

Design and Analysis of Renewable Energy Based Electric Vehicle Charging Station

By

Asef Jamil Ajwad

19121040

Pronoyan Saha

19121131

Quazi Rian Hasnaine

19121126

Fiaz Sadid

19121133

A Final Year Design Project (FYDP) submitted to the Department of Electrical and Electronic Engineering in partial fulfilment of the requirements for the degree of Bachelor of Science in Electrical and Electronic Engineering

Department of Electrical and Electronic Engineering

Brac University

December 2022

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Academic Technical Committee (ATC) Panel Member:

Md. Mosaddequr Rahman, PhD (Chair)

Professor and Chairperson, Department of EEE, BRAC University

Aldrin Nippon Bobby (Member)

Lecturer, Department of EEE, BRAC University

Mohaimenul Islam (Member)

Lecturer, Department of EEE, BRAC University

Department of Electrical and Electronic Engineering

Brac University

December 2022

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Declaration

It is hereby declared that

1. The Final Year Design Project (FYDP) submitted is our own original work while completing a degree at Brac University.
2. The Final Year Design Project (FYDP) does not contain material previously published or written by a third party, except where this is appropriately cited through full and accurate referencing.
3. The Final Year Design Project (FYDP) does not contain material which has been accepted, or submitted, for any other degree or diploma at a university or other institution.
4. We have acknowledged all main sources of help.

Student's Full Name & Signature:

Asef Jamil

Asef Jamil Ajwad
19121040

Pronoyan

Pronoyan Saha
19121131



Quazi Rian Hasnaine
19121126



Fiaz Sadid
19121133

Approval

The Final Year Design Project (FYDP) titled “Design and Analysis of Renewable Energy Based Electric Vehicle Charging Station (EVCS)” submitted by

1. Asef Jamil Ajwad (19121040)
2. Pronoyan Saha (19121131)
3. Quazi Rian Hasnaine (19121126)
4. Fiaz Sadid (19121133)

of Fall, 2022 has been accepted as satisfactory in partial fulfilment of the requirement for the degree of Bachelor of Science in Electrical and Electronic Engineering on 15th December 2022.

Examining Committee:

Academic Technical
Committee (ATC):
(Chair)

Md. Mosaddequr Rahman
PhD, Professor and Chairperson, Department of EEE
BRAC University

Final Year Design Project
Coordination Committee:
(Chair)

Dr. Abu S. M. Mohsin
Associate Professor, Department of EEE
BRAC University

Department Chair:

Md. Mosaddequr Rahman
PhD, Professor and Chairperson, Department of EEE
BRAC University

Ethics Statement

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Abstract/Executive Summary

The widespread adoption of electric vehicles is currently limited by the availability and convenience of charging infrastructure. To address this issue and contribute to the transition towards a more sustainable transportation system, this project proposes the development of a renewable energy-based electric vehicle charging station. By harnessing the power of solar panels, the charging station will provide a clean and sustainable source of electricity for EVs. This project aims to explore the feasibility, technical considerations, and potential benefits of implementing such a charging station, which could help to reduce our reliance on fossil fuels and mitigate the environmental impacts associated with traditional methods of electricity generation.

Dedication

We dedicate this paper to our families and friends who have supported us throughout this project. We thank our families for believing in us and encouraging us to pursue our passions. Their unconditional love and support provided us with the resources and guidance we needed to make our dreams a reality. We also thank our friends for being our constant companions and for cheering us on throughout this journey. We wouldn't have been able to make it this far without them. We are so grateful for all of the love and support that we have received along the way. Thank you.

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List of Acronyms

BESS	Battery Energy Storage System
BRTA	Bangladesh Road Transport Authority
CAD	Computer Aided Design
DOD	Depth of Discharge
DSM	Demand Side Management
EV	Electric Vehicle
EVCS	Electric Vehicle Charging Station
GDPR	General Data Protection Regulation
ICE	Internal Combustion Engine
MCB	Miniature Circuit Breaker
PCB	Printed Circuit Board
PV	Photovoltaic
ROI	Return on Investment
SREDA	Sustainable and Renewable Energy Development Authority

Chapter 1

Introduction

1.1 Introduction

Electric vehicles (EVs) have the potential to significantly reduce our reliance on fossil fuels and decrease greenhouse gas emissions. However, the widespread adoption of EVs is currently limited by the availability and convenience of charging infrastructure. In this project, we propose the development of a renewable energy based electric vehicle charging station as a solution to this problem. By harnessing the power of solar panels our charging station will provide a clean and sustainable source of electricity for EVs. In addition to reducing our reliance on fossil fuels, the use of renewable energy for charging EVs will also help to mitigate the environmental impacts associated with traditional methods of electricity generation. This project aims to explore the feasibility, technical considerations, and potential benefits of implementing a renewable energy based electric vehicle charging station and contribute to the transition towards a more sustainable transportation system and address the challenges facing the widespread adoption of EVs.

1.1.1 Problem Statement

The widespread adoption of electric vehicles has the potential to significantly reduce greenhouse gas emissions and contribute to the transition to a low-carbon transportation sector. However, the success of this transition is dependent on the availability of reliable and sustainable charging infrastructure. The current electric vehicle charging infrastructure is largely powered by fossil fuels, which contributes to greenhouse gas emissions and undermines the environmental benefits of electric vehicles. As such, there is a need to explore

alternative options for powering electric vehicle charging stations that rely on renewable energy sources. The problem that our project aims to address is the limited use of renewable energy in electric vehicle charging infrastructure and the potential for this technology to contribute to the transition to a low-carbon transportation sector.

1.1.2 Background Study

In the paper “Solar Energy based Net Metered Easy-Bike Charging Station in Bangladesh” [1], the authors suggested using a grid tied net metering system to implement the charging system. The system would have no battery energy storage system (BESS). Instead, the power generated by solar panels during the day would be exported to the grid. When power is required to charge the easy bikes, the grid would be used to charge them. The authors simulated their system in PVsyst in multiple azimuth orientations and found that the south orientation would generate the most power. The authors claimed that their system would have a payback period of only 45 months due to the absence of a BESS. A BESS would increase the cost of the system by more than double. Greenhouse gas (GHG) emissions for such a system would be 89.63 kg CO²-eq/MWh, which is much lower than the grid emission factor for Bangladesh, (670 kg CO²-eq/MWh) [1].

In another paper “Bangladesh Power System Peak Demand Shaving through Demand Side Management of the Battery Operated Easy Bike Load” [2] suggested using Demand Side Management (DSM) in order to reduce peak load demand. It is stated in the paper that the majority of EVs are plugged-in to the grid between 9 pm to 10 pm. Easy bikes generally have a battery capacity of 8 to 11 kWh. The authors stated that if 70% of the easy bikes are charged during off-peak hours, it would reduce the load by 700 MW. This would be done by using a timer based charging system that would prevent charging during peak hours. Since

the easy bikes are not used at night, they would be charged after midnight, when the demand is low [2].

Lastly in “Designing a Solar Powered DC charging Station for Easy Bikes: Bangladesh Perspective” [3], the authors suggested using a solar based charging system with a BESS. The BESS would store energy from solar during the day. The easy bikes would be charged using the BESS. The authors kept the grid as an emergency back-up system, in case of cloudy weather. They also had a grid-tie bidirectional inverter, that would be used to backfeed excess energy generated by the solar panels to the grid. This system allows easy bikes to be charged independent of grid demand using renewable energy [3].

In recent years, there has been a global rise in the amount of GHG in the atmosphere [1]. This production of GHG is mainly from the energy sector, which contributes around three-quarters of the total global GHG emissions [1]. To combat this, the European Union (EU) has proposed to ban internal combustion engine (ICE) vehicles by 2035 and replace them with electric vehicles (EV) [4]. The switch from ICE to EV will significantly decrease the emission of GHG as 11.9% of emission comes from the transportation sector [1]. In Bangladesh, there are about 1 million EVs that are at the forefront of the shift to electric power [2]. These EVs are commonly known as battery powered tricycles or Easy Bikes. From our own survey, we have found that easy bikes run on four 12V batteries connected in series, for a total of 48V. On a full charge the easy bikes can run for 8 to 10 hours. A significant portion of the energy needed to charge these vehicles comes from burning finite non-renewable fossil fuels, generating greenhouse gases. In addition to the GHG emission, easy bikes are charged during the peak hours of the grid. From the load curve obtained from PGCB, it can be seen that the grid evening peak is during 9 pm to 12 am. Our survey found

that the easy bikes are charged between 9 pm to 6 am, which shows the easy bikes are putting additional load on the grid during peak hours. These results match with the results we found in our literature review.

To help mitigate the issue of GHG emissions and to ease the pressure on the grid, we propose to implement a renewable energy based electric vehicle charging station. Using renewable energy sources such as solar to charge these EVs can reduce carbon dioxide emission per year per easy bike by approximately 1860.5 kg [5]. The geological position of Bangladesh makes it suitable for renewable energy like solar [3]. Renewable energy generation at the charging station, along with a BESS will make the system less dependent on the grid [3]. Since there will be less dependency on the grid to charge the easy bikes, it would reduce pressure on the grid during peak time.

We found some simulation tools while designing and analysing the proposed EVCS such as PVsyst, HOMER, Simulink, Helioscope, RETScreen etc. After comparing the different features between them, we decided to go with PVsyst for analytical purposes as well as for economic analysis and Simulink for designing purposes. PVsyst has up to date components in its library and can be used for detailed analysis. Optimization is also efficient and easy to do and ageing and degradation simulations can be carried out within the software. In Simulink we can create custom blocks as per our requirement to aid the designing process.

1.1.3 Literature Gap

From our research we haven't found a system that unifies the Demand Side Management [2] with an On Grid Solar System. We have also found that the On Grid Solar solutions either do not have any backup power mode in the event of a load shedding [1], or the battery backup is

too expensive [3]. Therefore, we have decided to implement a system that has the optimum amount of battery to balance the cost and backup capabilities, as well as unify Demand Side Management into the system to reduce load on the grid during peak time. Having an On Grid System would also be cheaper than an Off Grid System [5] as the grid can be used as a means of energy storage via net metering.

1.1.4 Relevance to Current and Future Industry

Renewable energy based electric vehicle charging stations are highly relevant to the current and future industry for several reasons.

First, the demand for electric vehicles is rapidly increasing as consumers and governments seek to reduce greenhouse gas emissions and transition to more sustainable transportation. In order to meet this demand, a reliable and sustainable charging infrastructure is necessary. Renewable energy based charging stations can play a key role in providing this infrastructure, as they can generate electricity from natural, renewable sources such as solar and wind power. This not only helps to reduce reliance on fossil fuels, but also helps to lower the overall cost of operating and maintaining charging stations.

Second, renewable energy based charging stations can help to address the challenges of grid integration and energy storage that are often associated with electric vehicle charging. By generating electricity on-site, these charging stations can reduce the strain on the grid and avoid the need for expensive battery storage systems. This can make them more cost-effective and efficient than traditional charging stations.

Finally, renewable energy based charging stations can help to support the development of a low-carbon transportation sector and contribute to the fight against climate change. As the world shifts towards renewable energy sources, these charging stations can play a crucial role in reducing greenhouse gas emissions and promoting a healthier environment.

Overall, renewable energy based electric vehicle charging stations are a key component of the current and future industry, and their adoption is likely to increase as the demand for electric vehicles continues to grow.

1.2 Objectives, Requirements, Specification and Constraint

We have carefully analysed the objectives, requirements, specifications and constraints of our project to ensure that all of the necessary components are in place for its successful completion. We have identified the specific requirements for the project and the resources needed to meet them. We have also examined the different specifications and constraints of the project, and determined the best way to implement them. By doing this, we have a better understanding of the project, allowing us to plan and execute it more efficiently.

1.2.1. Objectives

Our project aims to analyse and design an electric vehicle charging station, evaluate its system performance with data, and compare the findings with real-world results. We also plan to adhere to the standard codes for safety and reliability, as well as ensure that our skilled workforce is equipped to maintain sustainability. By doing so, we hope to provide a safe and effective way to charge electric vehicles.

1.2.2 Requirements

Functional Requirements

- **Simultaneously charging 10 easy bikes:** EVCS should be able to charge 10 easy bikes simultaneously as the majority of the easy bikes are plugged in around the same time.
- **Daily generation of 100 kWh of energy:** Each easy bike has a battery capacity of 10kWh, therefore at least 100 kWh of energy generation is required everyday.
- **Energy storage of 30 kWh:** The charging station should have an energy storage capacity of at least 30 kWh so that easy bikes can be charged during events of power outage. This would allow the easy bikes to be charged reliably, without any interruption.
- **Land area of 100 sqm:** Need sufficient space to park 10 easy bikes to charge simultaneously. There should be enough space to store the batteries and other electrical systems. From our research and field survey, we have seen that an easy bike takes an area of around 3 sqm. In order to fit 10 easy bikes as well as the charging equipment and battery storage, we need an estimated land area of 100 sqm.

