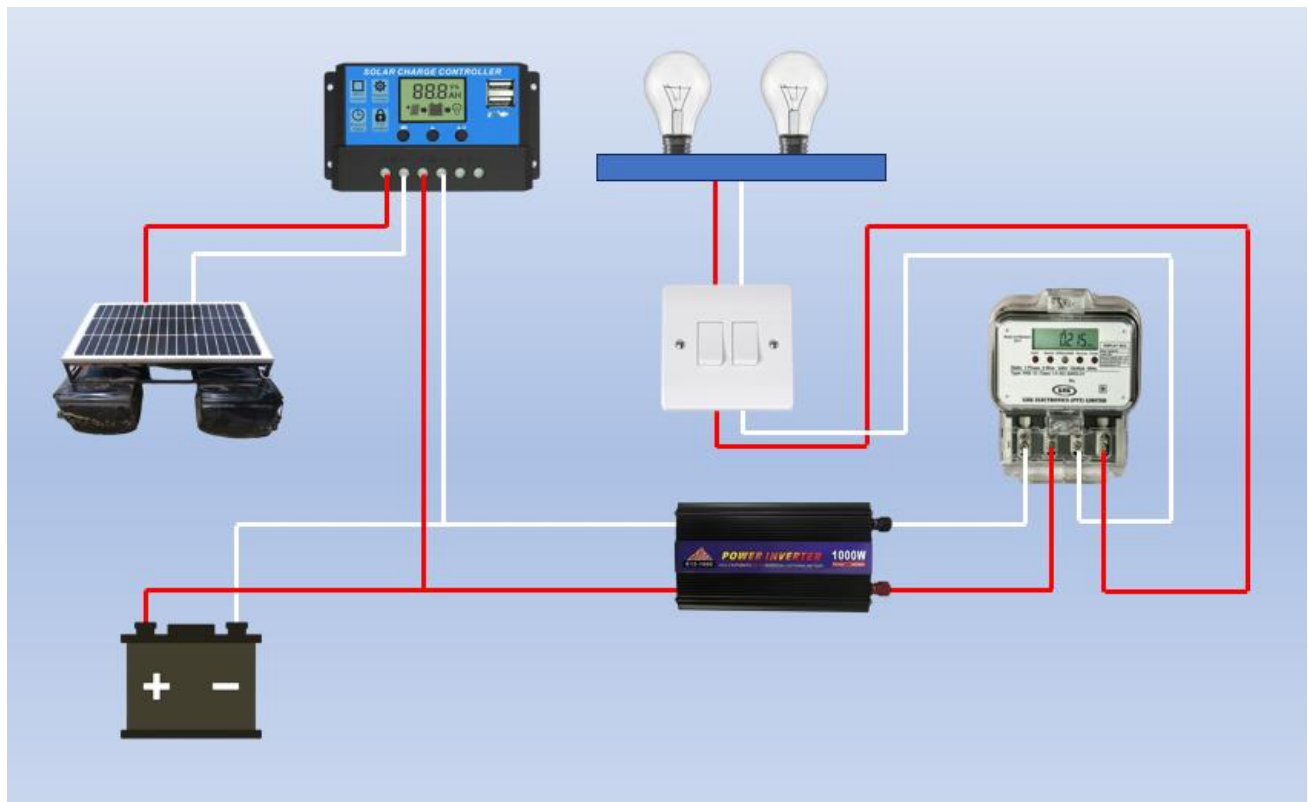


Figure 4.17: The Overall connection diagram of the system.

4.9 Economic Parameters:

An economic study is essential to determine the feasibility of the facility. The viability study of this research encompasses numerous economic difficulties, which are enumerated below. In this project trying to evaluate the economic assessment for the software and hardware:

For getting economic result for the software and manual obtained different parameters like payback period (PBP), Net Present Value (NPV), Levelized Cost of Electricity (LCOE).

Inflation rate = 9.90% according to Bangladesh Bank [37].

Electricity sell rate per unit = 7.20Tk which is 0.06\$ in US dollar and also peak and off pick are 12.95Tk i.e. in 0.110 USD and 9.68Tk i.e. 0.0810 USD accordingly hourly according to tariff of DPDC [38].

The discount rate has been taken = 12% [39].

There are some data collected from journal that in Bangladesh they categorized the life span of projects for making the initial investment cost marginal which are shown in table 4.14.

Table 4.14: Project life periods by sector [39]

Sector	Project Life
Railways	30
Roads	25-30
Ports and airports	25
Urban transport	25-30
Water management	25-30
Buildings	20
Energy	15-25
Broadband	15-25
Business Infrastructure	10-15
Other Sectors	10-15

According to the table above the project life time has been taken 15 years [40][41].

One way to deal with the inevitable decline in value of a physical item over time is to use depreciation, a method used in finance. A lower taxable income is the consequence of being able to deduct the yearly depreciation allowance.

Depreciation value's equation is [42]

$$\text{Yearly depreciation value} = \frac{(\text{Initial Investment} - \text{Salvage Value})}{\text{Life Time}}.$$

Salvage value basically tells the value about at the conclusion of a project's lifespan, the value of the investment assets is considered as a negative investment cost; this amount is known as the salvage value or residual value. The panels salvage value considered 15% [43]

For the Panel salvage value = $12.55 \times 15\% = 1.8825\text{USD}$

For the battery cost decreases 7% of primary cost [10] i.e., $5.86 \times 0.7 = 4.102$ will be decreased.

The Salvage value = $(5.86 - 4.102) = 1.758\text{USD}$

For the controller the salvage value 10% of its cost which is 0.293USD [40].

Table 4.15: Simulated parameters rating.

Parameters	Values (USD/Wp)
PV module	0.19
Battery	0.09
Controller	0.05
Other Components	0.01
Maintenance (yearly)	0.01

In the table 4.15 showing the parameters cost in USD per watt and operating cost per year. The total installation cost 0.34 USD/Wp and operating cost 0.01 USD/Wp/year. Total investment is 21.99USD which is fully outgone by own funds. The system is 65wp as the panel is 65watt.

Table 4.16: Financial Summery

Parameters	Installation Costs (USD/Wp)	Total Yearly Cost (USD/Wp)	Used Energy Cost (USD/kWh)	Payback Period (years)
Value	0.34	0.02	0.0571	11.9

In the table 4.16 shows the financial summary of the system. Total Yearly Cost 0.02USD/Wp used energy cost 0.0571USD per unit and payback period is 11.9 years.

Inflation rate, Discount rate, Electricity sell rate per unit has been taken same as software simulated value.

Table 4.17: Economic parameters for software and manual.

For Software		For Hardware	
Parameters	Value	Parameters	Value
Discount Rate	12%	Discount rate	12%
Inflation rate	9.90%	Inflation rate	9.90%
Time span	15 years	Time span	15 years
Electricity sell rate per unit	7.20Tk	Electricity sell rate per unit	7.20Tk

Table 4.17 shows the parameters ratings for software and manual. In this project total manually installment cost is 20273Tk.

Chapter 5

Result Analysis

As the project has been done in two ways software and hardware. So, the result is going to be describe in two sections.

5.1 Simulated Result

The simulation result in PVsyst software has been discussed

5.1.1 Normalized production

Normalized production represents the actual energy output of a solar power system based on its rated capacity and is frequently adjusted to specific characteristics (i.e., temperature, irradiance, etc.). The performance of different systems can be compared by normalizing the energy production to a standard measurement, such as kWh/kWp (kilowatt-hours per kilowatt-peak), regardless of the systems' sizes. Figure 4.18 displays the evaluation of normalized production derived from the simulation. The system is good, collection loss is 1 kWh/kWp/day, system losses and battery charging are 0.17 kWh/kWp/day, and energy given to the user is 3.22 kWh/kWp/day, according to the figure for a 65watt solar panel.

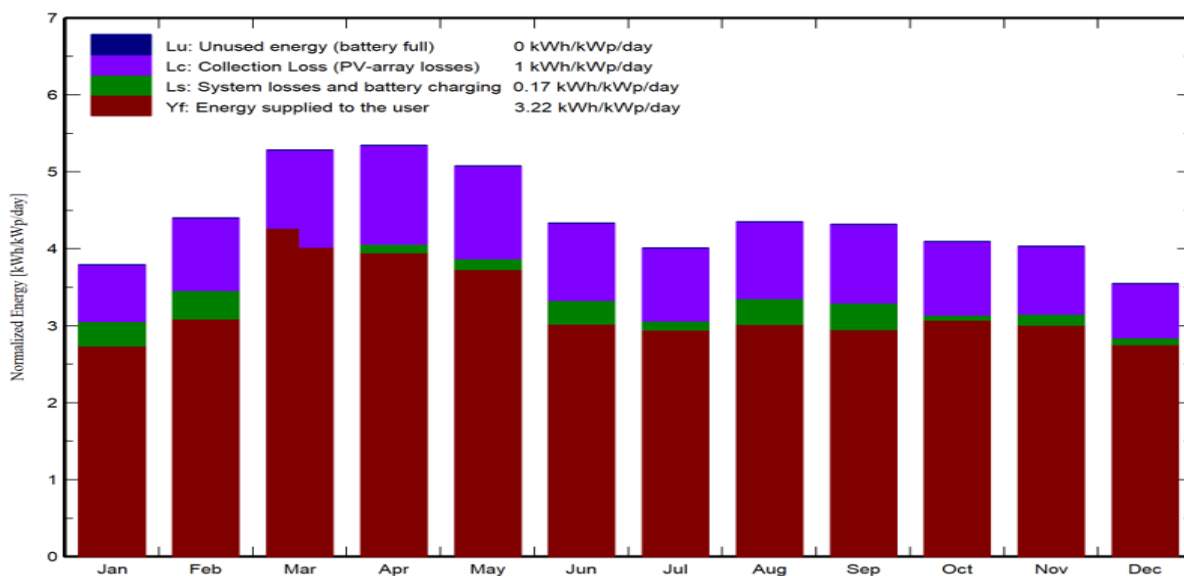


Figure 5.18: Monthly normalized production with losses.

5.1.2 Performance ratio and solar fraction

The performance ratio (PR) is a critical metric for evaluating a solar power system's efficiency. It compares energy production under real and ideal circumstances. It considers losses from shade, temperature changes, and inefficient inverters. The ratio between the intended yield and actual yield, as indicated by the following equation, is known as the performance ratio [31].

$$\text{Performance Ratio: } \frac{Y_f}{Y_r}$$

The percentage of a system's total energy demand that is satisfied by solar energy is expressed as the Solar Fraction (SF); a metric used in solar energy systems. The ratio of energy supplied to energy required is shown by the sun percentage [32].

The highest performance ratio can be seen in the figure 5.19 recorded 82% in March and the lowest performance in February due to less irradiation. The overall average performance ratio of the year is 0.734 i.e. 73.4% and the solar fraction is 0.387 i.e. 38.7%.