Non-Functional Requirements

- **Web-based monitoring system/Customer web portal:** These could help to visualise charging and monthly earnings/expenditure data for the station owner and/or easy bike drivers.
- **Backup diesel generator:** A diesel generator could be placed in the station as a backup power supply for scenarios such as when power is unavailable from both the solar panels and the grid during load shedding on a cloudy day.
- **Backfeeding to the grid:** Excess power produced by the solar panels could be provided to the grid by backfeeding as an optional feature.
- **Smart card prepaid metering:** Using smart card prepaid metering could digitalize the payment process for the easy bike drivers. However, normal cash payment would work as well, and thus a smart card system will be optional.
- **Solar panel cleaning system:** Although clean solar panels are required to maximise energy extraction, it is not mandatory for the project. The panels can be manually cleaned every month instead.

1.2.2 Specifications

TABLE 1.1. SYSTEM SPECIFICATIONS

Subsystem	Component	Specifications
Solar	Solar Panel	Panel Type: Mono PERC Maximum Power: 545W Voc: 49.65V Isc: 13.92A Vmp: 41.80V Imp: 13.04A
	Solar charge controller	Type: MPPT Maximum supported panel power: 10,000 Wp
	Batteries	Type: Li-ion or Li-poly Life Cycles: 3000+ Voltage per cell: 3.7 V
Charging	DC to DC Boost Converter	Output Voltage: 60V Output Current: 15A Output Ripple: 2% (max)
	AC to DC Rectifier	Input Voltage: 230 V Output Voltage: 60 V
	DC to AC Inverter	Phases: 3 Output Phase Voltage: 230 V Waveform: Sine Frequency: 50 Hz
Safety & Protection	GFCI	Trip Current: 6 mA Rated Current: 15 A
	Overcurrent	Rated Voltage AC: 230 V Rated Current AC: 100 A Rated Voltage DC: 60 V Rated Current DC: 15 A

1.2.3 Technical and Non-technical Consideration and Constraint in Design Process

Number of vehicles: The total number of vehicles that can be charged simultaneously is a constraint. To charge more vehicles, more land as well as more batteries and solar panels are required. This would increase the initial upfront cost of the charging station.

High solar irradiance: Having stations with high solar irradiance is important as the output of the solar panels depend on it. Low solar irradiance locations would require more panels, thus higher cost.

Location: Station should be within the reach of vehicles. Otherwise easy bike drivers would not travel long distances to charge their easy bikes.

Charging cost: Low charging cost is required to remain competitive with other charging stations. If the charging cost is more than other charging stations, drivers would not prefer to charge at our station.

1.2.4 Applicable Compliance, Standards and Codes

TABLE 1.2. APPLICABLE STANDARDS AND CODES

Subsystem	Standard	Definition
Charging Socket Outlet	IEC 60320-1	Appliance couplers for household and similar general purposes (IEC C15 connector - T jack)
	NEMA 14-50	Wall socket with 50-amp maximum amperage
Supply Station	IEC 61851-1	Electric vehicle conductive charging system - General requirements
Solar Module	BDS IEC 61215	Terrestrial photovoltaic (PV) modules – Design qualification and type approval
	BDS IEC 61853	Photovoltaic (PV) module performance testing and energy rating
	BDS IEC 61730-1:2019	Photovoltaic (PV) module safety qualification part 1: Requirements for Construction
	BDS IEC 61730-2:2019	Photovoltaic (PV) module safety qualification part 2: Requirements for Testing
Inverter	BDS IEC 62109-1	Safety of power converters for use in photovoltaic power systems - Part 1: General requirements
	BDS IEC 62109-2	Safety of power converters for use in photovoltaic power systems - Part 2: Particular requirements for inverters
	BDS IEC 61683	Photovoltaic systems – Power conditioners
	BDS IEC 62116:2020	Utility-interconnected photovoltaic inverters - Test procedure of islanding prevention
Solar Charge Controller	BDS IEC 62509	Battery charge controllers for photovoltaic systems
Battery	BDS IEC 61427-1	Secondary cells and batteries for renewable energy storage
	BDS IEC 60086-4	Primary batteries - Part 4: Safety of lithium batteries

1.3 Systematic Overview/Summary of the Proposed Project

The proposed charging station will charge 10 easy bikes simultaneously using 100% renewable energy. The total energy generation will be 100kWh per day, with a backup energy storage of 30kWh. The station needs an estimated land area of 100 sqm and should include features such as a web-based monitoring system, backfeeding to the grid etc. All of this should be done while keeping the charging cost low to remain competitive with other non-renewable charging stations. This charging station will reduce load on the grid during peak hours, and also pave the way for a renewable future.

1.4 Conclusion

Renewable energy based EVCS is vital to the current and future industry because they help to reduce the carbon footprint of electric vehicles, reduce reliance on fossil fuels, and support the growth of electric vehicles in a sustainable way. The use of renewable energy in EVCS can also contribute to the transition to a more sustainable energy system and help to reduce the demand for fossil fuels. As the demand for EVCS increases with the growth of electric vehicles, renewable energy sources can help to ensure that this demand can be met in an environmentally-friendly and sustainable way.

Chapter 2

Project Design Approach

2.1 Introduction

Multiple design approaches in engineering design is important because it allows engineers to explore different possible solutions to a problem. This can help engineers to make informed decisions about the best approach for a particular project. By considering multiple design approaches, engineers can identify potential risks, develop innovative solutions, and identify potential costs and benefits associated with each approach. Additionally, multiple design approaches allow engineers to capitalise on their strengths and minimise their weaknesses, while also considering the needs of their customer or client. Ultimately, multiple design approaches provide an opportunity to explore creative solutions and to ensure that the finished product meets the expectations of the customer.

2.2 Identify Multiple Design Approach

Some design approaches that could meet our requirements are:

- Design approach 1: Biogas from animal waste [6]
- Design approach 2: Off-grid solar system [5]
- Design approach 3: On-grid solar system [1] [3]

2.3 Describe Multiple Design Approach

2.3.1 Design of Approach 1: Biogas System

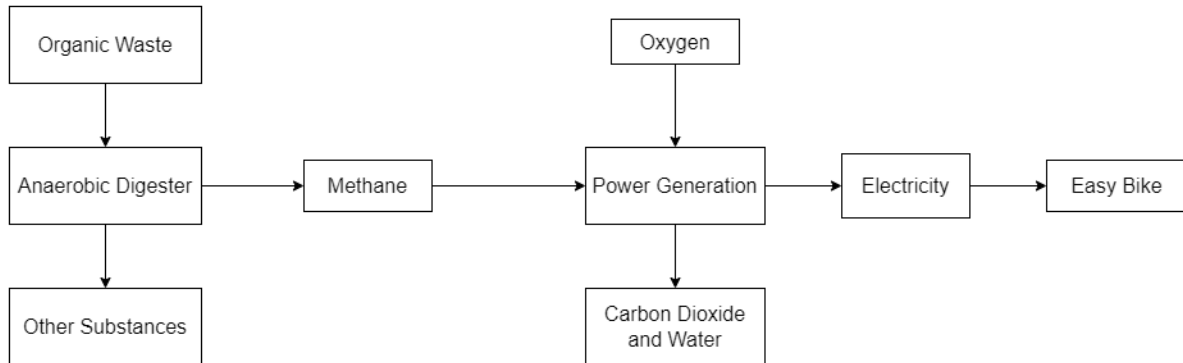


Fig. 2.3.1. Biogas system block diagram

- Biogas generated from animal waste is collected in farms
- Stored biogas is burned to produce electricity and provide the necessary power to the EVCS
- Grid could be used as backup source of power
- Alternative solutions for obtaining biogas:
 - a. Using animal waste
 - b. Using landfill waste
 - c. Using activated sludge from wastewater treatment plants

2.3.2 Design of Approach 2: Off grid system

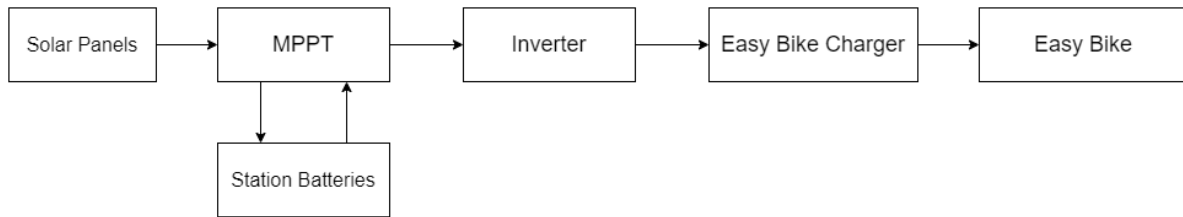


Fig. 2.3.2. Off-grid solar system block diagram

- Solar panels used to charge the battery storage
- Battery storage is then used to charge Easy Bikes
- System is completely independent from the grid
- Alternative solutions for mounting solar panels:
 - a. Fixed tilt panels
 - b. Vary tilt based on season
 - c. Single/Dual axis tracking

2.3.3 Design of Approach 3: On grid system

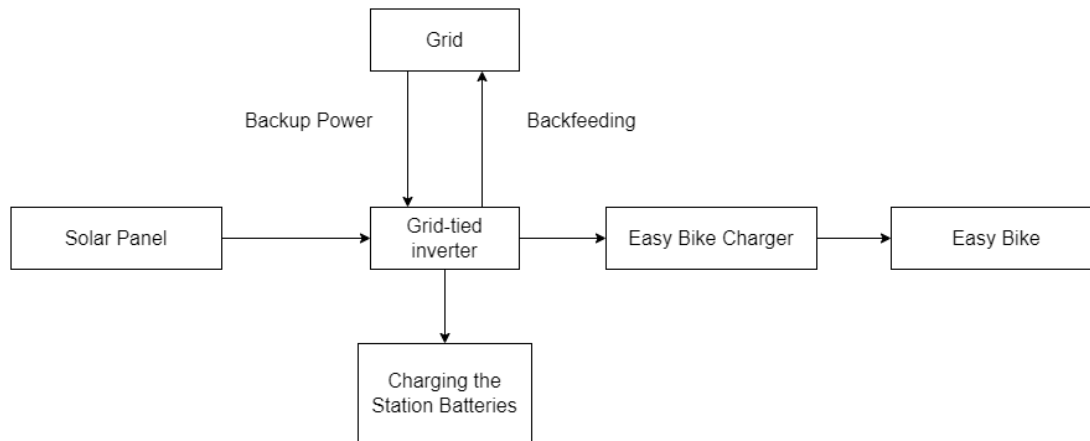


Fig. 2.3.3. On-grid solar system block diagram

- Solar panels used to charge the battery storage and supply excess power to grid
- Grid is then used to charge Easy Bikes
- Battery storage is present as a form of backup power
- Demand Side Management (DSM) for peak shaving [2]
- Alternative solutions for mounting solar panels:
 - a. Fixed tilt panels
 - b. Vary tilt based on season
 - c. Single/Dual axis tracking
- Alternative solutions for backup power:
 - a. Batteries (Li-ion or Lead Acid)
 - b. Diesel Generators

2.4 Analysis of Multiple Design Approach

We have simulated our design approaches in PVSyst in order to compare the strengths and weaknesses of each approach and chose the best one based on our requirements.

2.4.1 Design Approach 1: Biogas system

For simulating a biogas system there are variables such as temperature, pH, nature of substrate, loading rate, inoculums, dosing, hydraulic retention time etc. In PVSyst, these parameters do not exist and due to this we were unable to perform simulation for the biogas system.

Since we were unable to perform the analysis of the biogas system, we have used the analysis from [6].

TABLE 2.1. ECONOMIC ANALYSIS FOR BIOGAS SYSTEM

Items	Cost (BDT)
Digester	850,000
Gasholder	30,000
Purification unit	20,000
Biogas generator	500,00
Charging assemblies	20,000
O & M costs + transportation	185,000
Total Cost	1,625,000
Payback period	5 years

2.4.2 Design Approach 2: Off grid system

Simulation parameters

- Tilt 23.8° and Azimuth 0°
- 72 Modules – 18 in series, 4 in strings, 545 W each
- Fixed power consumption of 100 kWh per day
- 170 kWh of battery capacity – 2 in series, 35 in parallel
- Each battery is 48 V with 51 Ah capacity
- Depth of discharge (DOD) set to 80%
- Soiling loss set to 3%
- Inflation set to 5% per year
- Project lifetime 30 years

TABLE 2.2. ECONOMIC ANALYSIS FOR OFF-GRID SYSTEM

Energy produced	52.03 MWh
Energy used	35.75 MWh
Missing energy	0.752 MWh
Performance ratio	0.709
Payback period	Unprofitable

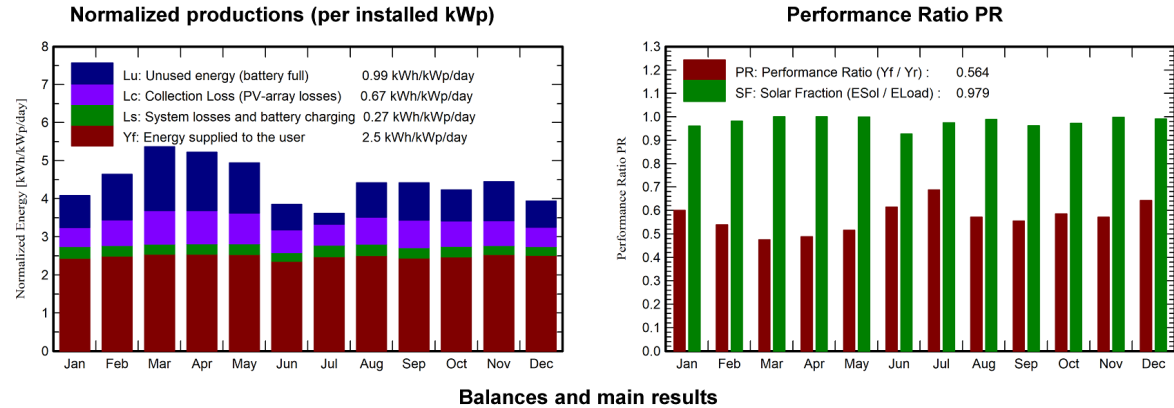
System Production

Available Energy 52030 kWh/year
 Used Energy 35748 kWh/year
 Excess (unused) 14146 kWh/year

Specific production 1326 kWh/kWp/year
 Performance Ratio PR 56.37 %
 Solar Fraction SF 97.94 %

Loss of Load

Time Fraction 2.6 %
 Missing Energy 752 kWh/year



Balances and main results

	GlobHor	GlobEff	E_Avail	EUnused	E_Miss	E_User	E_Load	SolFrac
	kWh/m ²	kWh/m ²	kWh	kWh	kWh	kWh	kWh	ratio
January	103.3	120.6	4223	1017	123.7	2976	3100	0.960
February	112.1	124.1	4247	1314	53.1	2747	2800	0.981
March	153.8	158.7	5328	2039	0.0	3100	3100	1.000
April	156.5	149.1	4988	1806	0.0	3000	3000	1.000
May	163.3	145.4	4877	1597	2.3	3098	3100	0.999
June	125.4	109.2	3664	771	219.4	2781	3000	0.927
July	120.5	105.7	3560	339	78.6	3021	3100	0.975
August	141.9	129.7	4356	1087	36.8	3063	3100	0.988
September	128.0	125.9	4207	1152	115.6	2884	3000	0.961
October	118.2	125.1	4195	995	86.1	3014	3100	0.972
November	109.2	127.4	4350	1206	8.3	2992	3000	0.997
December	97.6	116.4	4035	823	28.2	3072	3100	0.991
Year	1529.9	1537.5	52030	14146	752.1	35748	36500	0.979

Legends

GlobHor	Global horizontal irradiation	E_User	Energy supplied to the user
GlobEff	Effective Global, corr. for IAM and shadings	E_Load	Energy need of the user (Load)
E_Avail	Available Solar Energy	SolFrac	Solar fraction (EUsed / ELoad)
EUnused	Unused energy (battery full)		
E_Miss	Missing energy		

Fig. 2.4.1. Main results of off-grid system from PVsyst

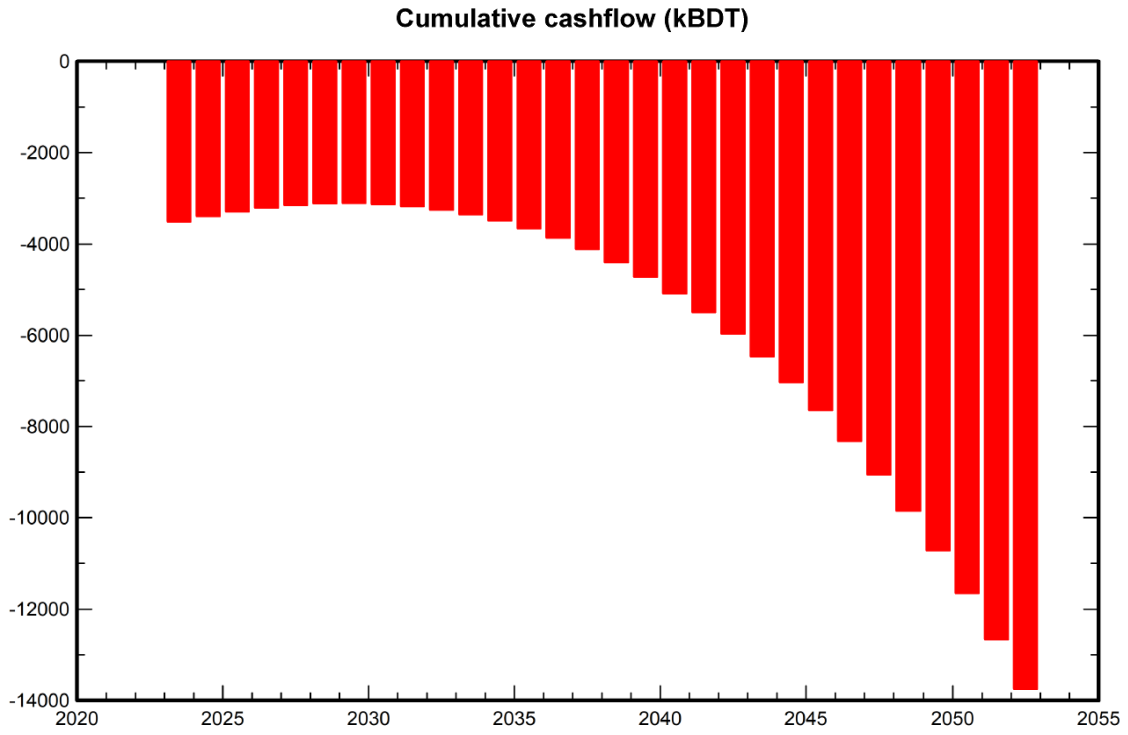


Fig. 2.4.2. Financial analysis (cumulative cashflow) of off-grid system from PVsyst

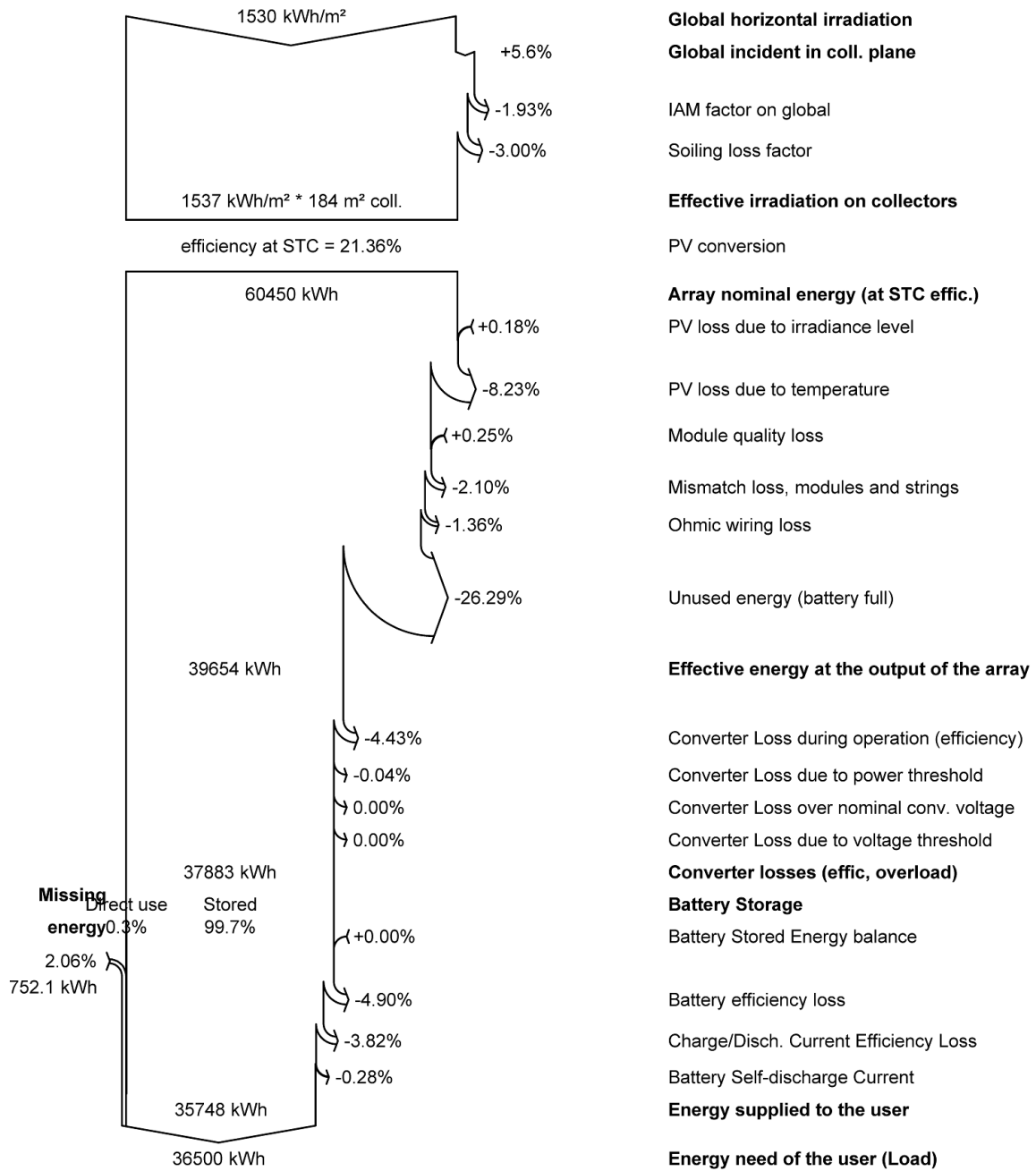


Fig. 2.4.3. Loss diagram of off-grid system from PVsystem

2.4.3 Design Approach 3: On grid system

Simulation parameters

- Tilt 23.8° and Azimuth 0°
- 60 Modules – 15 in series, 4 in strings, 545 W each
- 2 Inverters – 12 kW each
- Each inverter has 2 MPPTs
- Fixed power consumption of 100 kWh per day
- 40 kWh of battery capacity – 2 in series, 8 in parallel
- Each battery is 48 V with 51 Ah capacity
- Depth of discharge (DOD) set to 80%
- Soiling loss set to 3%
- Module degradation set to 0.4% per year
- Inflation set to 5% per year
- Project lifetime 30 years

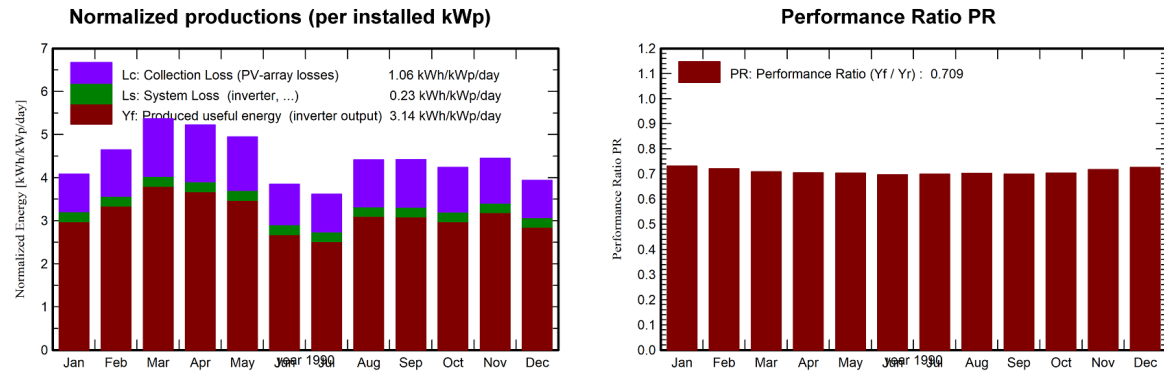
TABLE 2.3. ECONOMIC ANALYSIS FOR ON-GRID SYSTEM

Energy injected into grid, E_Grid	27.814 MWh
Energy taken from the grid, EFrGrid	26.826 MWh
Performance ratio	0.709
Payback period	4.8 years

System Production

Produced Energy 39.47 MWh/year
 Used Energy 36.50 MWh/year

Specific production 1207 kWh/kWp/year
 Performance Ratio PR 70.93 %
 Solar Fraction SF 26.50 %



Balances and main results

	GlobHor kWh/m ²	DiffHor kWh/m ²	T_Amb °C	GlobInc kWh/m ²	GlobEff kWh/m ²	EArray MWh	E_User MWh	E_Solar MWh	E_Grid MWh	EFrGrid MWh
Jan.	103.3	60.51	17.14	126.5	120.6	3.258	3.100	0.806	2.218	2.294
Feb.	112.1	62.44	20.99	130.0	124.1	3.267	2.800	0.742	2.321	2.058
Mar.	153.8	82.75	25.74	166.4	158.7	4.088	3.100	0.825	3.029	2.275
Apr.	156.5	89.24	27.61	156.7	149.1	3.837	3.000	0.799	2.811	2.201
May	163.3	98.19	28.28	153.2	145.4	3.758	3.100	0.826	2.699	2.274
June	125.4	85.12	28.13	115.4	109.2	2.857	3.000	0.794	1.837	2.206
July	120.5	91.72	28.51	111.9	105.7	2.786	3.100	0.827	1.732	2.273
Aug.	141.9	89.61	28.67	136.8	129.7	3.373	3.100	0.826	2.319	2.274
Sep.	128.0	74.74	27.99	132.6	125.9	3.258	3.000	0.794	2.239	2.206
Oct.	118.2	71.85	27.13	131.3	125.1	3.251	3.100	0.821	2.199	2.279
Nov.	109.2	58.77	23.01	133.4	127.4	3.349	3.000	0.794	2.336	2.206
Dec.	97.6	56.14	18.93	122.0	116.4	3.118	3.100	0.820	2.075	2.280
Year	1529.9	921.07	25.19	1616.3	1537.5	40.200	36.500	9.674	27.814	26.826