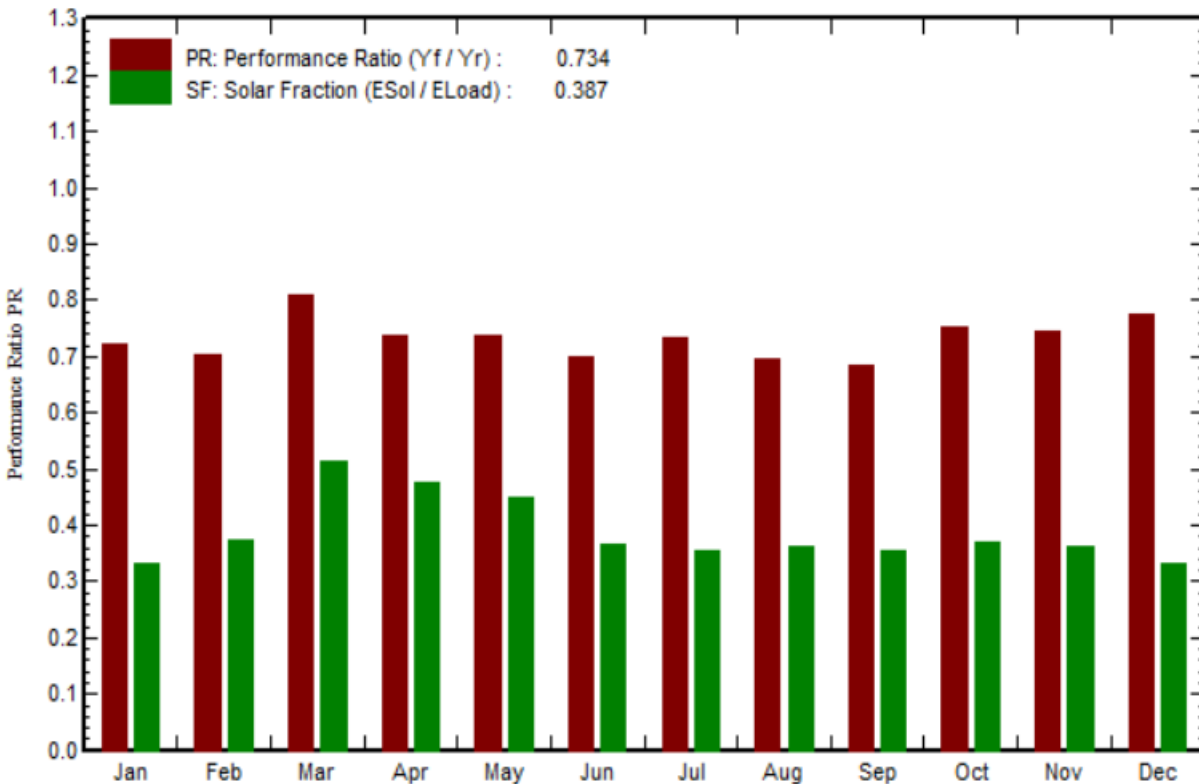


Figure 5.19: Performance ratio and solar fraction

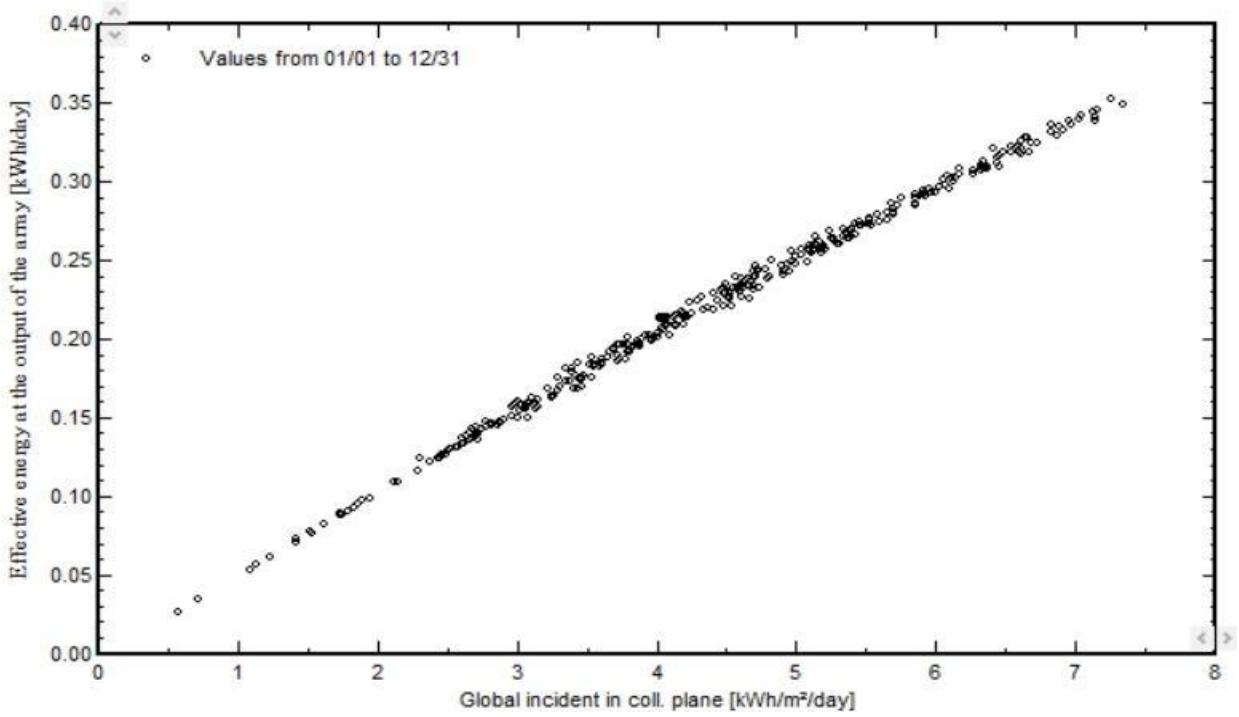


Figure 5.20: Daily input output diagram.

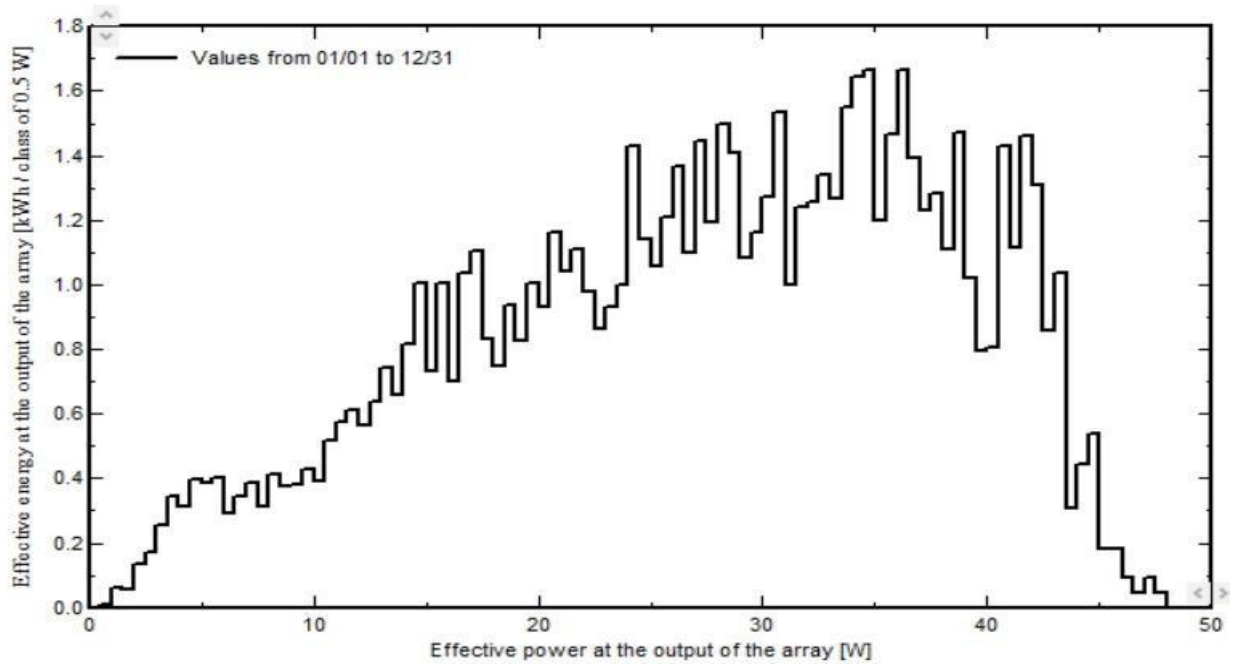


Figure 5.21: Array power distribution.

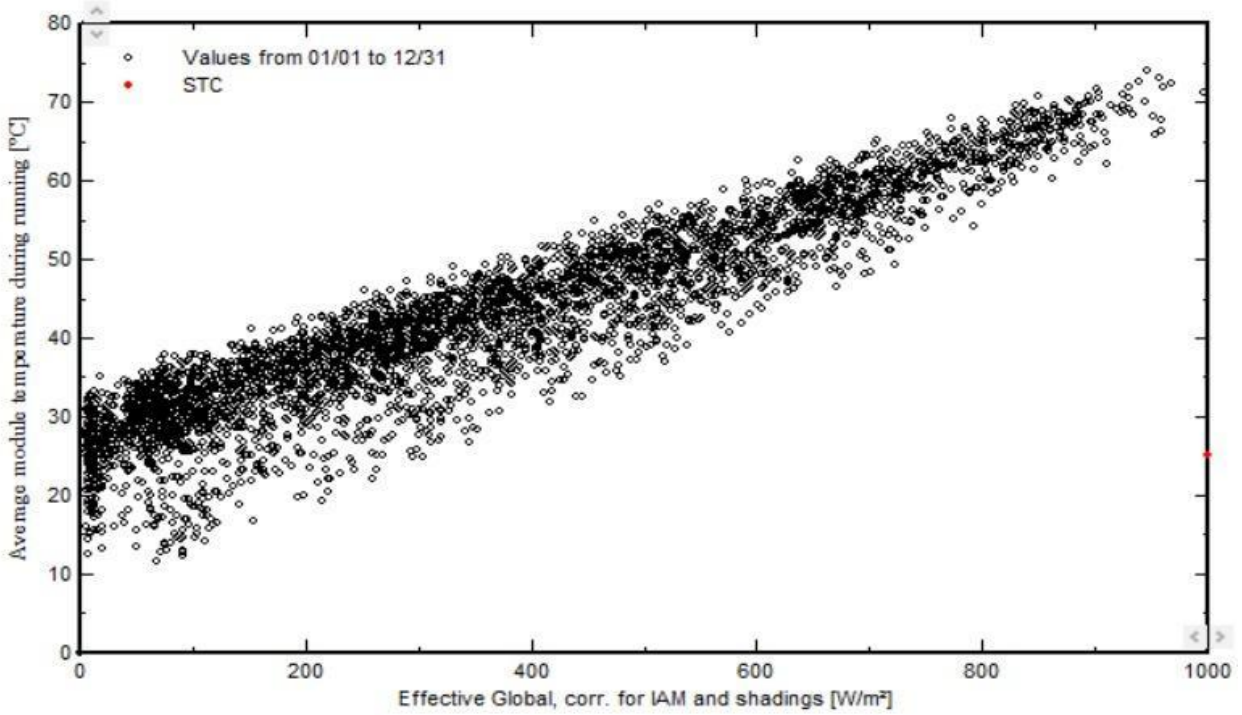


Figure 5.22: Array temp vs Effective irradiance.

In figure 5.20, 5.21, 5.22 depict the plot of daily input output, power distribution across the array, and temperature of the array relative to effective irradiance. In figure 5.21 shows highest output power of array 35W and effective energy of array at output is 1.7kwh. In array temperature vs. effective irradiance plot at figure 5.22 indicates with the increasing of irradiance the array temperature also increases.

5.1.3 Losses

Simulation result shows the performance ratio 0.734. So there has must be different kinds of losses. The losses easily determine PVsyst software. The figure 5.23 represents the overall losses of the year. The global horizontal irradiation is 1537 kwh/m², the effective irradiation on collector 1506 kwh/m². The efficiency of PV array at Standard Test Condition (STC) is 11.75%. After the all losses in the system available energy got as output of the panel is 197.1kwh. Table 5.1 represents the losses of the system.

Table 5.1: The all losses from PVsyst.