Legends

GlobHor	Global horizontal irradiation	EArray	Effective energy at the output of the array
DiffHor	Horizontal diffuse irradiation	E_User	Energy supplied to the user
T_Amb	Ambient Temperature	E_Solar	Energy from the sun
GlobInc	Global incident in coll. plane	E_Grid	Energy injected into grid
GlobEff	Effective Global, corr. for IAM and shadings	EFrGrid	Energy from the grid

Fig. 2.4.4. Main results from PVsyst for on-grid system

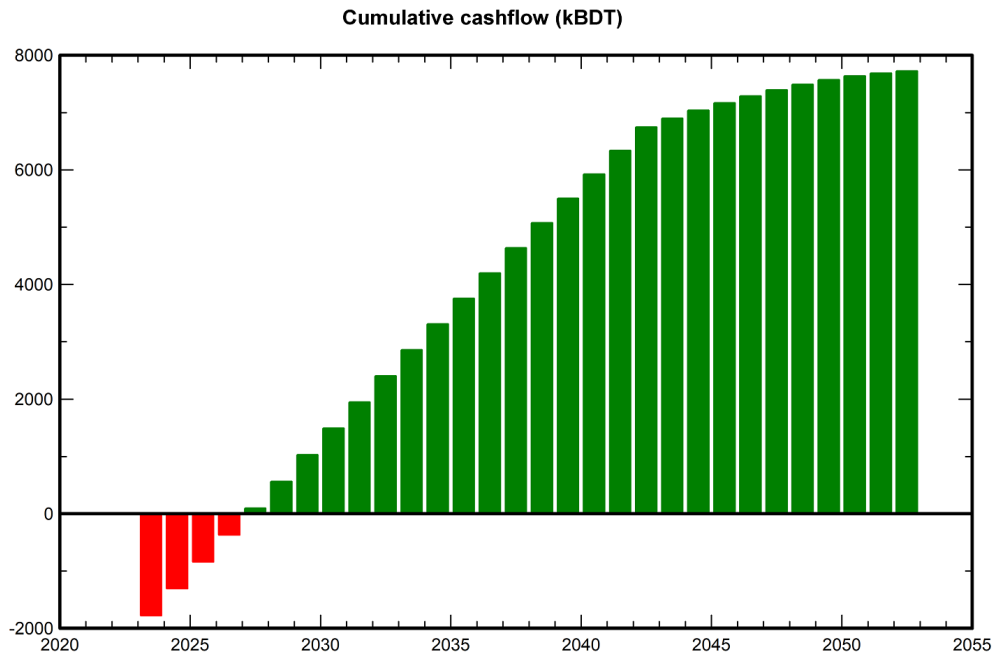


Fig. 2.4.5. Financial analysis (cumulative cashflow) of on-grid system from PVsyst

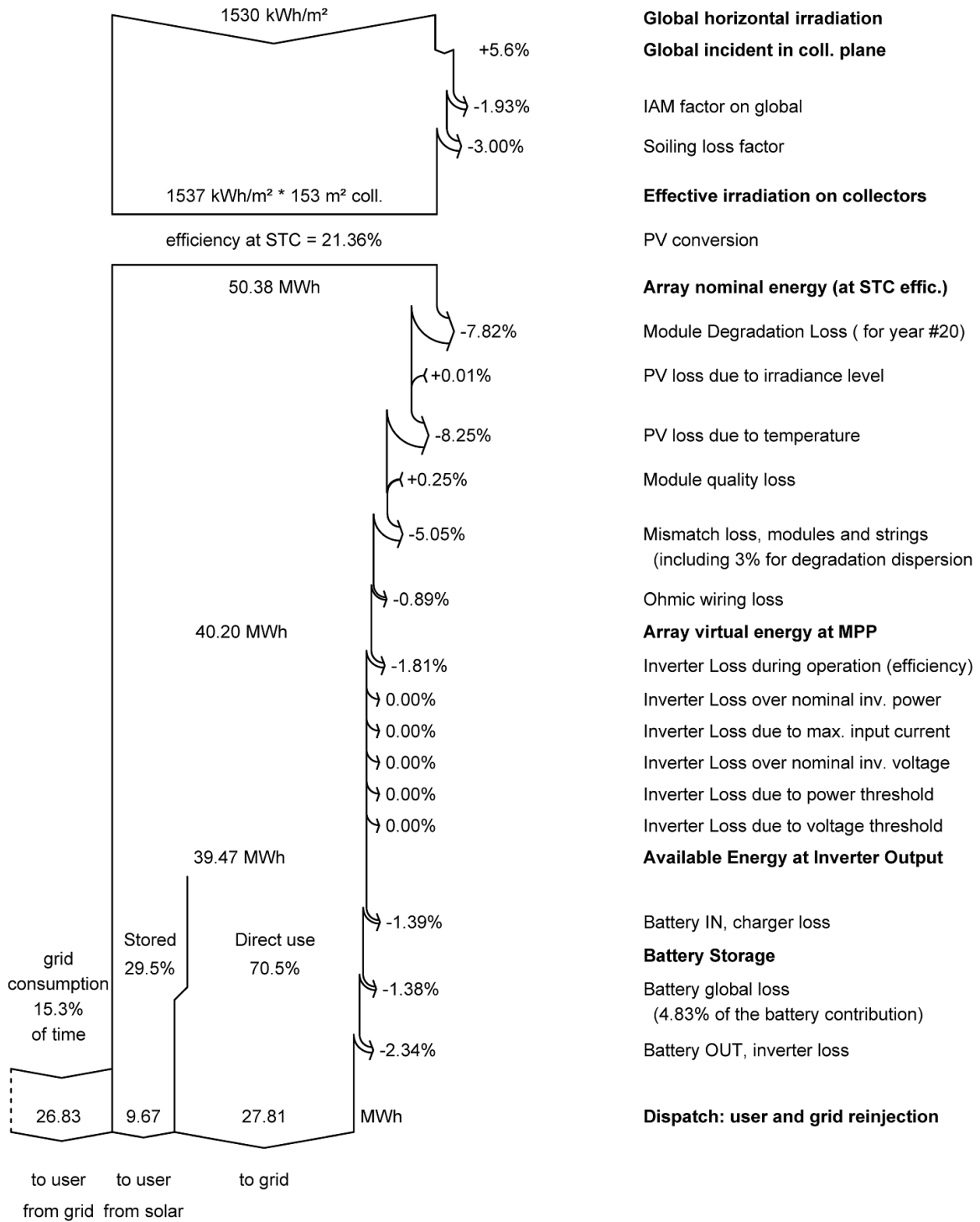


Fig. 2.4.6. Loss diagram of on-grid system from PVsyst

2.4.4 Comparison Between Multiple Design Approaches

TABLE 2.4. COMPARISON BETWEEN MULTIPLE DESIGN APPROACHES

	Design Approach 1: Bio Gas System	Design Approach 2: Off-Grid System	Design Approach 3: On-Grid System
GHG Emission	Medium	Low	Low
Energy Storage Type	Gas Storage	Battery	Battery
Backup power	Grid	Unavailable	Battery
Implementation cost	Medium	High	Low
Lifetime	10 years	20-30 years	20-30 years

TABLE 2.5. WEIGHTED AVERAGE OF MULTIPLE DESIGN APPROACHES

	Assigned Weight	Design Approach 1: Bio Gas System	Design Approach 2: Off-Grid System	Design Approach 3: On-Grid System
GHG Emission	15	2	13	13
Energy Storage	5	3	4	4
Backup power	10	8	0	9
Cost	35	21	15	29
Longevity	35	25	33	35
Total	100	59	65	90

Therefore, Design Approach 3 is the best solution.

2.4.5 3D Model of Chosen Design Approach



Fig. 2.4.7. 3D model of design approach 3 (aerial view)

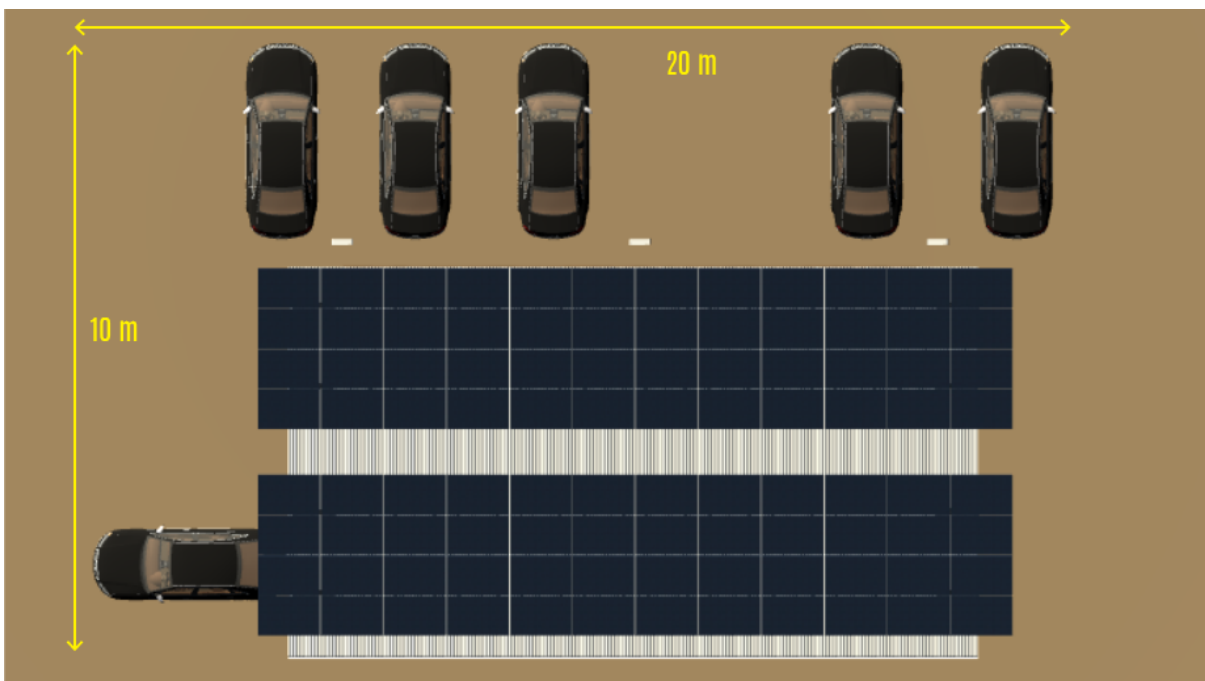


Fig. 2.4.8. 3D model of design approach 3 (top view)

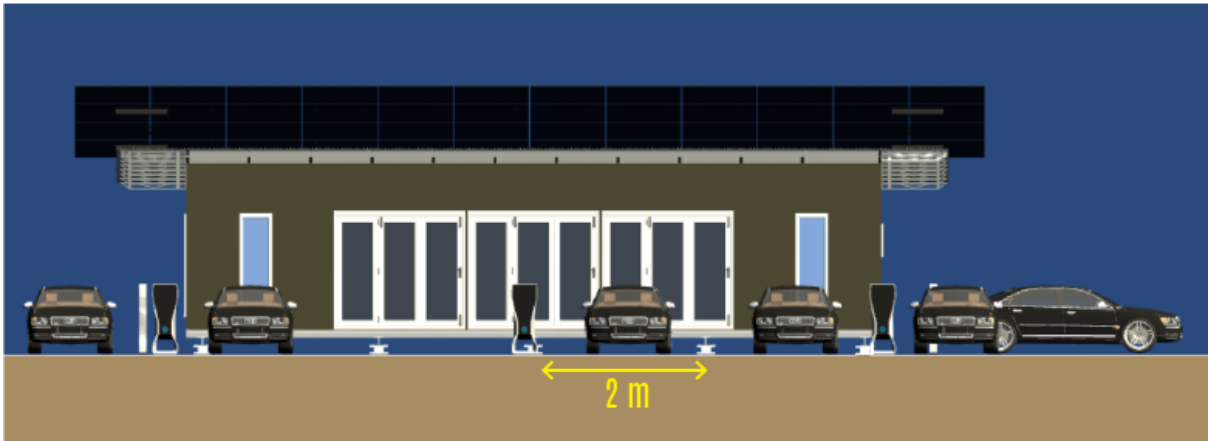


Fig. 2.4.9. 3D model of design approach 3 (front view)

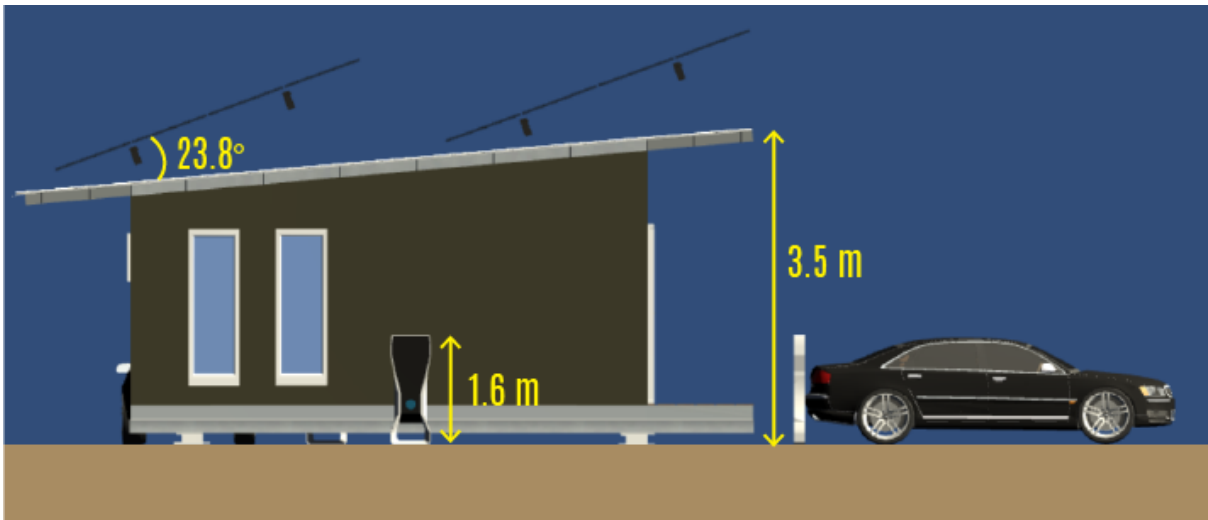


Fig. 2.4.10. 3D model of design approach 3 (side view)

2.5 Conclusion

From our research, we have identified three design approaches: biogas system, off grid system and on grid system. We have researched, simulated and analysed the design approaches and compared them against one another. From that, we have found that the on grid system is the most suitable for our project.

Chapter 3

Use of Modern Engineering and IT Tool

3.1 Introduction

The responsibility of choosing suitable tools for the creation and validation of the final prototype fell to us once we had decided on the best design strategy. Software and hardware tools were separated into two categories based on their intended uses. Tasks like 3D modelling, code compilation, and functional verification all needed the use of software tools for simulation, interfacing, and visualisation. We initially made a list of every resource that was available before doing a comparison study to identify the best tools for the job. We considered the drawbacks and advantages of employing each unique software package during this procedure.

3.2 Select appropriate engineering and IT tools

For our tool selection, we chose tools from four categories:

- 3D Modelling
- PV System Analysis
- Economic Analysis
- Circuit Simulation

3.2.1 3D Modelling Software: For design visualisation

TABLE 3.1. COMPARISON BETWEEN DIFFERENT 3D DESIGNING SOFTWARES

Criteria	SketchUp	Blender	AutoCAD	Maya
Pricing	Free	Free	Paid	Paid
Usage	Architectural Design	3D Modeling, Rendering and Animation	2D and 3D Modelling and designing	3D Modeling, Rendering and Animation
Learning Curve	Gentle	Gentle	Moderate	Steep
Supported File Types	Basic	Additional file types supported	Basic	Additional file types supported
Quality of Design	Creates lifelike drawings quickly and easily	Produces excellent picture renderings	Realistic render is challenging	Realistic render is challenging

We concluded from this table that SketchUp was the best choice for us because it was simple to use. It was also well-documented and provides a helpful internet community. Also, SketchUp is free to use with a G Suite email, and has the required features for our needs.

3.2.2 For the study, sizing and data analysis of complete PV systems

TABLE 3.2. COMPARISON BETWEEN DIFFERENT PV SYSTEM ANALYSIS SOFTWARES

Criteria	PVsyst	Helioscope	HOMER	Pylon
Analysis	Detailed	Medium	Simple	Detailed
Pricing	Paid	Paid	Paid	Paid
3D Models Input	Can be imported easily	Does not allow importing 3D models	Can be imported easily	Can be imported easily
Optimization	Efficient and easy	Complicated and time consuming	Efficient and easy	Complicated and time consuming
Components	PV components are up to date	PV components are sometimes incorrect	PV components are up to date	Extensive database of PV components

For the study, sizing and data analysis of complete PV systems we have chosen PVsyst as it is one of the most popular and widely used tools in this field. It has given users the ability to size, simulate, and study PV systems, carry out in-depth design and research, and provide comprehensive reports for more than 20 years. Thousands of engineers worldwide utilise the complete solar design tool PVsyst Software. For large-scale and utility-scale solar projects, PVSyst is the industry standard. It facilitates the design of both grid-connected and standalone battery powered PV systems.

3.2.3 Economic Analysis Tool Comparison

TABLE 3.3. COMPARISON BETWEEN DIFFERENT ECONOMIC ANALYSIS SOFTWARES

Criteria	PVsyst	HOMER	RETScreen	Solar Pro
Module Degradation	Module degradation taken into consideration while performing analysis	Module degradation not present	Module degradation not present	Module degradation not present
Components	Wide database of updated real world components	Database is small	Wide database of updated real world components	Wide database of updated real world components
Temperature Effect	Includes temperature effect on PV system	Includes temperature effect on PV system	Does not includes temperature effect on PV system	Does not includes temperature effect on PV system
Import Option	Has time series data import option	Has time series data import option	No time series data import option	Has time series data import option

Among these softwares, we have chosen PVsyst as our tool for the evaluation of economic analysis. This is because, since the data analysis of complete PV systems was done using the same software, to keep things simpler we used PVsyst as our choice. Moreover, it has all the necessary features to carry out our economic analysis and it provides a detailed report of the analysis.

3.2.4 Simulation software: For circuit simulation and functional verification

TABLE 3.4. COMPARISON BETWEEN DIFFERENT SIMULATION SOFTWARES

Criteria	Simulink	Proteus	AutoDesk Eagle	NI Multisim
Component Library	Lot of libraries and add-ons can be included	External libraries can be included	Lack of components in library and challenging to design custom components	Several parts are not accessible
Usage	Data visualisation and testing	Digital circuits, schematics and verification	For layout of printed circuit board (PCB)	Research and teaching purpose in educational institutions
User Interface	User friendly interface	User friendly interface	User friendly interface	Outdated interface

We found that the optimal software for our design is Simulink since it has numerous libraries and external libraries can also be added. It has a user-friendly interface among other facilities and the component library can be readily used for designing the charging station, solar panel, rectifier, communication box etc.

3.3 Use of modern engineering and IT tools

Simulink is a platform for Model Based Design which helps in modelling and simulating dynamic systems. Simulink offers a graphical editor, adaptable block libraries, and solvers. It is integrated with MATLAB, allowing us to import simulation data and MATLAB methods into models for further analysis. It has many features which include: libraries of predefined blocks for modelling continuous-time and discrete-time systems. Also, there is a simulation engine with fixed-step and variable-step ODE solvers. Moreover, scopes and data displays are available for viewing simulation results.

PVSyst is a software for the investigation, sizing, and data analysis of total PV systems. It comprises substantial meteorological and PV systems components databases as well as basic solar energy tools and handles with grid-connected, stand-alone, pumping, and DC-grid (public transportation) PV systems. Within PVSyst, importable or comparably accessible public meteorological data are available. Also, automatic string sizing is present depending on the project's machinery and the site's severe temperatures. It can also perform examples of shading losses optimization. PVSyst also has built-in tools for economic analysis, based on the parameters of the simulation. Using this, it is easier to perform the economic analysis for our project.

SketchUp is a 3D modelling Computer-Aided Design (CAD) tool for a wide range of drawing and design applications, including architectural, interior design, industrial and product design, and landscape architecture. The features of SketchUp consist of lighting effects, generating 2D and 3D models, generating animations and textures and also includes layer managing capability. SketchUp stands out from similar programs because it is quick, simple to use, and widely available. It has features and tools that are user-friendly and has straightforward interfaces. For each job, it may provide a wide variety of designs. Additionally, it is compatible with the AutoCAD drawings. When constructing 3D architecture models, SketchUp provides extremely accurate dimensions, item locations, and object slopes. It also offers a variety of information and methods for referencing and drawing conclusions from already existing items or axes. It is easier to determine how accurate we want the measurements to be in SketchUp, whether we are using it for engineering or architectural purposes. To the thousandth of an inch, it is accurate. Also we get to choose and plan how much or little detail we require. In addition to that SketchUp has an option in which we can place our model within Google Earth. The use of this software helped us in

determining how much room the EVs would require and how much area is needed for the completion of our project. It gave us a virtual demonstration how it would look in real life once the project has been implemented. With the aid of this tool we varied different parameters and observed the change to our whole system and came up with the best solution. PVsyst is used as it is the most popular solar simulation tool for estimating energy production and determining the best layout for solar power plants. Nearly all of the well-known solar energy firms utilise this software.

3.4 Conclusion

Software that could give statistics on solar irradiance, PV panels, and inverters was necessary for our project. After thorough consideration, PVsyst was selected in case of functional verification and circuit simulation.

In this section mainly, we have learnt how to design, build, and validate solutions using contemporary engineering and IT techniques. We had to gather data about the hardware and software that could be utilised to do this. Therefore, we separated the activities into two categories first: software and hardware. We then determined the tools we could utilise for each activity. As previously, we compared them all and picked the best. We also thought about the tools' various limitations and looked for solutions to overcome them. The creation and assessment of the solution using the chosen tools. Additionally, certain methods had to be mastered in order to execute the jobs, therefore we consulted manuals, tutorials, articles, and internet groups for assistance.

Chapter 4

Optimization of Multiple Design and Finding the Optimal Solution

4.1 Introduction

In our project, we have identified four major components that can be implemented using various methods. Each method has its own advantages and disadvantages that must be weighed when making a decision. There as follows:

- Subsystem 1: Solar Panel Tracking and Tilt
 - Fixed tilt
 - Seasonal tilt adjustment
 - Single axis tracking
 - Dual axis tracking
- Subsystem 2: Inverter + Solar Controller System
 - PWM controller with separate inverter
 - MPPT controller with grid tied inverter
- Subsystem 3: Battery Technology
 - Lead-acid battery
 - Nickel-metal hydride battery
 - Lithium-ion battery
- Subsystem 4: Load Management
 - Plug-in on arrival
 - Battery backup
 - Demand Side Management

4.2 Optimization of multiple design approach

4.2.1 Subsystem 1: Solar Panel Tracking and Tilt

TABLE 4.1. ALTERNATE DESIGN SOLUTIONS FOR SUBSYSTEM 1

Parameter	Design Solution 1: Fixed tilt	Design Solution 2: Seasonal tilt adjustment	Design Solution 3: Single axis tracking	Design Solution 4: Dual axis tracking
Method	Fixed tilt at optimum angle of 23.8°	Change tilt angle to optimise for summer and winter months	Track the sun on the vertical axis	Track the sun on both vertical and horizontal axis
Cost	Low	Low	Moderate	High
Effectiveness	Produces the required power	Slightly reduces losses, improving efficiency	Significant reduction in losses	Slight improvement over single axis system

4.2.2 Subsystem 2: Inverter + Solar Controller System

TABLE 4.2. ALTERNATE DESIGN SOLUTIONS FOR SUBSYSTEM 2

Parameter	Design Solution 1: PWM controller with separate inverter	Design Solution 2: MPPT controller with grid tied inverter
Method	Use PWM controller for power tracking and a separate inverter for backfeeding	Use a single module for power tracking and backfeeding. MPPT is more efficient than PWM. Single module reduces cost and has better performance.
Efficiency	Low	High
Cost	Moderate	High

4.2.3 Subsystem 3: Battery Technology

TABLE 4.3. ALTERNATE DESIGN SOLUTIONS FOR SUBSYSTEM 3

Parameter	Design Solution 1: Lead-acid battery	Design Solution 2: Nickel-metal hydride battery	Design Solution 3: Lithium-ion battery
Cycle life expectancy	500-1200	3000	3000-6000
Energy density (Wh/kg)	25-35	55.3	88.0-112.0
Self-discharge rate (per month)	4-6%	13.9-70.6%	1.5-2%
Memory effect	Absent	Present	Absent
Charge-discharge energy efficiency (%)	70	80	90
Battery management system required	No	Optional	Yes

4.2.4 Subsystem 4: Load Management

TABLE 4.4. ALTERNATE DESIGN SOLUTIONS FOR SUBSYSTEM 4

	Design Solution 1: Plug-in on arrival	Design Solution 2: Battery backup	Design Solution 3: Demand Side Management
Method	Plug-in when EVs arrive to recharge	Plug-in when EVs arrive to recharge through BESS, then switch over to grid when BESS runs out	Delay charge until off-peak hour starts
Load on grid	Charged during peak hours	Charged during peak hours (delayed slightly by BESS)	Charged during off-peak hours
Backup	BESS would provide backup during load shedding	BESS would not have sufficient charge during load shedding	BESS would provide backup during load shedding

4.3 Identify optimal design approach

4.3.1 Solar Panel Tracking and Tilt

Both single and dual axis tracking increases power generated by the solar panels but they also increase the cost of the project as they require additional components. The power produced by the fixed tilt setup is sufficient for our project. Therefore, we have chosen to use fixed tilt setup for solar panel tracking and tilt.