	Module Quality (kwh)	Mismatch Loss (kwh)	Ohmic wiring Loss (kwh)	Energy of array at fixed voltage (kwh)	Energy of array at fixed voltage (kwh)	Energy output of the array (kwh)
January	0.168	0.007	0.392	6.167	6.170	6.167
February	0.172	0.007	0.422	6.297	6.308	6.297
March	0.223	0.009	0.576	8.107	8.118	8.107
April	0.218	0.008	0.562	7.925	7.927	7.925
May	0.214	0.008	0.545	7.806	7.811	7.806
June	0.178	0.007	0.441	6.496	6.507	6.496
July	0.169	0.007	0.420	6.171	6.181	6.171
August	0.185	0.007	0.456	6.758	6.761	6.758
September	0.176	0.007	0.444	6.430	6.836	6.430
October	0.174	0.007	0.434	6.331	6.341	6.331
November	0.168	0.007	0.410	6.146	6.157	6.146
December	0.157	0.006	0.363	5.737	5.741	5.737
Year	2.203	0.086	5.463	80.370	80.459	80.370

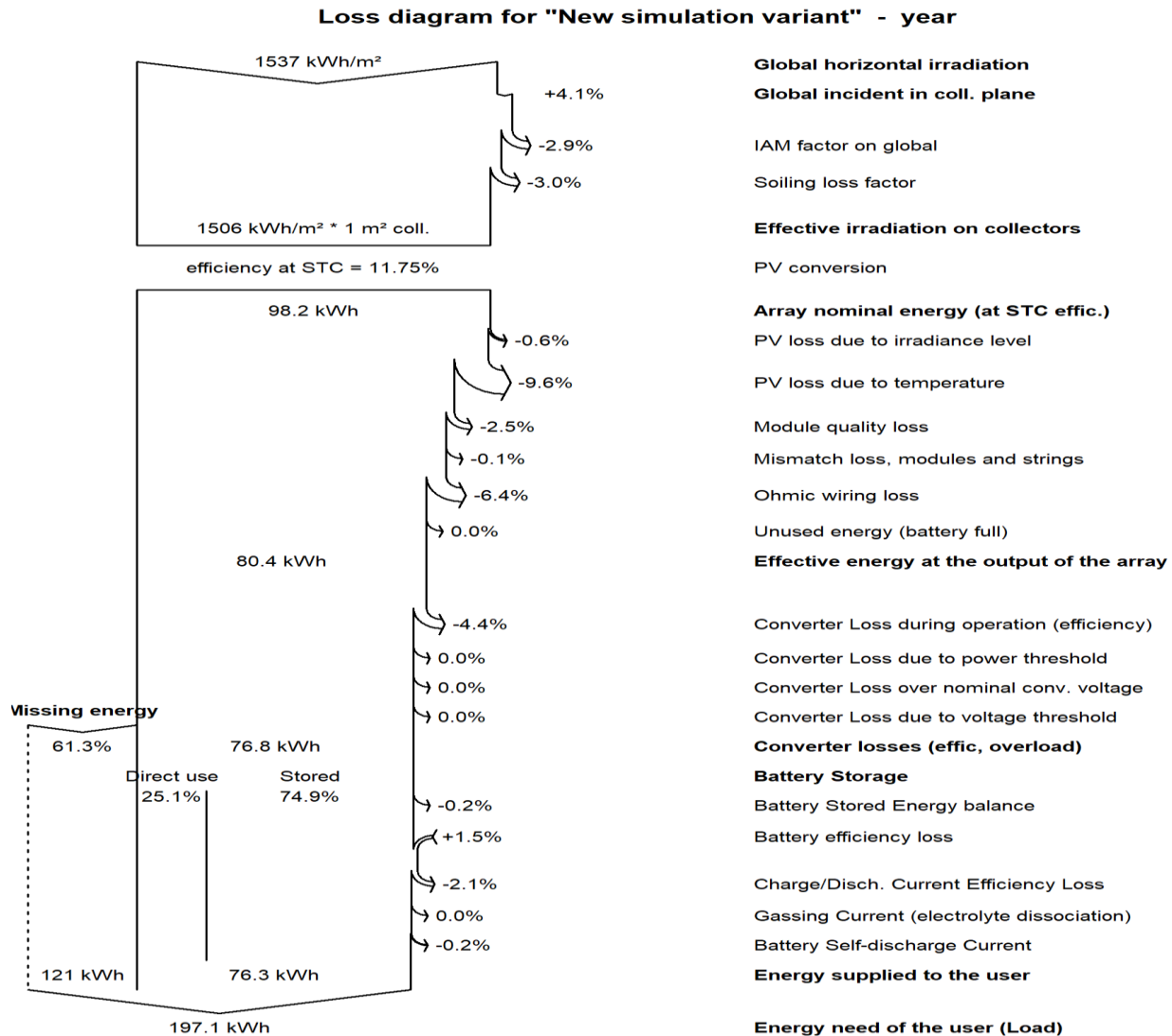


Figure 5.23: Loss diagram of the system in PVsyst software.

In the figure 5.23 the different losses indicate by the simulated software. This diagram is also known as fish bone diagram. The global horizontal irradiation falls on the PV panel area is 1537 kWh/m². As global incident on collector plate of PV increased 4.1% but for the Incident Angular Modifier Factor and soiling factor it decreases and becomes 1506 kwh/m² as effective irradiation on the collector. Here PV panel efficiency conversion is 11.75% at Standard Test Condition. The array nominal energy 98.2 kwh/m². For the irradiance level, temperature loss, Module quality loss, mismatch loss, wiring loss the effective energy at the output becomes 80.4 kWh. Here mismatch loss little because there is no number of panels just one array has been used in the system.

Furthermore, for the converter efficiency loss and battery efficiency loss the energy falls on 76.3kwh which is basically supplied to the user.

5.1.4 Balanced and main result

Table 5.2 shows the balanced and main result of the system in PVsyst software. The available solar energy per year is 76.80 kWh, the unused energy (battery full) is 0.00 kWh, the energy supplied to the user is 76.294 kWh, the energy needed for load is 197.10 kWh, and solar fraction is 0.387.

Table 5.2: Balance and main result of the system.

	Global Horizontal irradiation (kwh/m²)	Effective global irradiation (kwh/m²)	Available energy (kwh)	User Energy (kwh)	User need energy (kwh)	Solar Fraction
January	104.9	110.4	5.905	5.528	16.74	0.330
February	113	116.2	6.040	5.629	15.12	0.372
March	155.2	154.9	7.775	8.602	16.74	0.514
April	157.8	151.5	7.587	7.703	16.20	0.475
May	159.3	148.6	7.470	7.527	16.74	0.450
June	133.3	122.5	6.188	5.903	16.74	0.364
July	127	116.9	5.852	5.936	16.20	0.355
August	135.2	126.9	6.443	6.089	16.74	0.364
September	125.9	121.9	6.126	5.757	16.20	0.355

October	119	119.5	6.043	6.198	16.74	0.370
November	108.3	113.7	5.886	5.867	16.20	0.362
December	97.8	103.7	5.487	5.555	16.74	0.362
Year	1536.7	1506.0	76.802	76.294	197.10	0.387

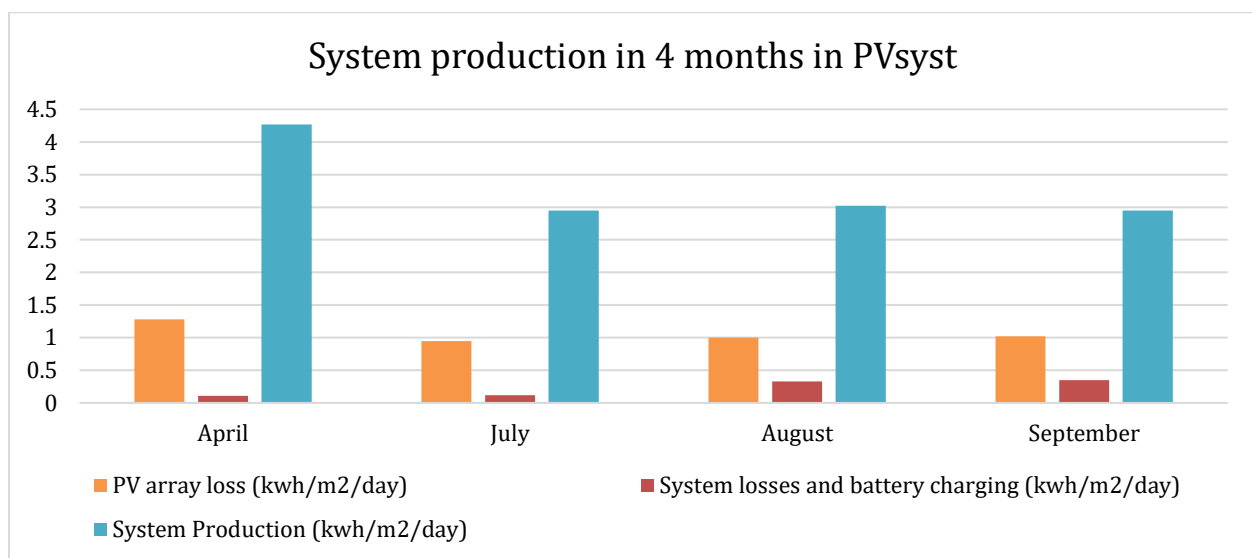


Figure 5.24: System production in 4 months in PVsyst.

Table 5.3: System production, array loss and system loss in 4 months.

Month	April	July	August	September
PV array loss (kWh/m²/day)	1.28	0.95	1	1.02
System losses and battery charging (kWh/kWp/day)	0.11	0.12	0.33	0.35
System Production kWh/m²/day	4.27	2.95	3.02	2.95

The table 5.3 shows in April there is highest production due to summer season, enough irradiation getting PV array and battery full charged.

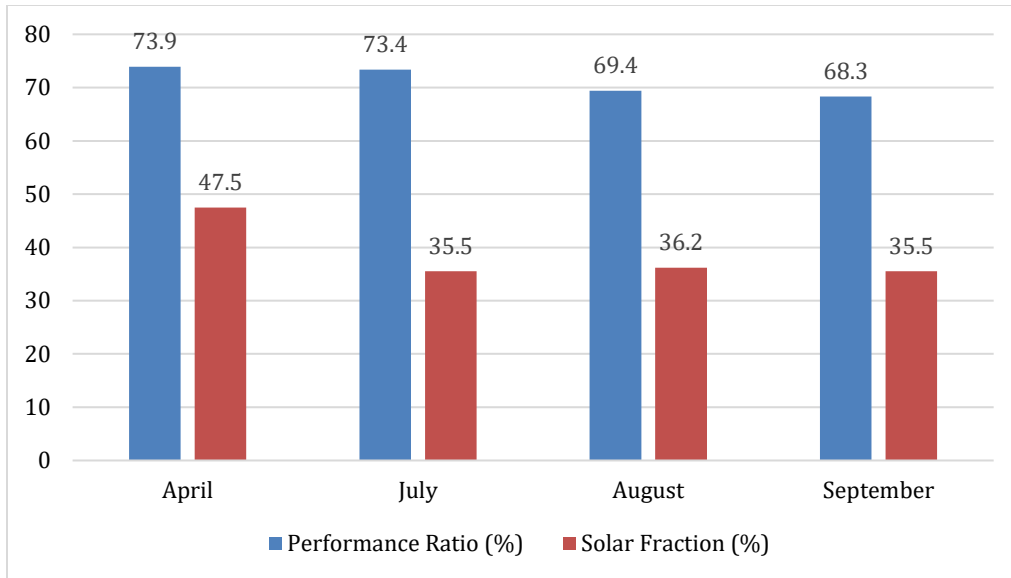


Figure 5.25: Performance Ratio and Solar fraction in 4 months from PVsyst.

Table 5.4: Performance Ratio and Solar Fraction in 4 months from PVsyst.

Month	Performance Ratio (%)	Solar Fraction (%)
April	73.9	47.5
July	73.4	35.5
August	69.4	36.2
September	68.3	35.5
Average	71.25	38.675

From the figure 5.24, 5.25 and table is shown the highest performance ratio is in the month of April and lowest in September. The performance ratio and solar fraction in 4 months 71.25% and 38.675% which can be written as 0.7125 and 0.38675.

5.2 Manual result:

For this project data has been collected physically. From the panel the power flows into the controller which is solar output power that shown in the controller. Then from the controller it flows into the inverter. In the energy meter can be seen the output power as AC after conversion by the inverter. Here is the collected data shown in the table 5.5.

Table 5.5: For 16 days PV Panel, DC Energy supply to battery (Watt) & Performance Ratio:

PV Panel (Watt)	Per day DC Energy supply to the battery (Watt)	Performance Ratio for PV Panel
65	47.4558	0.73008923
65	49.48028	0.76123508
65	49.50674	0.76164215
65	48.6447	0.74838
65	48.27936	0.74275938
65	48.41496	0.74484554
65	48.94038	0.75292892
65	49.57916	0.76275631
65	49.43748	0.76057662
65	49.55124	0.76232677
65	49.6376	0.76365538
65	49.76622	0.76563415
65	49.34026	0.75908092
65	49.88946	0.76753015
65	48.7695	0.7503
65	49.37906	0.75967785

The average performance ratio from the table got 0.75584.

Here to get Performance ratio this equation has been used

$$\text{Performance Ratio (PR)} = \frac{\text{Dc energy supplied to the battery}}{\text{Expected panels power}}$$

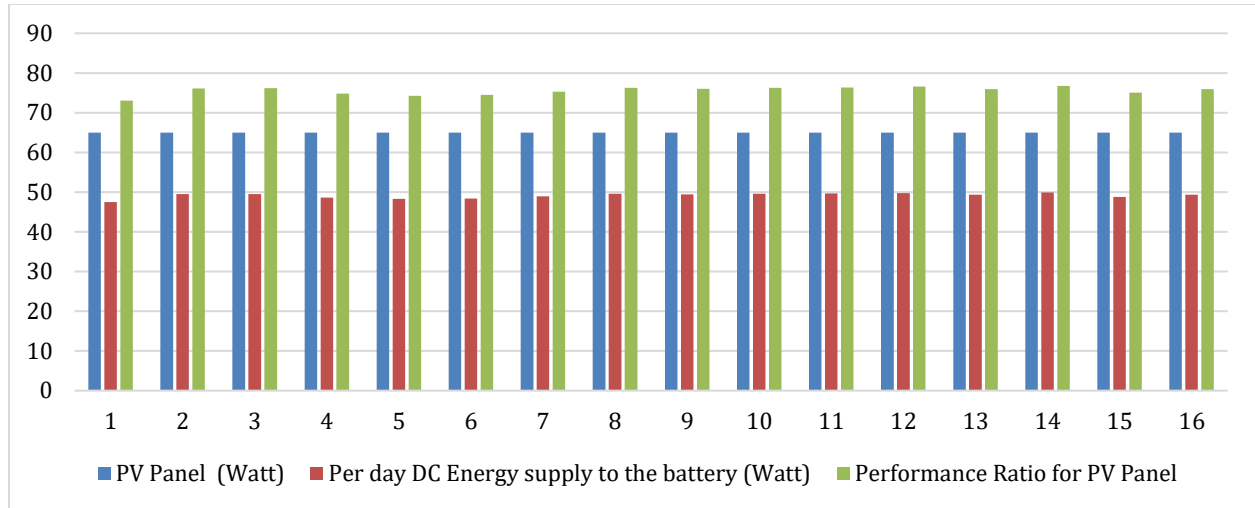


Figure 5.26: Performance ratio for the panel.

In figure 5.26 shows the performance ratio for the panel.

For the average performance ratio has been used this equation

$$\text{Performance Ratio (PR)} = \frac{\text{Total Dc energy supplied to the battery in 16 days}}{\text{Expected panels power} \times 16}$$

The average PR has been obtained for DC 0.6625

Table 5.6: For 16 days Inverter, AC Energy supply to an Inverter (Watt) & Performance Ratio for Inverter data:

Inverter (Watt)	Per day AC Energy supplied by the Inverter (Watt)	Performance Ratio for Inverter
1000	678.0403458	0.67804035
1000	712.2766571	0.71227666
1000	669.2795389	0.66927954

1000	706.5706052	0.70657061
1000	679.5389049	0.6795389
1000	665.0720461	0.66507205
1000	685.3602305	0.68536023
1000	619.6541787	0.61965418
1000	631.1815562	0.63118156
1000	637.925072	0.63792507
1000	653.5446686	0.65354467
1000	683.8616715	0.68386167
1000	728.0115274	0.72801153
1000	642.017291	0.64201729
1000	702.5936599	0.70259366
1000	700.9798271	0.70097983
Average Performance Ratio		0.6747

Table 5.6 shows that 16 days Inverter, AC Energy supply to an Inverter (Watt) & Performance Ratio for Inverter.

Here to get Performance ratio this equation has been used

$$\text{Performance Ratio (PR)} = \frac{\text{AC energy supplied to the Energy meter}}{\text{Inverters power ratings}}$$

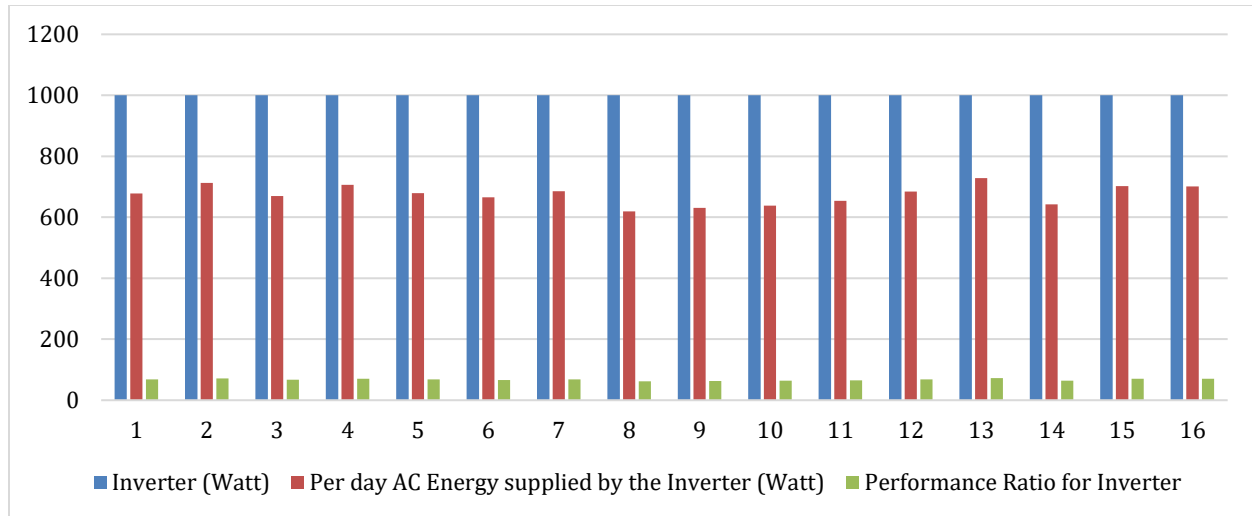


Figure 5.27: Performance ratio

Figure 5.27 depicts the performance ratio of 16 days data.

For the average performance ratio has been used this equation

$$\text{Performance Ratio (PR)} = \frac{\text{Total AC energy supplied to the energy meter in 16 days}}{\text{Inverter power ratings} \times 16}$$

The average has been obtained for AC 0.6747

Table 5.7: For 16 days Per-day Useable Load (Watt), Load Useable Time (H) & Energy Consume (Wh) data:

Per-day Useable Load (Watt)	Per-day Load Useable Time (H)	Per-day Energy Consume (Wh)
9	4.5	40.5
8	4.25	34
8	4.5	36
7	4.25	29.75
8	4.5	36
9	4.25	38.25
10	4.5	45

10	4.25	42.5
6	4.5	27
7	4.25	29.75
10	4.5	45
9	4.25	38.25
8	4.5	36
8	4.25	34
7	4.5	31.5
10	4.25	42.5
Total consume in 16 days		586

Table 5.7 shows the 16 days Per-day Useable Load (Watt), Load Useable Time (H) & Energy Consume (Wh) data.

To get energy consume equation is

Per day energy Consume = Per-day Useable Load (Watt) × Per-day Load Useable Time (H)

Table 5.8: For 4 months PV Panel, DC Energy supply to battery (Watt) & Performance Ratio data.

Months	PV Panel (Watt)	DC Energy supply to a battery (Watt)	Performance Ratio for PV Panel
April-24	65	46.97	0.72269231
Jul-24	65	46.43	0.71430769

Aug-24	65	44.73	0.68823077
Sep-24	65	44.15	0.67938462
Performance Ratio in 4 months for DC			0.70114

Table 5.8 shows the 4 months PV Panel, DC Energy supply to battery (Watt) & Performance Ratio data.

The performance ratio for dc power is 71.3% in 4 months.

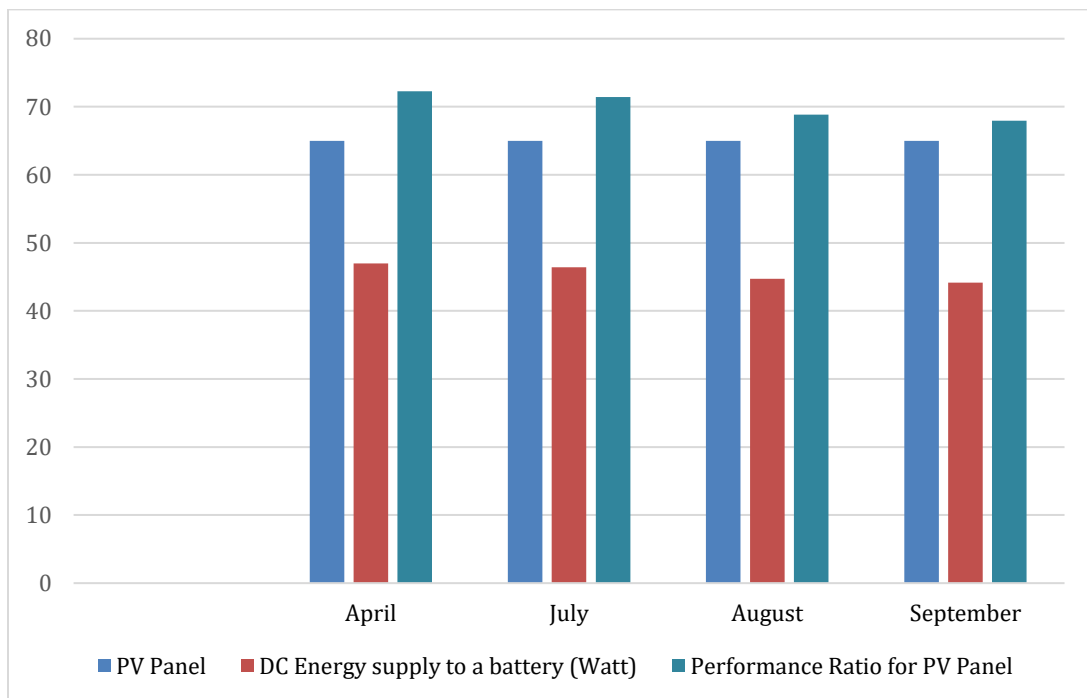


Figure 5.28 Performance ratio for panel in 4 months.

Table 5.9: For 4 months Inverter, AC Energy supply to an Inverter (Watt) & Performance Ratio data:

Months	Inverter (Watt)	AC Energy supply to an Inverter (Watt)	Performance Ratio for PV Panel
April-24	1000	809.51	0.80951
Jul-24	1000	679.56	0.67956
Aug-24	1000	674.74	0.67474
Sep-24	1000	663.97	0.66397
Performance ratio in 4 months for AC			0.70695

In the table 5.9 shows that 4 months Inverter, AC Energy supply to an Inverter (Watt) & Performance Ratio data.

The performance ratio for AC power is 70.695% in 4 months.

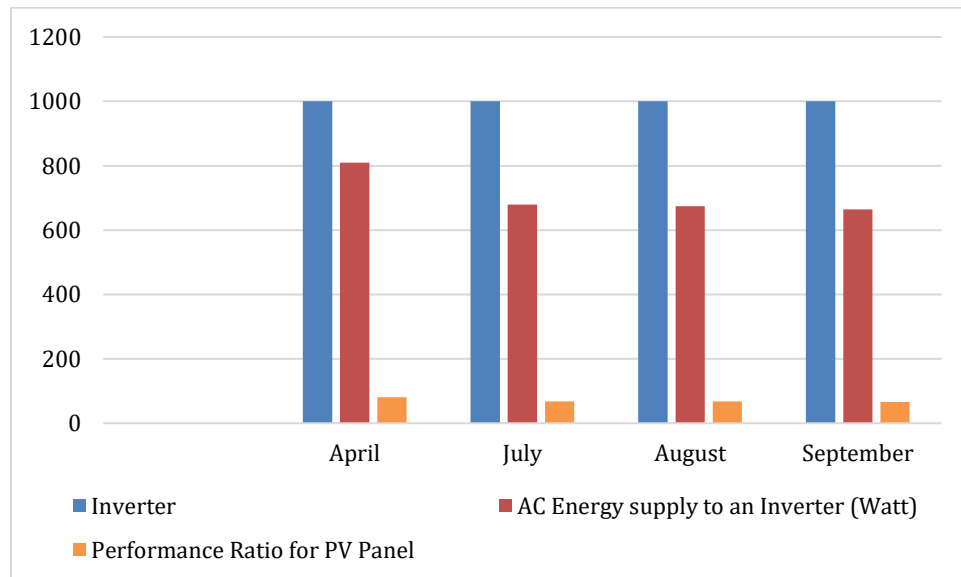


Figure 5.29: Performance Ratio in 4 months.