4.3.2 Inverter + Solar Controller System

Though MPPT controllers are expensive compared to PWM controllers, they have much higher efficiency. Due to this, we have chosen to use the MPPT controller in our project as the benefits outweigh the cost.

4.4.3 Battery Technology

We have chosen to use lithium-ion batteries for our project as it has higher cycle life expectancy and energy density compared to lead-acid and nickel-metal hydride batteries. The charge-discharge efficiency of lithium-ion batteries is also high and there is no memory effect present.

4.3.4 Load Management

We have chosen to use demand side management in our project as it reduces load on the grid during peak hours and less number of station batteries are required in this approach, helping to keep the upfront cost of the project low.

4.4 Performance evaluation of developed solution

We have tested our proposed design using MATLAB Simulink. We have developed a few test cases in order to evaluate the performance of our system. These cases would ensure if the system is behaving to our requirements as expected.

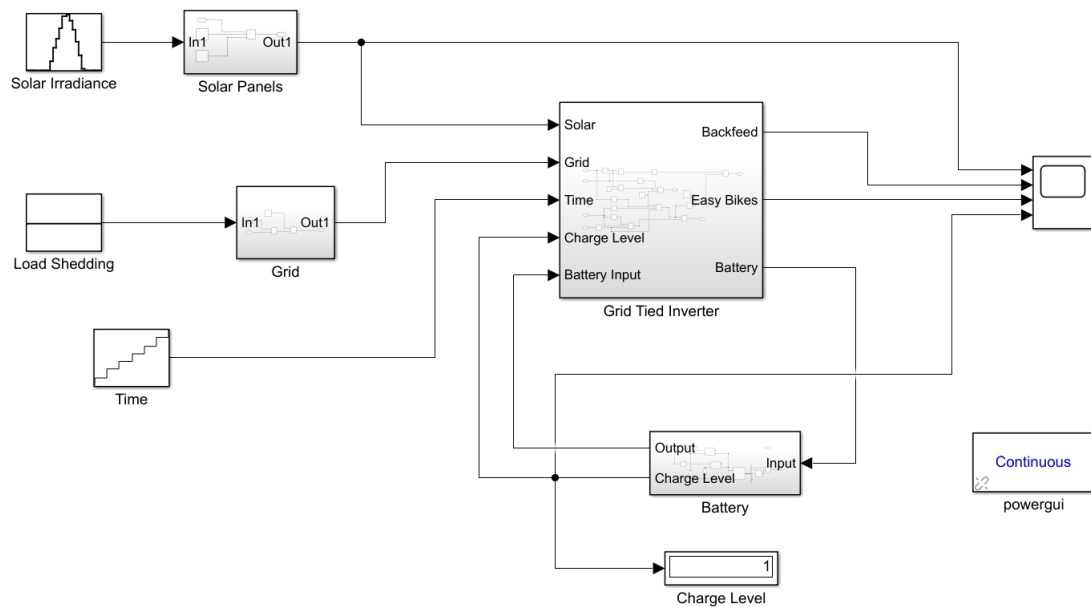


Fig. 4.4.1. Setup of On-grid system in Simulink

Test Case 1: No load shedding, battery is fully charged

Since there is no load shedding, all the energy used to charge the easy bikes comes from the grid. Thus the battery storage does not discharge. Here, the easy bikes are charged between 12 am and 5 am. During the day, the solar panel output is backfed to the grid.

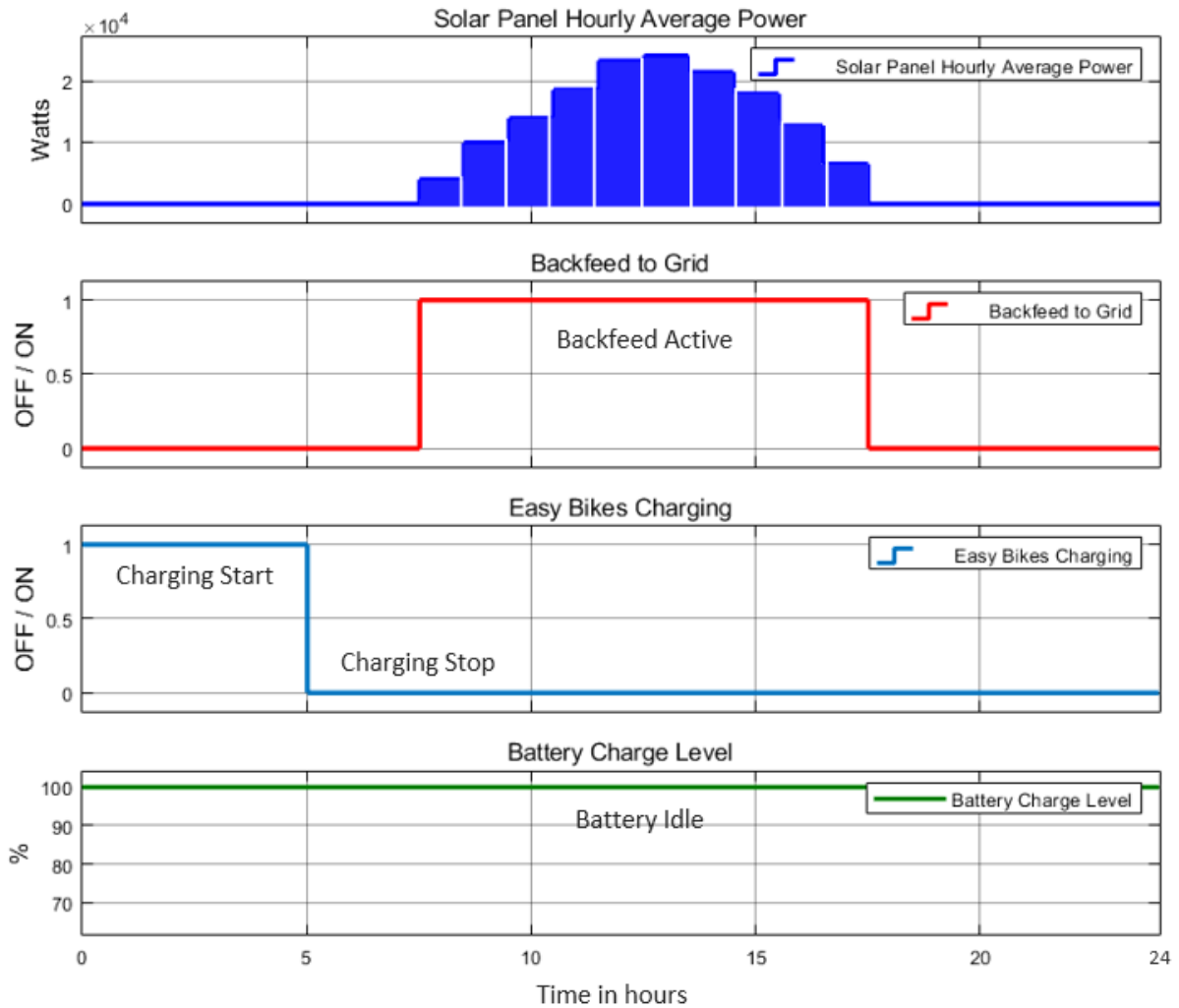


Fig. 4.4.2. Simulink output for no load shedding, battery fully charged

Test Case 2: No load shedding, but battery is not fully charged

Since there is no load shedding, all the energy used to charge the easy bikes comes from the grid. Thus the battery storage does not discharge. Here, the easy bikes are charged between 12 am and 5 am. However, during the day, the solar panel output is initially used to charge the battery storage. After the battery storage is full, the excess energy is backfed to the grid.

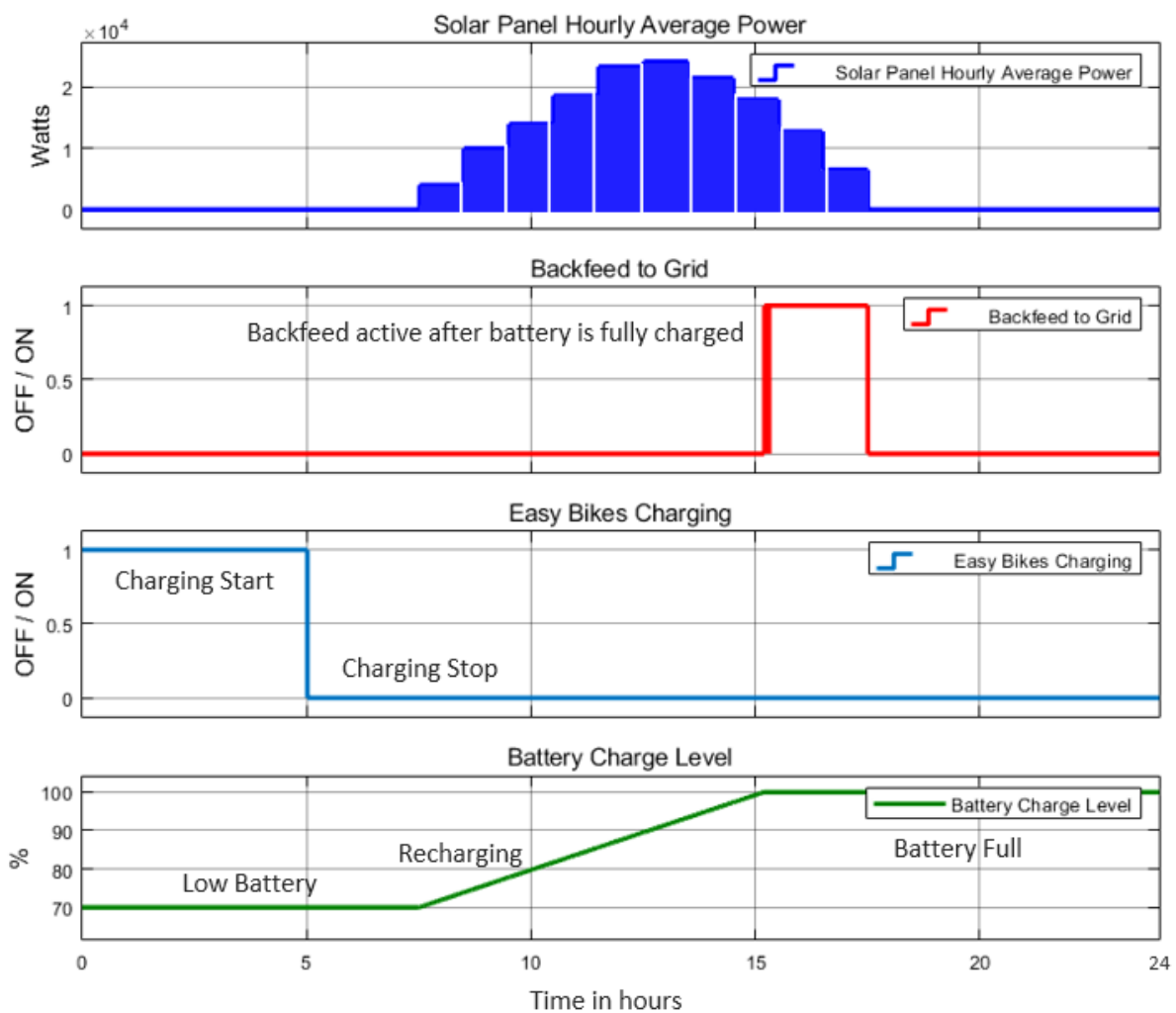


Fig. 4.4.3. Simulink output for no load shedding, battery not fully charged

Test Case 3: Load shedding, battery fully charged and used for charging easy bikes

Since there is no electricity due to load shedding, all the energy used to charge the easy bikes comes from the battery. Thus the battery storage discharges. Here, the easy bikes are charged between 12 am and 5 am. During the day, the solar panel output is used to charge the battery storage, until they are fully charged. After the battery storage is full, the excess energy is backfed to the grid.