Figure 5.29 depicts the performance ratio of 4 months data.

Table 5.10: For 4 months Useable Load (Watt), Load Useable Time (H) & Energy Consume (Wh) data:

Months	Useable Load average per day (Watt)	Load Useable Time (H)	Energy Consume average per day (Wh)	Energy Consumed per month(Wh)
April-24	9.13	6	54.78	1643.4
Jul-24	8.37	6	50.22	1556.82
Aug-24	7.88	6	47.28	1465.68
Sep-24	9.23	6	55.38	2555.787
Total energy consumes in 4 months				7221.687

Table 5.10 shows that 4 months Useable Load (Watt), Load Useable Time (H) & Energy Consume (Wh) data. The total energy consumed by the load is 7221.687Wh i.e., 7.2217 kWh

5.3 Economical outcomes

As this project is techno economic so there is obviously have economic impacts. There is obtained economic outcomes for both software and hardware. Different financial factors have been figured out like Payback period, Net present value, Levelized Cost of Energy, Internal Return of Rate and Return on Investment. Here trying to evaluate economic outcomes of the project in simulated and manually.

5.3.1 Simulated economic outcomes

With the parameters of values mentioned in economical parameters putting in PVsyst found many financial parameters and results these are describing below:

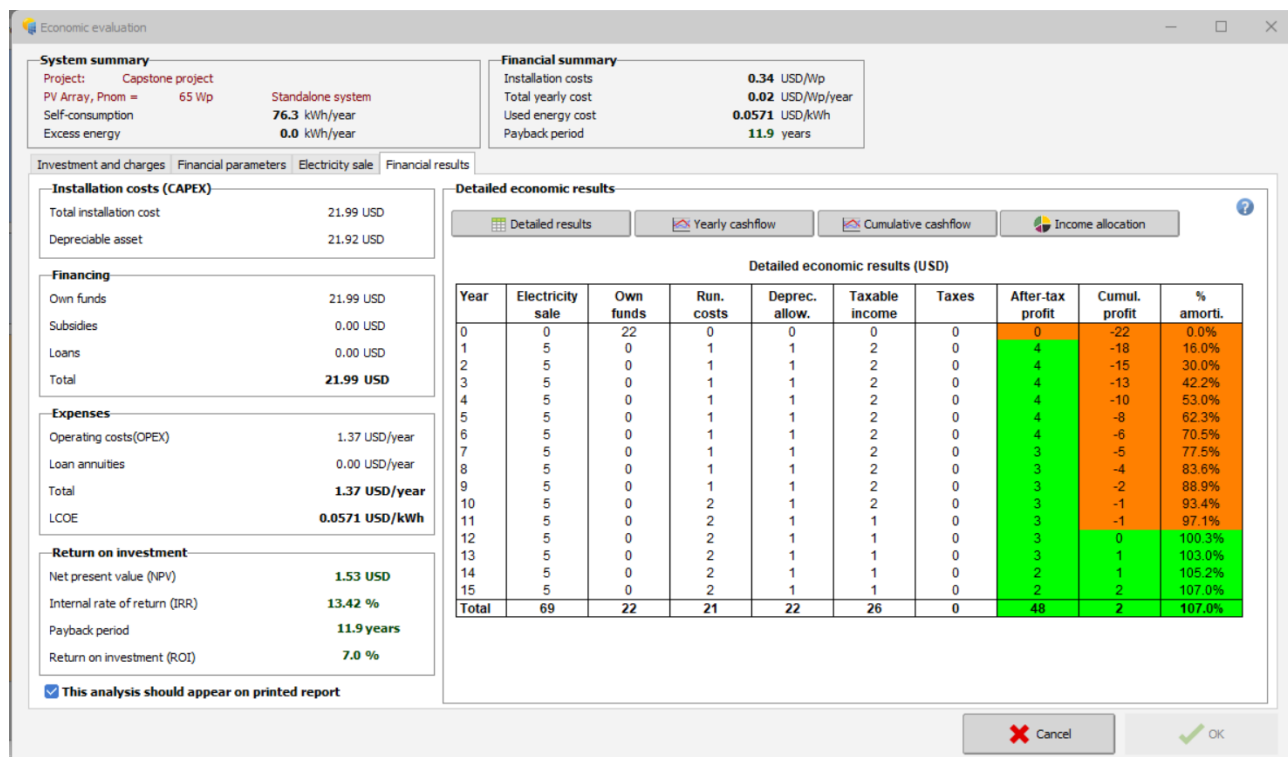


Figure 5.30: The main economic results in PVsyst.

Figure 5.30 depicts the main result of economic financial factors in the software. In the Table below values are being determined

Table 5.11: The output parameters of financial factors.

Parameter	Net present value (NPV) (USD)	Internal Rate of Return (IRR)	Payback Period (PBP) (year)	Return on Investment (ROI) (%)	LCOE (USD/kwh)
Value	1.53	13.42%	11.9	7.0%	0.0571

From the result Net present Value 1.53 which is positive that means the project is profitable. Payback period is 11.9 years. Internal Rate of Return is 13.42% which means it is going to return the 13.42% of investment annually i.e., annual growth rate. Return on Investment 7% that indicates the growth rate after finished whole life span. ROI is positive so this investment is not unprofitable. Levelized Cost of Electricity is 0.0571USD which is 6.85 in BDT. This express that project is feasible because the electricity rate in tariff now 7.20BDT. The cost of per unit generate is 6.85BDT. From the LCOE rate undoubtedly tells the project is profitable and effective.

Table 5.12: Detailed economic result.

Year	Electricity sell	Own funds	Run costs	Taxable income	After tax profit	Cumulative profit	Percentage of amortization (%)
0	0	22	0	0	0	-22	0.0
1	5	0	1	2	4	-18	16.0
2	5	0	1	2	4	-15	30.0
3	5	0	1	2	4	-13	42.2
4	5	0	1	2	4	-10	54.5
5	5	0	1	2	4	-8	66.7
6	5	0	1	2	4	-6	78.9
7	5	0	1	2	3	-5	91.1
8	5	0	1	2	3	-4	103.3
9	5	0	1	2	3	-2	115.6
10	5	0	2	2	3	-1	127.8
11	5	0	2	1	3	-1	140.0
12	5	0	2	1	3	0	152.2
13	5	0	2	1	3	1	164.4
14	5	0	2	1	2	1	176.7
15	5	0	2	1	2	2	188.9
Total	69	22	21	26	48	2	107.0

In the table 5.12 given the detailed economic outcomes of the system. In the table there is no section for tax cause the govt doesn't involved the green energy into the taxation. Here in the table till 11 years cumulative profit remains negative after that it becomes positive.

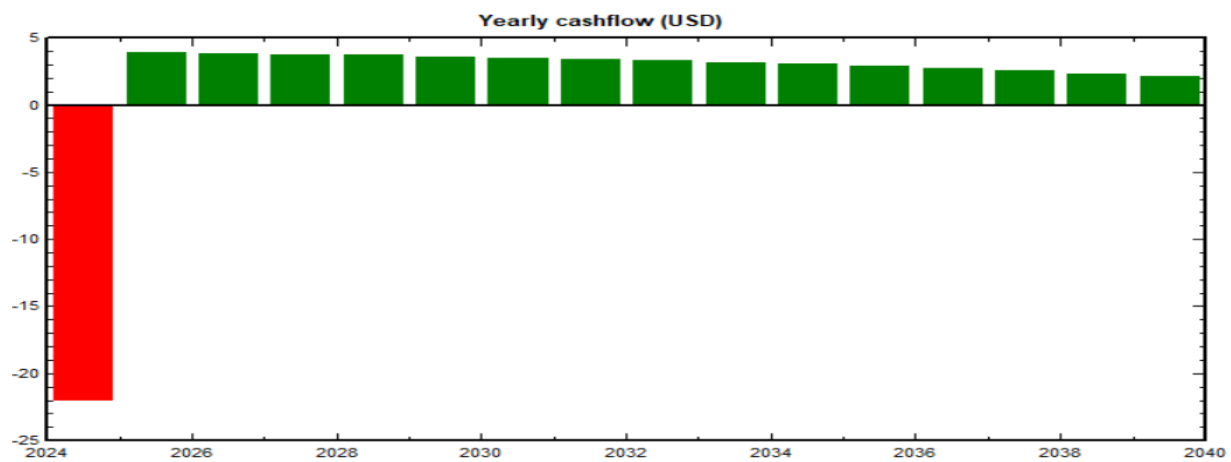


Figure 5.31: Yearly Cashflow.

Figure 5.31 depicts a complete cash flow analysis of the solar power project. This cash flow analysis includes all income and expenses incurred by the system during its operation. A full summery of the financial dynamics is provided. Cash flow decreases gradually due to there are operating costs and depreciations that will be deduct from the cash flow.

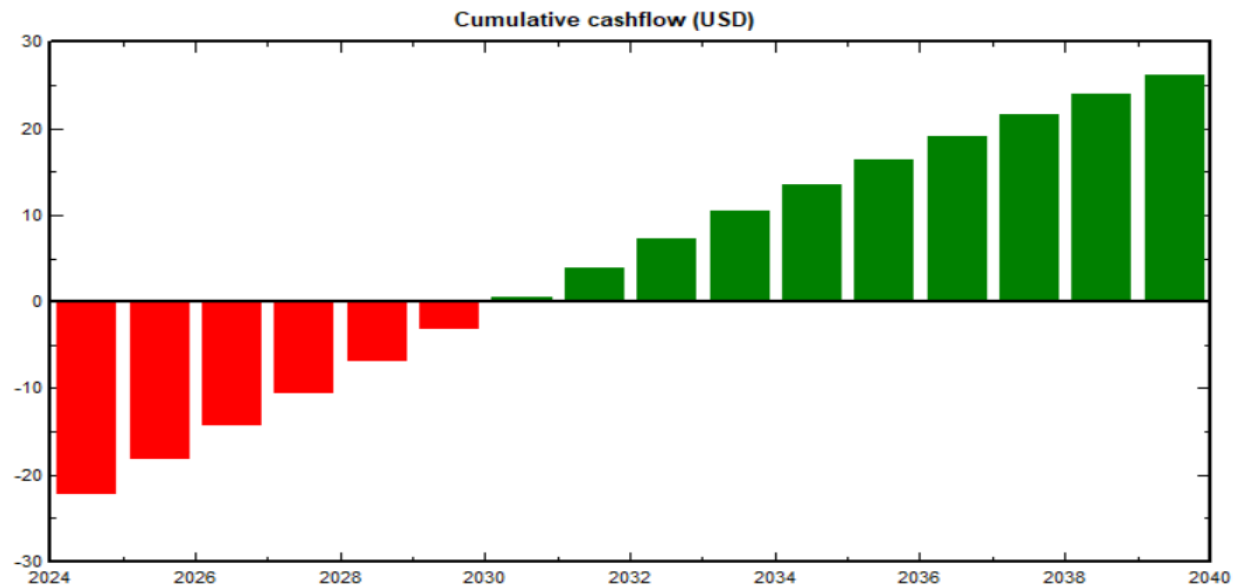


Figure 5.32: Cumulative Cashflow.

The solar power plant's cumulative cash flow is shown in Figure 5.32. Throughout the course of the project's 15-year lifetime, the average yearly cash flows are used to compute the cumulative cash flow. Here is clearly shown in the figure how the overall financial performance of the solar power plant is anticipated to evolve over time by summarizing the annual cash flows. The cumulative cash flow is a critical indicator for evaluating a solar power plant's financial trajectory over the duration of its entire operational life. It provides crucial insights into how the financial system functions as well as the long-term consequences of revenue generation and spending. The cumulative cash flow is calculated using the provided equation, allowing for a comprehensive evaluation of solar power.

Cumulative cash flow = Summation of the annual cash flow [10]

In the figure the cumulative cash flow is positive after 2030 to over its life time. This means the system will generate more revenue than its expenditure. This graph plays significant role for defining the financial performance of the system.

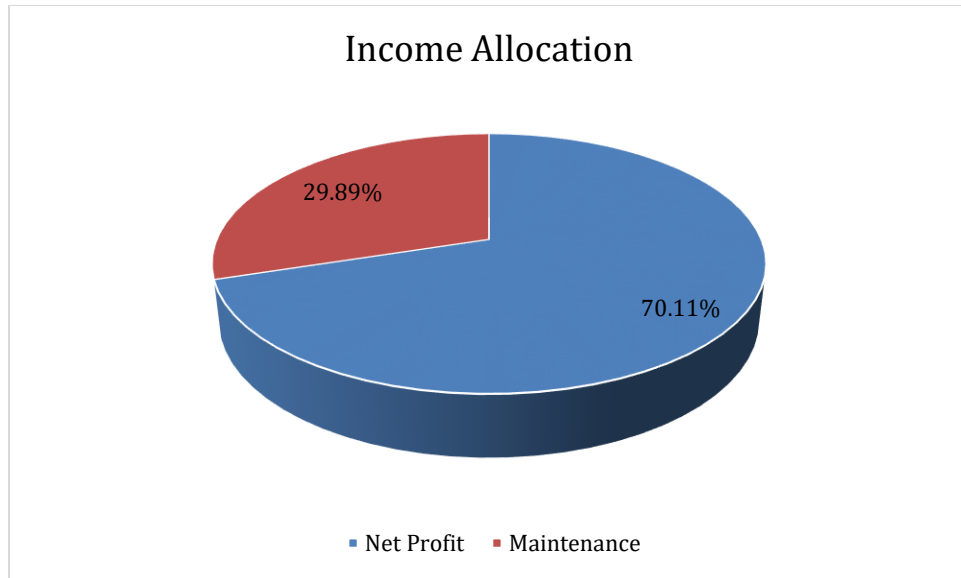


Figure 5.33: *Income Allocation.*

In the figure 5.33 talks about income partition. In 15 years, life time of this project and because of own funds and other parameters the net profit becomes 70.11% where the maintenance expenditure took 29.89% from the full income.

5.3.2 Manual economic outcomes

According to the project Net Present Value (NPV) Calculation: By applying a discount rate to future cash flows and discounting them to their present value, one can calculate the net present value (NPV) of an investment and assess its profitability. Now the formula for NPV is:

$$NPV = \sum_{t=0}^n \frac{R_t}{(1+r)^t} - C_0$$

Here,

R_t = Net cash inflow during the period t

r = Discount rate (cost of capital)

t = Time period

C_0 = Initial investment (cost of setting up the project)

Assuming NPV Calculation for the FPV Project for the 15-year period:

If the initial investment (C_0) for setting up the FPV system at ULAB is 20,273 Tk, as per the final budget. Let's assume,

- Assumed annual cash inflows from electricity savings and other economic benefits: 5,000 Tk per year.
- Discount rate: 12%
- Project life: 15 years.

$$\text{Payback Period (PBP)} = \frac{\text{initial installation}}{\text{Cash in flow}}$$

$$= \frac{20273}{5000}$$

$$= 4.05 \text{ year}$$

By using this data, the NPV calculation,

For the 1st year:

$$\begin{aligned} \frac{R_t}{(1+r)^t} &= \frac{5000}{(1+0.12)^1} + \frac{5000}{(1+0.12)^2} + \frac{5000}{(1+0.12)^3} + \frac{5000}{(1+0.12)^4} + \frac{5000}{(1+0.12)^5} \\ &+ \frac{5000}{(1+0.12)^6} + \frac{5000}{(1+0.12)^6} + \frac{5000}{(1+0.12)^7} + \frac{5000}{(1+0.12)^8} + \frac{5000}{(1+0.12)^9} \\ &+ \frac{5000}{(1+0.12)^{10}} + \frac{5000}{(1+0.12)^{11}} + \frac{5000}{(1+0.12)^{12}} + \frac{5000}{(1+0.12)^{13}} + \frac{5000}{(1+0.12)^{14}} \\ &+ \frac{5000}{(1+0.12)^{15}} \\ &= \frac{5000}{(1+0.12)^1} + \frac{5000}{(1+0.12)^2} + \frac{5000}{(1+0.12)^3} + \frac{5000}{(1+0.12)^4} + \frac{5000}{(1+0.12)^5} + \frac{5000}{(1+0.12)^6} \\ &+ \frac{5000}{(1+0.12)^6} + \frac{5000}{(1+0.12)^7} + \frac{5000}{(1+0.12)^8} + \frac{5000}{(1+0.12)^9} + \frac{5000}{(1+0.12)^{10}} \\ &+ \frac{5000}{(1+0.12)^{11}} + \frac{5000}{(1+0.12)^{12}} + \frac{5000}{(1+0.12)^{13}} + \frac{5000}{(1+0.12)^{14}} + \frac{5000}{(1+0.12)^{15}} \end{aligned}$$

$$= 34054.324 \text{ Tk}$$

Now the NPV,

$$= 34054.324 - 20273$$

$$= 13781.324 \text{Tk}$$

According to the results:

An NPV of 13781.324 Tk indicates that the project will be considered profitable if the project runs for 15 years. NPV shows that the expected benefits within 15 years exceed the initial investment. Which made the project a sound financial decision. In addition, environmental benefits such as reduced greenhouse gas emissions and water conservation add to the attractiveness of FPV systems that contribute to its overall value.

According to LCOE calculation:

$$\text{LCOE} = \frac{\sum_{n=0}^N \frac{C_n}{(1+i)^n}}{Q \times \sum_{n=1}^N \frac{1}{(1+i)^n}}$$

$$\sum_{n=0}^N \frac{C_n}{(1+i)^n}$$

According annual cash flow 5000tk at 20 years.

$$\text{PV of Benefits} = 5000 \left(\frac{1 - (1+0.12)^{-15}}{0.12} \right)$$

$$\text{So, Annuity Factor} = \frac{1 - 0.182696}{0.12} = 6.8109$$

$$\text{PV of Benefits} = 5000 \times 6.8109$$

$$= 34054.5 \text{ Tk}$$

$$\text{Yearly Produce Energy} = 21.6651 \text{ kwh/year}$$

$$\text{Total Energy Produced} = 20 \times 21.6651 \text{ kwh/year}$$

$$= 433.302 \text{ kWh}$$

$$\text{Cost of PV } C_0 = 20,273 \text{ tk}$$

$$\sum_{n=0}^N \frac{C_n}{(1+i)^n} = \sum_{n=0}^N \frac{20273}{(1+0.12)^0} = 20273$$

In this way calculating for 15 years

$$\sum_{n=1}^N \frac{1}{(1+i)^n}$$

For 1st year = 0.8829

For 2nd year = 0.791

For 3rd year = 0.712

For 4th year = 0.634

For 5th year = 0.567

For 6th year = 0.506

For 7th year = 0.452

For 8th year = 0.403

For 9th year = 0.361

For 10th year = 0.321

For 11th year = 0.287

For 12th year = 0.256

For 13th year = 0.229

For 14th year = 0.205

For 15th year = 0.184

Total summing of these result = 8.784

$$LCOE = \frac{\text{Cost of Pv}}{Q \times 8.784}$$

$$LCOE = \frac{20273}{433.302 \times 8.784} = 5.326 \text{ Tk/kWh}$$

LCOE is represent the cost of per unite generated energy for this project life time. After calculated, we can see that per unit cost is 5.326Tk/kWh.

This project will be financially feasible cause the unit price is 5.326 Tk/kWh which less than electricity sell rate in our country. This project will provide electricity in less cost from the national power.

The software and manual economic results become different for the ratings of the components and usage of the components. For the limitation of the software there couldn't be used inverter but in manual there has been used inverter. Moreover, the difference of production plays significant role to give result difference. After all, from the economic outcomes both software and manual this is clear that this system is feasible, productive and efficient.

5.4 Environmental Impacts

The FPV has many better impacts on the environment than ground PV systems. This project is small scale but in the large scale there will be more environmental impacts. Greenhouse gas emissions from the FPV plant are anticipated to decrease by about 61 tons per year, a significant development in the fight against climate change. FPV systems may help with water saving and sustainability by preventing water from evaporating. Goal 7 of the Sustainable Development Goals (SDGs) is to ensure that all people have access to modern, cheap, dependable, and sustainable energy. The FPV project corresponds with this goal by decreasing emissions and preserving water resources. Using metrics like rates of decrease in greenhouse gas emissions and deductions for water evaporation, the study assesses environmental consequences, offering a holistic perspective of the environmental advantages.

5.4.1 Environmental Effect on SDG7 Goals:

"Design and implementation of a small-scale Floating Photovoltaic System in ULAB campus A techno-economic assessment" project's environmental impact is aligned with several Sustainable Development Goals (SDGs). Project support for the SDGs and their impact on the environment given below:

5.4.1.1 SDG 7: Affordable and clean energy

Floating Photovoltaic (FPV) systems are one way in which it helps achieve SDG 7 to generate renewable energy. The project generates electricity by using solar energy, renewable and renewable energy sources to avoid contributing to global warming and reduce greenhouse gas emissions. This technology is implemented in a small-scale pilot project. It is demonstrating the integration of renewable energy in the context of ULAB University. This will help reduce dependence on fossil fuels and facilitate the transition to a sustainable energy system.

5.4.1.2 SDG 6: Clean water and sanitation

Installing FPV projects in water helps reduce water evaporation. This will result in reduced water reserves in drought-prone or agriculture-intensive regions. Which is a major plus for water conservation. Additionally, SDG 6 is supported by the FPV system as it also improves water quality. It also helps prevent eutrophication by reducing algae growth and shading the water.

5.4.1.3 SDG 9: Industry, Innovation, and Infrastructure

By integrating solar power generation with water surface use, the FPV system offers a new perspective on renewable energy technology. This assists in the advancement of durability in industrial relations and infrastructure designs. The approach enhances the aspects of the environment as well as energy at once.

5.4.1.4 SDG 11: Sustainable cities and communities

The vital objective of creating such urban areas is to supply global cities with renewable energy sources and preserve the land areas within the cities. This integration is a boon for sustainable community development and helps reduce the impact of urban areas on the environment. As a result, along with environmental development, the structure of a digital city is structured.

5.4.1.5 SDG 13: Climate Action

FPV systems can reduce greenhouse gas emissions during power generation, thereby reducing the impact of climate change. This initiative is important to show preventive measures to tackle the problems arising due to climate change. Using surface water for energy production also reduces land use thereby protecting ecosystems and biodiversity.

5.4.1.6 SDG 15: Life on Earth

This system promotes biodiversity. In addition, it conserves terrestrial ecosystems by generating solar energy from water bodies instead of land. This reduces the land impact which can have a positive impact on populated countries. Finding a middle ground between human energy needs and environmental protection can be achieved through the use of innovative technologies.

5.5 Project-specific environmental benefits

Greenhouse Gas Emissions: The project intends to create clean energy and at the same time cut down on carbon dioxide emissions to the fullest extent possible. This has a multifaceted effect against the background that it inspires other corporate/communal societies in the like use of such techniques and technology.

Water Conservation: Such benefits of the FPV system restrain water evaporation and stabilize the pond water levels which benefits the biosphere and even agricultural practices. This sub-activity involves the construction of floating PV plants on surface water bodies. Using surface water for

energy generation means that the issue of land space competition is less of a problem, an aspect that is very vital in land-scarce countries such as Bangladesh which has a high population density.