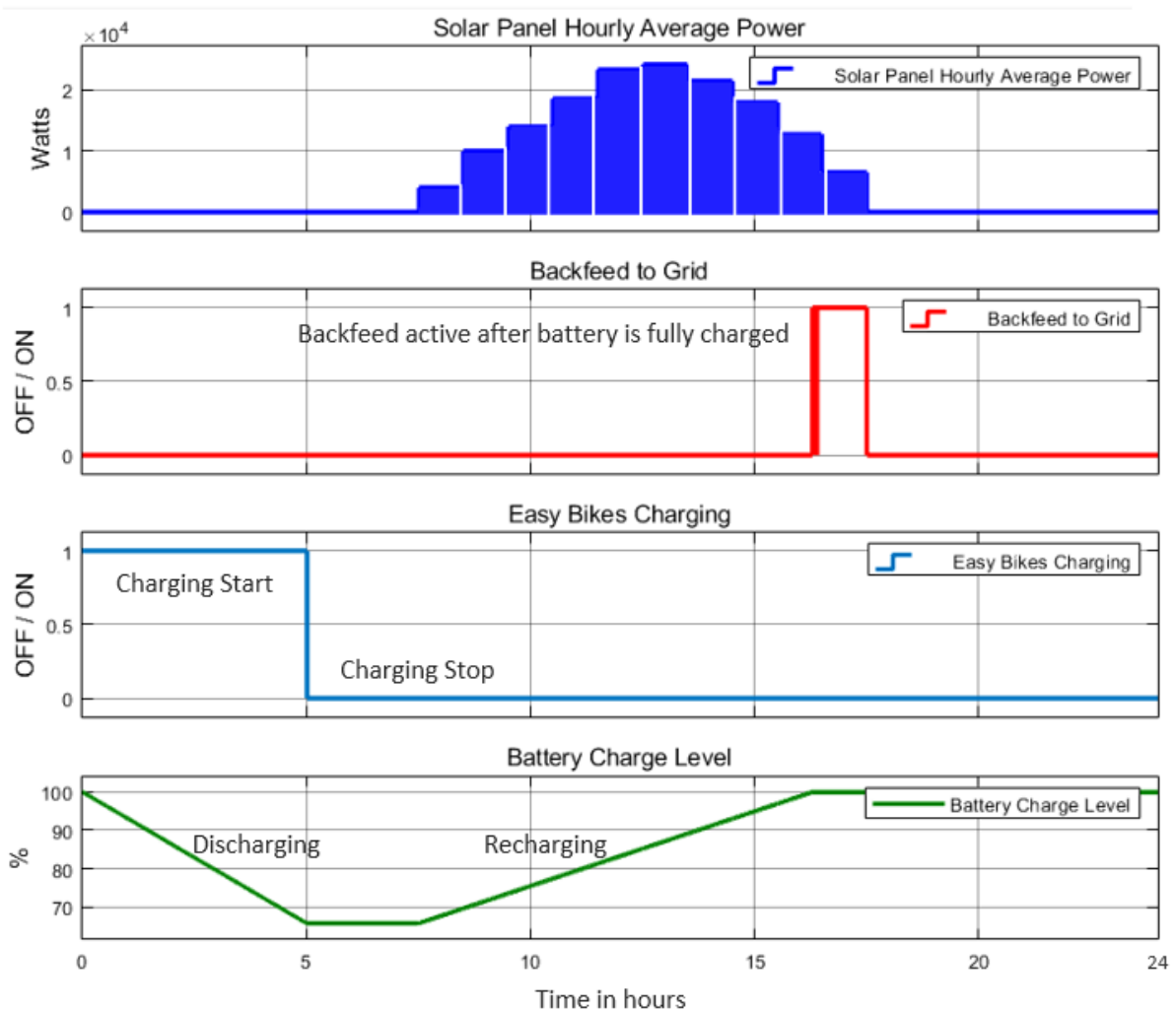


Fig. 4.4.4. Simulink output for load shedding, battery fully charged and used for charging easy bikes

4.5 Conclusion

We have identified and chosen the best design solution of different subsystems. We have chosen to use fixed tilt setup for solar panel tracking and tilt and MPPT controller in our project. We have also opted to use lithium-ion batteries for our project as it has a higher cycle life expectancy. Finally, the load management would be done using demand side management. After choosing the best design solution, we have performed a simulation using MATLAB Simulation in order to test our system.

Chapter 5

Completion of Final Design and Validation

5.1 Introduction

After verifying the design, we proceeded to create a hardware version of our project. As it was not feasible to test the project in a full scale model, we scaled down the project for a prototype implementation. The scaled down version had all the features of the real scenario model except the backfeed/export to grid. Exporting to the actual grid added complexity and cost to our project due to the need of a grid tie inverter. Thus, we have opted to show the export in a different way.

5.2 Completion of final design

For our prototype version, we have chosen to show the following:

- Charging the station batteries using solar power
- Charging easy bikes using station batteries in the event of a load shedding
- Charging easy bikes from the grid during off peak hours
- Uploading data to a web server
- Exporting power to the grid

Here is the overall block diagram of our prototype.

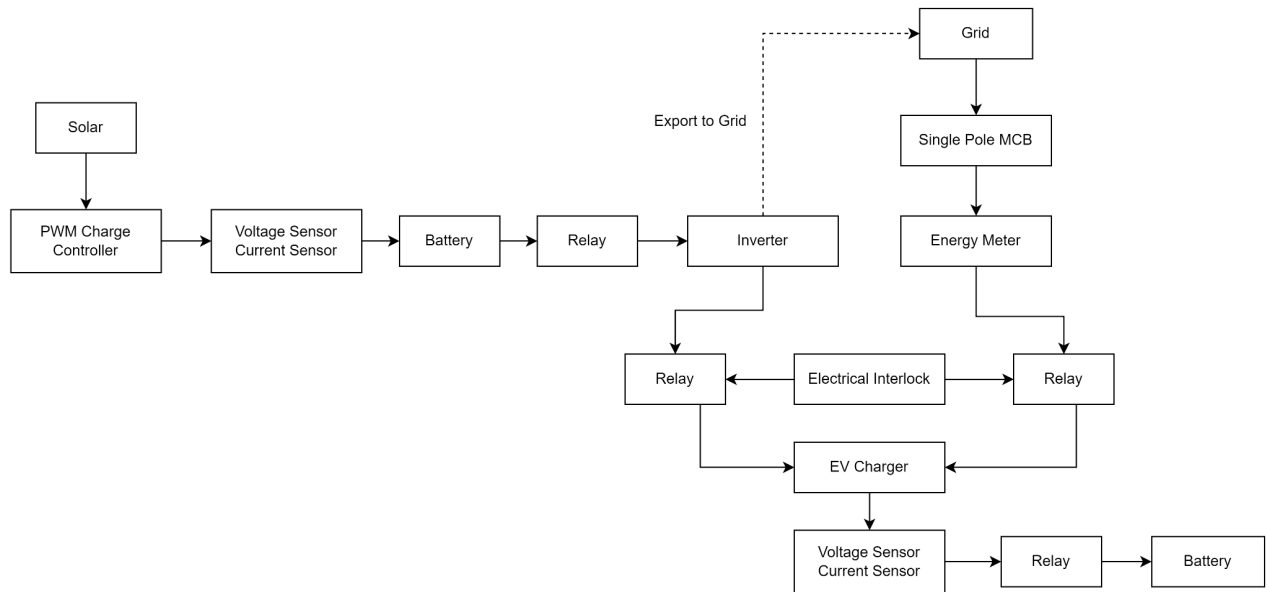


Fig. 5.2.1. Block diagram

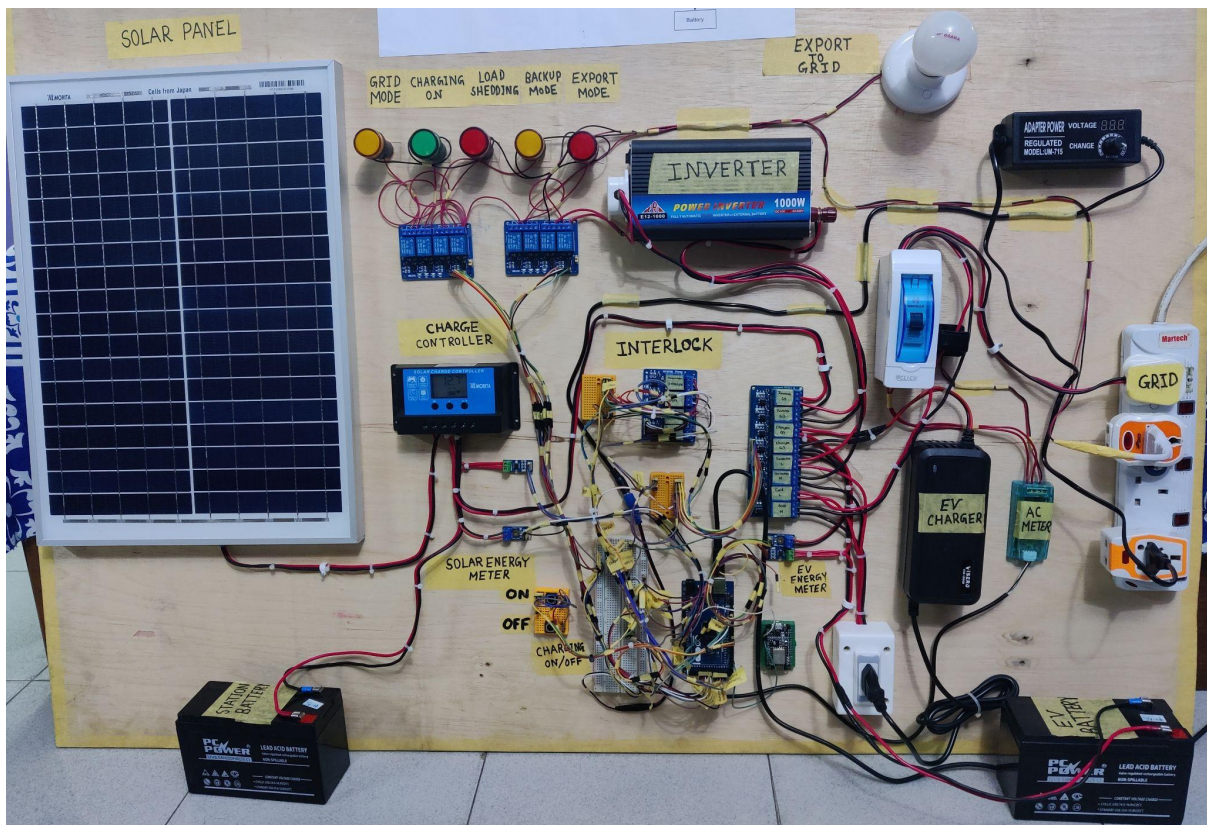


Fig. 5.2.2. Overall prototype

We have developed a prototype based on our block diagram, which is a visual representation of the system's design that shows the relationships between the different components. The prototype consists of a physical implementation of the system, which we have created in order to test and evaluate its performance. The detailed explanation of each part of the prototype is given below, including the specific functions and features of each component and how they work together to achieve the overall goals of the system. The prototype development process involved taking the block diagram and turning it into a tangible, functional system that can be tested and refined. By creating a prototype, we are able to better understand the capabilities and limitations of the system, and make any necessary modifications before moving forward with a full-scale implementation.

5.2.1 Solar power generation and charging station battery

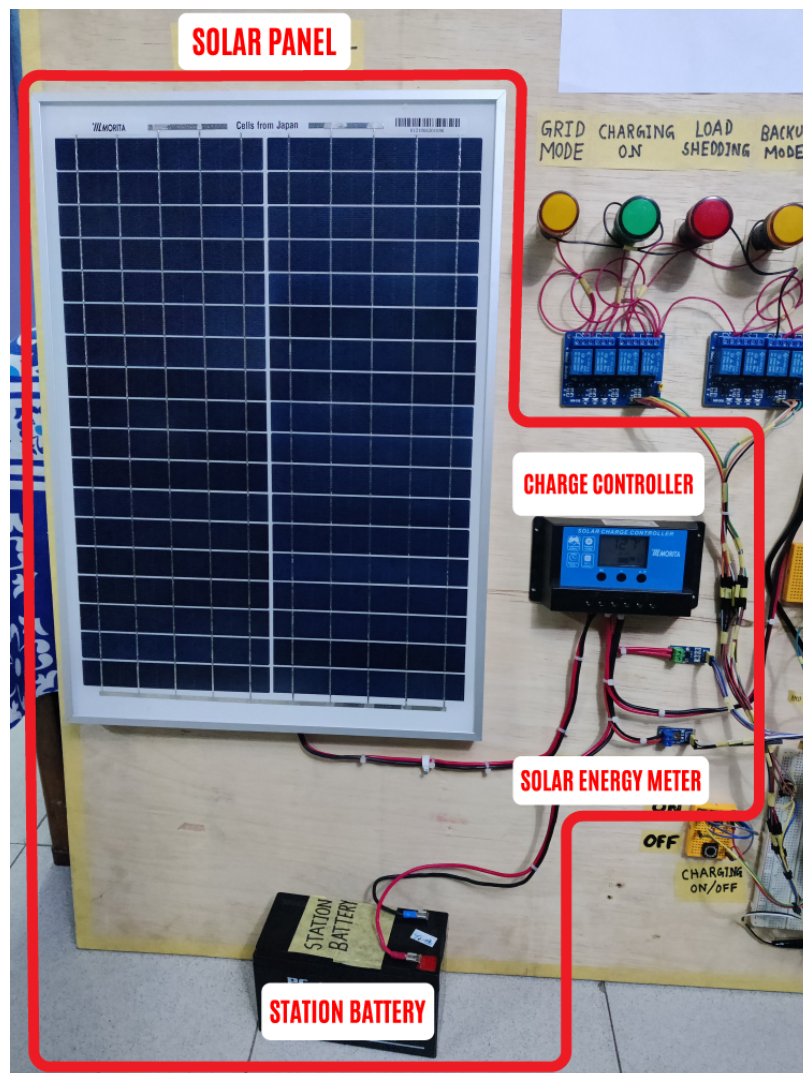


Fig. 5.2.3. Solar power generation and station battery

For our solar power generation, we have a 20W solar panel connected to a PWM charge controller. We chose to use a PWM charge controller for our prototype as it is cheaper. The PWM charge controller is connected to the station batteries. Station batteries will provide backup power in the event of load shedding. They can also provide urgent power to easy bike charging if needed during peak time of the grid. During daytime, the solar panel generates electricity. The PWM controller ensures that maximum power is extracted from the panels to charge the station batteries.