The project illustrates how energy, environmental and social issues can be addressed in an integrated manner and at the same time contribute to several SDG targets. It provides a solution that can be scaled up and can be rolled out for harnessing clean energy in a city and peri-urban environment and the process helps build towards future sustainability.

5.6 Limitations and Discussion

In this project there are some limitations. In the hardware project system has inverter but, in the software, there is no inverter in stand-alone system. So, in the software implementation inverter was not used. Moreover, in the software simulation just focused on the performance improvement and efficiency that's why there are different ratings of some components like controller and battery. Software simulation result says that the system is quite good and effective. But in the hardware result must be not same as the software for the different ratings of components and weather. The meteorological data can't be accurate in the system cause it's been taken from NASA website by the software. Apart from there will be many losses in the hardware system like system loss, wiring loss, temperature loss, equipment efficiency loss etc. From the literature review found that in stand-alone system performance ratio can't be get high normally it remains in under 80% approximately [32] [33]. In that case simulation result is not bad. But solar fraction is low 0.387 in figure 20. It does not affect the system because solar fraction can be different in the different location. Though solar fraction indicates the reliance on the solar energy. As this system is in small scale it will not become major issues for hampering the production. The irradiation affects the temperature of the panel excessive irradiation is shattered the production of the panel seen in the figure 24 that exceeds the temperature of the array. On the other hand, in hardware implementation the data has been taken for 4 months. There in the software DC power performance ratio obtained 71.3% where from the software obtained 73.4%. The software simulation was on the basis of online data and gained with accuracy. But in the hardware system there is must real losses like wiring losses, system efficiency, irradiation mismatch with simulation result and meteorological data. By the way data is collected in summer when maximum irradiation gets. There will be over radiation that rises the temperature of PV array that's why the performance ratio is not so high. Apart from the software result is on annually made. So, the in the contrast this hardware result is

not bad. As data is collected for 4 months. So, with the comparison with software segregated data of 4 months from year there can be seen the performance ratio between software and hardware shown in figure 5.34

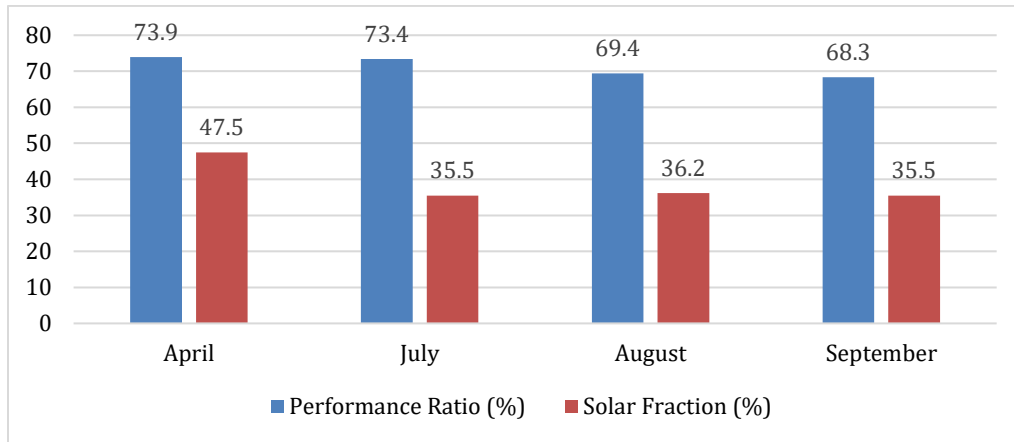


Figure 5.34: Software performance Ratio.

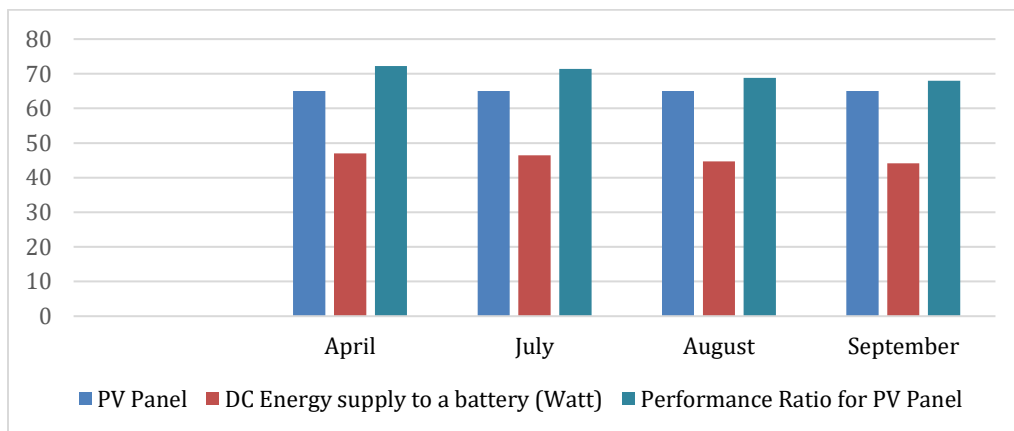


Figure 5.35: Hardware performance ratio.

From figure 5.35 there can be seen the performance ratio for software and hardware are 0.7125 and 0.70114. The difference between the result of software and hardware = $(0.7125 - 0.70114) \times 100\% = 1.136\%$. Which is for the mismatching data between the software and hardware. By the way, the system's performance ratio can be said to be quite similar and convenient. Moreover, the performance ratio for the AC power is 70.695% which is also an optimizing rate. But it can be raised by taking some steps like increasing battery capacity, adding cooling systems, cleaning the solar surface etc. In the end this small-scale project is quite efficient, cost effective and ecological friendly.

CHAPTER 6

CONCLUSION & RECOMMENDATION

6.1 Conclusion:

Floating photovoltaic systems promote a convincing solution that would fulfill the energy demand while keeping the environmental concerns and giving up a solution to mitigate the issues. Harnessed solar panels on water bodies, or the FPV system come up with a sustainable and much more efficient substitute to the traditional land-based solar panels. It is not only satisfied with clean renewable energy demand, the technology itself also has a potential outcome with climate actions and improved water quality.

As shown with successful implementations in multiple countries, FPV systems are potentially increasing as feasible and inexpensively attractive. The positive aspects of reduction in using lands and increasing the efficiency of energy makes it a more convincing concept, especially for the regions that have limitations in land resources and have higher energy demand.

In the end, the FPV system demonstrates a notable step towards a more sustainable and stronger energy future. By using the great potential of water bodies in countries like Bangladesh that have an immense water body can utilize the concept for solar energy generation. This innovative technology can put up an eye-catching contribution to achieve the demand of clean energy, with also certain feedback through mitigating the issues for climatic changes and moving forward for a sustainable development.

6.2 Recommendation

This entire study focuses on evaluating the technical, financial and environmental performance of a small-scale floating photovoltaic (FPV) system. Since this is a small-scale floating photovoltaic (FPV) system, several challenges remain in optimizing such systems for large-scale implementation. Especially as observed in the context of off-grid and independent energy solutions. The addition of FPV systems to existing grid facilities will positively contribute to increasing the efficiency and reliability of power transmission. As a result, it can be extended in several ways in future research. For example, floating photovoltaic (FPV) systems can be useful in further evaluating potential threats and options for improving the long-term performance of floating structures and their impacts on water quality and cooling. The causes of corrosion, bio fouling and degradation of floating and mooring system components need to be studied in more detail and more research is needed to further assure long-term reliability. This study only considered a small-scale floating photovoltaic (FPV) system at one location that used meteorological data from that location. Focusing on the wider applicability of FPV technology, future research may include large-scale deployment of FPV in floating reservoirs in Bangladesh, in different regions of Bangladesh, and more diverse weather conditions across Bangladesh. Due to the nature of current research based on quantitative models and a limited amount of primary data, further studies will be needed to reach a better perspective on the technical and economic implications of a wider range of physical configurations of FPV systems. The performance-economy ratio of the system can also be improved by making improvements such as battery size, cooling and routine practices.

CHAPTER 7

CO-PO mapping and breakdown of cost

7.1 CO-PO mapping

Table 7.1 Project features addressing course and program outcomes.

Course Outcome	Program Outcome	K-profile	Complex Engineering Problem Solving	Features of Project
CO1 Problem Analysis	PO2	K1-K4	P1,P2,P3	1. Designed a PV model for this model in PVsyst and Helioscope. 2. Try to figure out limitation from previous research paper. 3. Developed our project design.
CO2 Lifelong Learning	PO12	K8		1. The similar 22 papers of this project has studied. 2. For knowledge on making hardware model additionally 4 papers have been studied. 3. Collected information from previous literature review financial and project management.
CO3 Project management and finance	PO11			1. The timeline of work has been depicted in Grantt Chart. 2. For the hardware model tentative budget has been made. 3. Trying to make the project cost efficient.
CO4 Investigation	PO4	K8	P1, P3	1. Study of hardware specifications and produce datasheets. 2. Study of required computer and simulation outcomes.
CO5 Modern Tool Use	PO5	K6	P1	1. Use of charge controller, electrical machine and output devices in hardware implementation. 2. PVsyst for data processing and result analysis.

CO6 Design/ Development of Solution	PO3	K5	P1-P7	1. Making the budget friendly and pontoons design. 2. Solving the inverter difficulties. 3. Maintenance of the system.
CO7 The Engineer & Society	PO6	K7	P1, P2, P6	1. Knowledge on power systems and domestic load patterns. 2. Contribution to the society by developing systems beneficial for everyone. 3. Identification of limitations of the development systems for actual implementation.
CO8 Environment & Sustainability	PO7	K7	P1, P6	1 Integrating of renewable energy source (PV solar panel was used), efficiency testing of implemented.
CO9 Individual & Teamwork	PO9			1. Individually assigning task. 2. Task Completion is in subgroup. 3. Parallel workflow between individuals and groups.
CO10 Ethics	PO8	K7		1. Giving presentation and implementation projects honestly. 2. Proper explanation of the project, taking data, processing and finding result in sooth. 3. Practice ethics in teamwork. 4. Trying to no keep ethical dilemma regarding our work.
CO11 Communication	PO10			1. Continuous communication with the project supervisor and updating about the progress of the project. 2. Continuous communication in between project members.

7.2 Complex engineering problem solving

Table 7.2: Project features addressing complex engineering problem solving requirements.

Complex Engineering Problem	Description	Requirement's fulfillment
P1	Depth of Knowledge required K7	Knowledge on following topics is required for implemented model: 1. PVsyst software simulation 2. Power system. 3. Electrical machines like Charge controller, solar, inverter. 4. Power generation. 5. Existing small scale FPV systems
P2	Range of conflicting requirements K7	1. The components unavailable in local market. 2. Losses should be minimal when the production. 3. Configuration of manual override priority against automatic control. 4. Balancing tradeoff between energy vs comfort.
P3	Depth of analysis	1. Working knowledge on renewable energy. 2. Study of the error and system calibration. 3. Simulation and collecting data for real condition 4. Analysis for production and economy
P5	Extent of applicable codes	1. Maintaining Privacy. 2. Proper simulation and update hardware.
P6	Extent of stakeholders K7	1. General people who are consumers of electricity. 2. Policy makers in the government. 3. Authorities concerned with power generation and distribution.

7.3 SWOT analysis

Table 7.3: SWOT analysis.

Strengths 1. Simulation of real scenario. 2. Cost effective for small scaled. 3. Quite unique than other energy resource.	Weaknesses 1. Hardware model has its limitations emulating practical conditions 2. Measurement errors may produce less accurate results 3. Long term difficulty of SDG challenge. 4. Parameter's rating similarity between hardware and software.
Opportunities 1. Data collection for and efficiency analysis of the implemented model. 2. Scalable model. 3. Satisfies with SDG 7 goals.	Threats 1. Electrical safety features must be included. 2. Risk of hardware failure. 3. Economic impacts of funding. 4. Advancement of components may affect the result.

7.4 Cost breakdown

Table 7.4: Breakdown of costs of the project.

Project Cost		
Product Name	Quantity	Price (Taka)
Cable	15 Gauj	1200
Holder	2	50
Switch	2	30
Frame	1	300
Dim light	2	130
Tester	1	30
Tep	2	40
Energy meter	1	800
Plug	1	80
Socket	1	35
Inverter	1	950
Battery	1	1000
Charge controller	1	530
Solar plate	1	2000
Bottle	4	1000
Solar angle	1	4000
Build cost		3500
Wire		348
Colors		300
Rope		390
Box		460
Convenience		3100
Total		20273

REFERENCES

- [1] G. Chowdhury, M. Haggag, and J. Poortmans, “How cool is floating PV? A state-of-the-art review of floating PV’s potential gain and computational fluid dynamics modeling to find its root cause,” *EPJ Photovoltaics*, vol. 14, 2023, doi: 10.1051/epjpv/2023015.
- [2] M. I. Islam *et al.*, “Feasibility analysis of floating photovoltaic power plant in Bangladesh: A case study in Hatirjheel Lake, Dhaka,” *Sustainable Energy Technologies and Assessments*, vol. 55, Feb. 2023, doi: 10.1016/j.seta.2022.102994.
- [3] A. Al Mansur, M. I. Islam, M. A. Ul Haq, M. H. Maruf, A. S. M. Shihavuddin, and M. R. Amin, “Investigation of PV Modules Electrical Characteristics for Laboratory Experiments using Halogen Solar Simulator,” *2020 2nd International Conference on Sustainable Technologies for Industry 4.0, STI 2020*, vol. 0, pp. 19–20, 2020, doi: 10.1109/STI50764.2020.9350496.
- [4] IEA, “World Energy World Energy,” 2022, pp. 23–28, 2017.
- [5] A. Sahu, N. Yadav, and K. Sudhakar, “Floating photovoltaic power plant: A review,” *Renewable and Sustainable Energy Reviews*, vol. 66, pp. 815–824, 2016, doi: 10.1016/j.rser.2016.08.051.
- [6] T. T. E. Vo, H. Ko, J. Huh, and N. Park, “Overview of possibilities of solar floating photovoltaic systems in the offshore industry,” *Energies (Basel)*, vol. 14, no. 21, 2021, doi: 10.3390/en14216988.
- [7] H. M. Pouran, “From collapsed coal mines to floating solar farms, why China’s new power stations matter,” *Energy Policy*, vol. 123, no. September, pp. 414–420, 2018, doi: 10.1016/j.enpol.2018.09.010.
- [8] E. Cuce, P. M. Cuce, S. Saboor, A. Ghosh, and Y. Sheikhnejad, “Floating PVs in Terms of Power Generation, Environmental Aspects, Market Potential, and Challenges,” *Sustainability (Switzerland)*, vol. 14, no. 5, 2022, doi: 10.3390/su14052626.
- [9] M. M. , & S. N. N. Wagh, “A review on floating solar photovoltaic power plants. International Journal of Scientific & Engineering Research,” no. June 2017, pp. 789–794, 2017.
- [10] A. Jawad, M. S. Hasan, M. F. I. Faruqui, and N. Al Masood, “Small-scale floating photovoltaic systems in university campus: A pathway to achieving SDG 7 goals in Bangladesh,” *Energy Convers Manag*, vol. 297, no. October, p. 117722, 2023, doi: 10.1016/j.enconman.2023.117722.
- [11] D. R. Aryani, T. A. Khairurraziq, G. R. Ramadhan, N. S. Wardana, F. Husnayain, and I. Garniwa, “Simulation of stand-alone floating photovoltaic and battery systems,” in *IOP Conference Series: Materials Science and Engineering*, IOP Publishing Ltd, Dec. 2019. doi: 10.1088/1757-899X/673/1/012059.
- [12] A. Jawad, M. S. Hasan, M. F. I. Faruqui, and N. Al Masood, “Small-scale floating photovoltaic systems in university campus: A pathway to achieving SDG 7 goals in Bangladesh,” *Energy Convers Manag*, vol. 297, Dec. 2023, doi: 10.1016/j.enconman.2023.117722.
- [13] “Techno-economic impacts of floating PV power generation for remote coastal regions,” 2021. [Online]. Available: <https://www.elsevier.com/open-access/userlicense/1.0/>
- [14] H. Liu, V. Krishna, J. Lun Leung, T. Reindl, and L. Zhao, “Field experience and performance analysis of floating PV technologies in the tropics,” *Progress in Photovoltaics: Research and Applications*, vol. 26, no. 12, pp. 957–967, Dec. 2018, doi: 10.1002/pip.3039.

- [15] F. Zhang, W. Shi, and Q. Wang, "A Study on the Hydrodynamics and Coupling Effects of the Multibody Floating Photovoltaic (FPV) Concept," *J Mar Sci Eng*, vol. 11, no. 8, 2023, doi: 10.3390/jmse11081491.
- [16] A. Sahu, N. Yadav, and K. Sudhakar, "Floating photovoltaic power plant: A review," *Renewable and Sustainable Energy Reviews*, vol. 66, pp. 815–824, 2016, doi: 10.1016/j.rser.2016.08.051.
- [17] M. I. Islam *et al.*, "Feasibility analysis of floating photovoltaic power plant in Bangladesh: A case study in Hatirjheel Lake, Dhaka," *Sustainable Energy Technologies and Assessments*, vol. 55, no. December 2022, p. 102994, 2023, doi: 10.1016/j.seta.2022.102994.
- [18] E. George and I. EdifonAbasi-Obot, "Performance evaluation of a standalone photovoltaic solar power system under different fixed optimal tilt angles," 2020. [Online]. Available: www.imjst.org
- [19] H. A. Guda and U. O. Aliyu, "Design of a Stand-Alone Photovoltaic System for a Residence in Bauchi," *International Journal of Engineering and Technology*, vol. 5, no. 1, pp. 34–44, 2015.
- [20] I. Ćatipović, N. Alujević, D. Smoljan, and A. Mikulić, "A review on marine applications of solar photovoltaic systems," *International Journal of Scientific & Technology Research*, no. October, 2019.
- [21] C. Breyer, A. S. Oyewo, A. Kunkar, and R. Satymov, "Role of Solar Photovoltaics for a Sustainable Energy System in Puerto Rico in the Context of the Entire Caribbean Featuring the Value of Offshore Floating Systems," *IEEE J Photovolt*, vol. 13, no. 6, pp. 842–848, 2023, doi: 10.1109/JPHOTOV.2023.3319022.
- [22] D. F. Silalahi and A. Blakers, "Global Atlas of Marine Floating Solar PV Potential," *Solar*, vol. 3, no. 3, pp. 416–433, 2023, doi: 10.3390/solar3030023.
- [23] Y. Obbink, "Environmental and technological advantages and disadvantages of Floating Photovoltaics in the Netherlands," 2023.
- [24] A. Jawad, M. S. Hasan, M. F. I. Faruqui, and N. Al Masood, "Small-scale floating photovoltaic systems in university campus: A pathway to achieving SDG 7 goals in Bangladesh," *Energy Convers Manag*, vol. 297, Dec. 2023, doi: 10.1016/j.enconman.2023.117722.
- [25] H. Liu, V. Krishna, J. Lun Leung, T. Reindl, and L. Zhao, "Field experience and performance analysis of floating PV technologies in the tropics," *Progress in Photovoltaics: Research and Applications*, vol. 26, no. 12, pp. 957–967, Dec. 2018, doi: 10.1002/pip.3039.
- [26] P. Mohanty, T. Muneer, and M. Kolhe, "Green Energy and Technology Solar Photovoltaic System Applications A Guidebook for Off-Grid Electrification."
- [27] N. D. Nordin and H. A. Rahman, "Design and economic analysis in standalone photovoltaic system," *2014 IEEE Conference on Energy Conversion, CENCON 2014*, pp. 152–157, 2014, doi: 10.1109/CENCON.2014.6967493.
- [28] H. A. Guda and U. O. Aliyu, "Design of a Stand-Alone Photovoltaic System for a Residence in Bauchi," *International Journal of Engineering and Technology*, vol. 5, no. 1, pp. 34–44, 2015.
- [29] M. M. H. Bhuiyan and M. A. Asgar, "Sizing of a stand-alone photovoltaic power system at Dhaka," 2003.
- [30] P. Mohanty, T. Muneer, and M. Kolhe, "Green Energy and Technology Solar Photovoltaic System Applications A Guidebook for Off-Grid Electrification." [Online]. Available: <http://www.springer.com/series/8059>

- [31] R. Kumar, C. S. Rajoria, A. Sharma, and S. Suhag, "Design and simulation of standalone solar PV system using PVsyst Software: A case study," *Mater Today Proc*, vol. 46, no. xxxx, pp. 5322–5328, 2020, doi: 10.1016/j.matpr.2020.08.785.
- [32] T. Tahar, M. Rachid, B. Brahim, and B. Miloud, "Study and Sizing of Stand-Alone Photovoltaic System Using PVsyst Software," *ACM International Conference Proceeding Series*, pp. 5–8, 2020, doi: 10.1145/3447568.3448529.
- [33] A. Shrivastava, R. Sharma, M. Kumar Saxena, V. Shanmugasundaram, M. Lal Rinawa, and Ankit, "Solar energy capacity assessment and performance evaluation of a standalone PV system using PVSYST," *Mater Today Proc*, vol. 80, no. xxxx, pp. 3385–3392, 2023, doi: 10.1016/j.matpr.2021.07.258.
- [34] A. Jawad, M. S. Hasan, M. F. I. Faruqui, and N. Al Masood, "Small-scale floating photovoltaic systems in university campus: A pathway to achieving SDG 7 goals in Bangladesh," *Energy Convers Manag*, vol. 297, no. October, p. 117722, 2023, doi: 10.1016/j.enconman.2023.117722.
- [35] A. Jawad, M. S. Hasan, M. F. I. Faruqui, and N. Al Masood, "Small-scale floating photovoltaic systems in university campus: A pathway to achieving SDG 7 goals in Bangladesh," *Energy Convers Manag*, vol. 297, no. October, p. 117722, 2023, doi: 10.1016/j.enconman.2023.117722.
- [36] E. George and I. EdifonAbasi-Obot, "Performance evaluation of a standalone photovoltaic solar power system under different fixed optimal tilt angles," 2020. [Online]. Available: www.imjst.org
- [37] "Bangladesh Bank." Accessed: Oct. 04, 2024. [Online]. Available: <https://www.bb.org.bd/en/index.php/econdata/inflation>
- [38] "Tariff-Rate - ঢাকা পাওয়ার ডিস্ট্রিবিউশন কোম্পানি লিমিটেড (ডিপিডিসি)-." Accessed: Oct. 04, 2024. [Online]. Available: <https://dpdc.gov.bd/site/page/27e77af7-1187-436c-9f80-b579d3493a46/Tariff-Rate>
- [39] E. Examples, "Handbook on Cost-Benefit Analysis (CBA) of Public Investment Projects Handbook on Cost-Benefit Analysis (CBA) of Public Investment Projects," no. January, 2024.
- [40] E. Examples, "Handbook on Cost-Benefit Analysis (CBA) of Public Investment Projects Handbook on Cost-Benefit Analysis (CBA) of Public Investment Projects," no. January, 2024.
- [41] M. M. H. Bhuiyan, M. A. Asgar, R. K. Mazumder, and M. Hussain, "Economic evaluation of a stand-alone residential photovoltaic power system in Bangladesh," *Renew Energy*, vol. 21, no. 3–4, pp. 403–410, 2000, doi: 10.1016/S0960-1481(00)00041-0.
- [42] "Depreciation Rate (Formula, Examples) | How to Calculate?" Accessed: Oct. 06, 2024. [Online]. Available: <https://www.wallstreetmojo.com/depreciation-rate/>
- [43] J. Jung and W. E. Tyner, "Economic and policy analysis for solar PV systems in Indiana," *Energy Policy*, vol. 74, no. C, pp. 123–133, 2014, doi: 10.1016/j.enpol.2014.08.027.
- [44] A. Chel, G. N. Tiwari, and A. Chandra, "Simplified method of sizing and life cycle cost assessment of building integrated photovoltaic system," *Energy Build*, vol. 41, no. 11, pp. 1172–1180, 2009, doi: 10.1016/j.enbuild.2009.06.004.