5.2.2 Control system

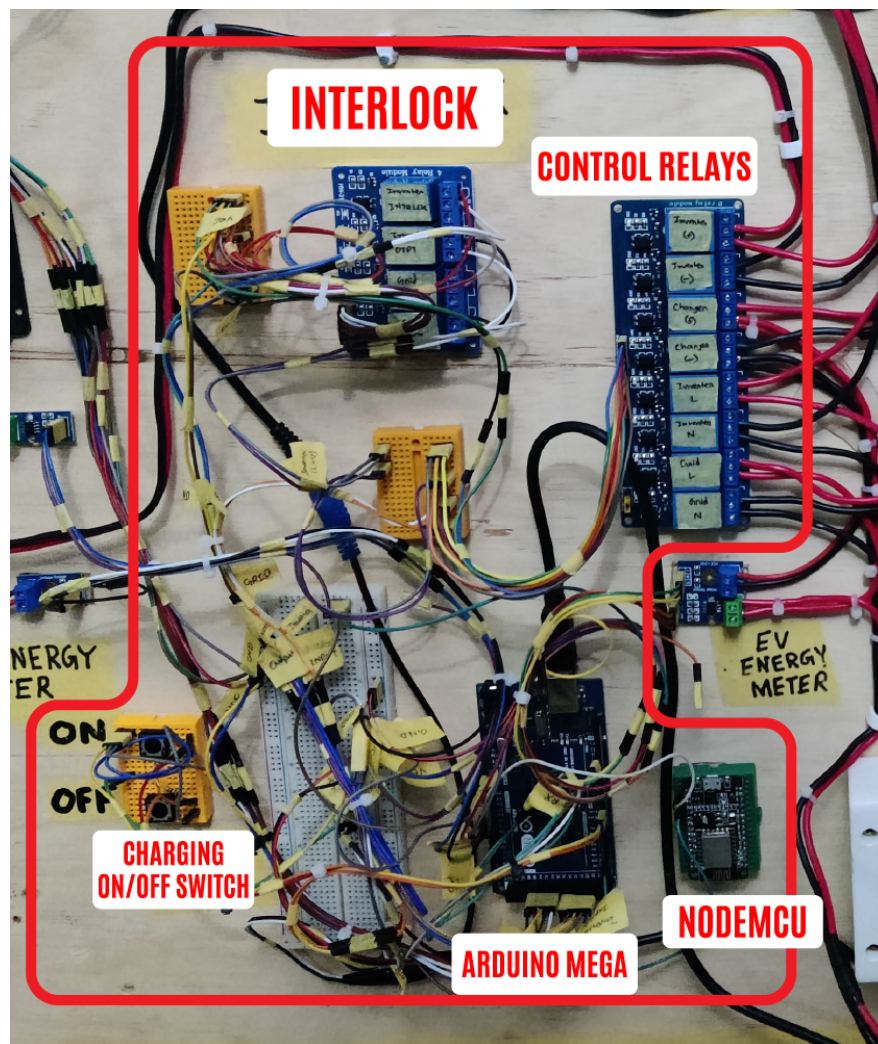


Fig. 5.2.4. Control system

This is the control system for our project. The Arduino Mega handles all the switching logic for the relays. It also reads the data from the voltage and current sensors, as well as control the status LEDs. The voltage and current sensor data is transmitted to the NodeMCU, which in turn transmits the data to the web server via the internet. There is an ON and OFF switch in order to override the DSM system, in case urgent charging is required. An electrical interlock is also present, which ensures that the grid and inverter are not connected at the same time.

5.2.3 EV Charging system

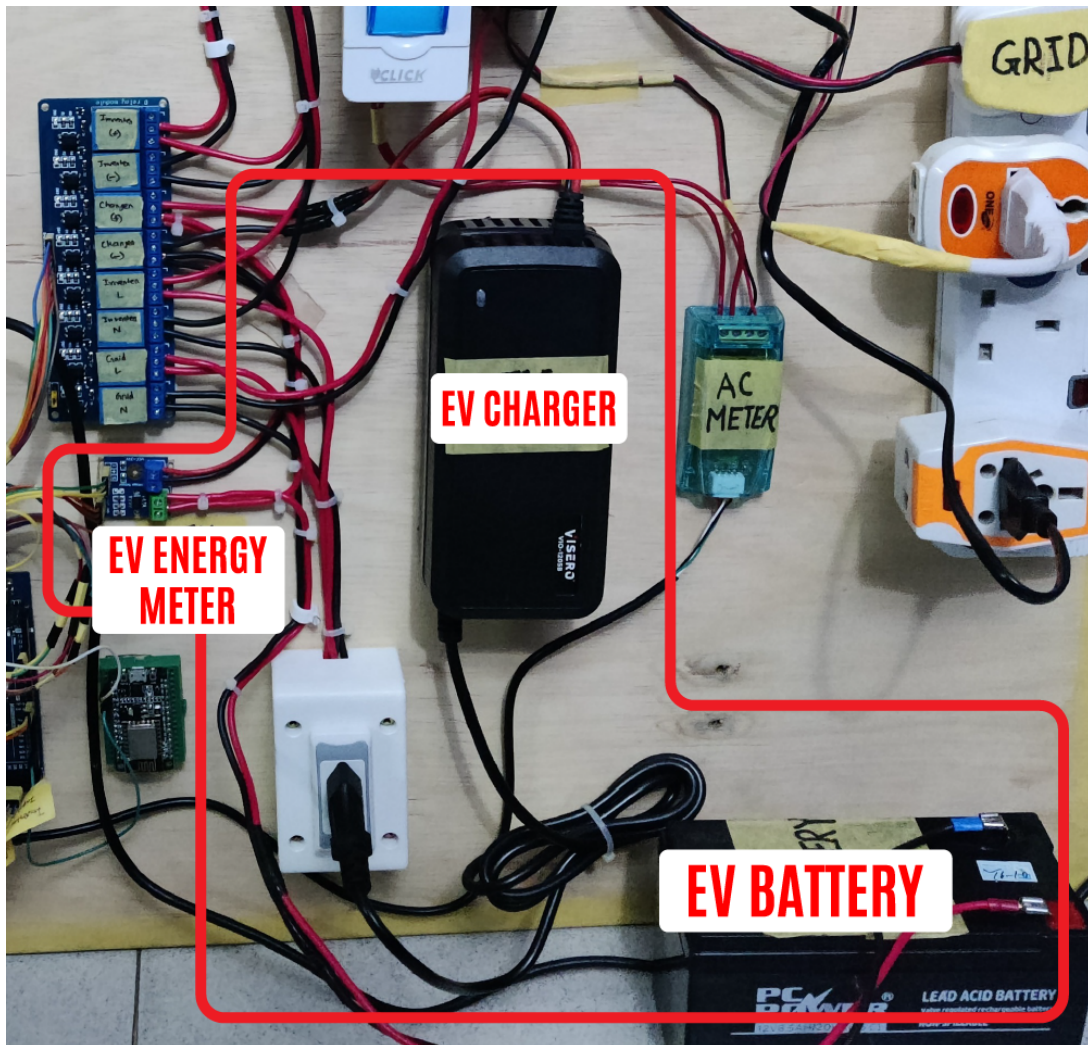


Fig. 5.2.5. Charging system

For our EV charging system, we are using an off the shelf battery charger. Here, the battery is used to show the battery of an actual easy bike. The EV charger gets AC power, converts it to DC and then charges the EV battery. The EV energy meter is a voltage and current sensor. Using the data of the EV energy meter, we can calculate the energy consumed by the EV battery for billing of the customer.

5.2.4 Status LEDs

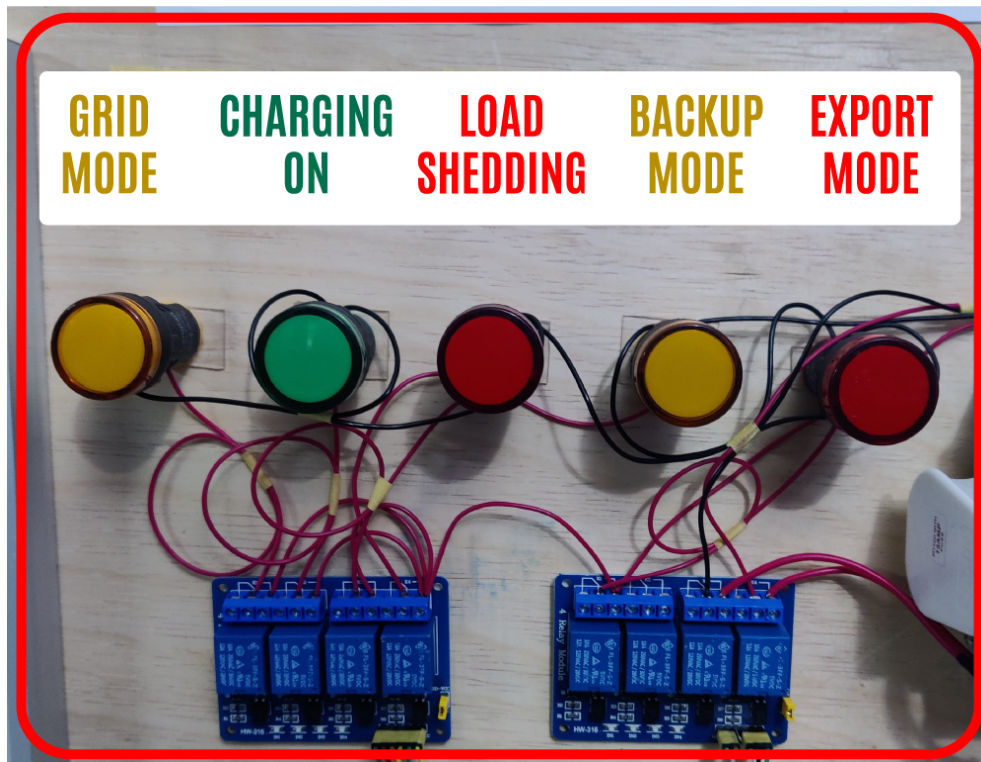


Fig. 5.2.6. Status LEDs

The status LEDs are used to show the current state of the charging station. There are five LEDs, which are (from left to right): grid mode, charging on, load shedding, backup mode and export mode. When the charging status is ON, the charging LED is ON. If there is grid power and it is off-peak time, power is taken from the grid. The grid mode LED is ON. Otherwise, the inverter is turned on and the backup mode LED is ON. During load shedding, the load shedding LED is ON, implying that the grid is unavailable at the moment. During this time if charging is started, it would take from the backup mode. Lastly, the export mode LED is ON when power is exported to the grid.

5.2.5 Export to grid

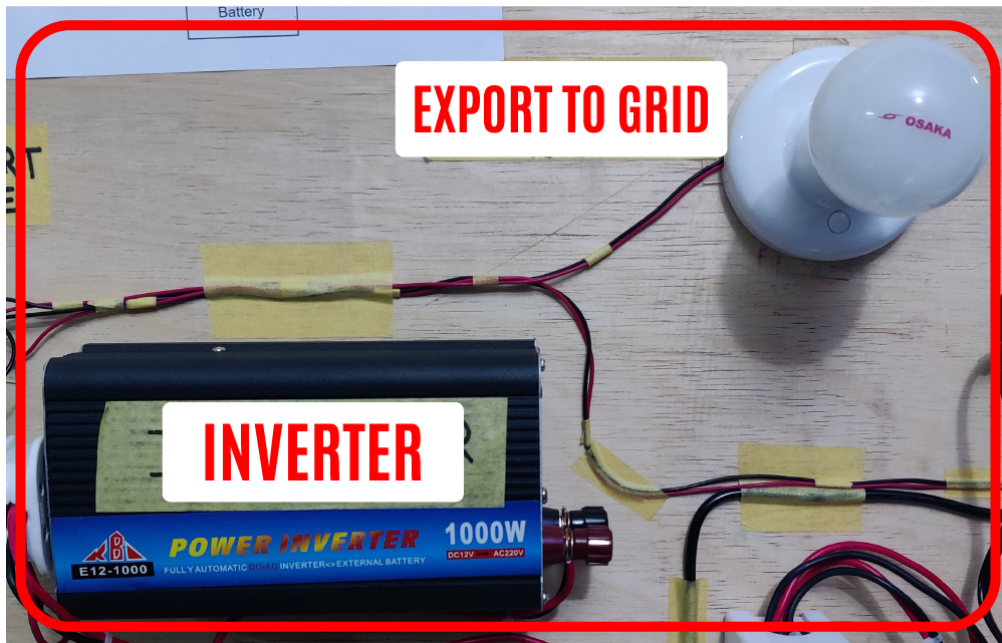


Fig. 5.2.7. Export to grid

Due to the added complexity and cost of adding a grid tie inverter to the prototype, we have opted not to connect our inverter to the grid. Instead, we are showing the export power using a bulb. If the bulb is turned ON, it implies that power is being exported to the grid.

5.2.6 Inverter and Grid

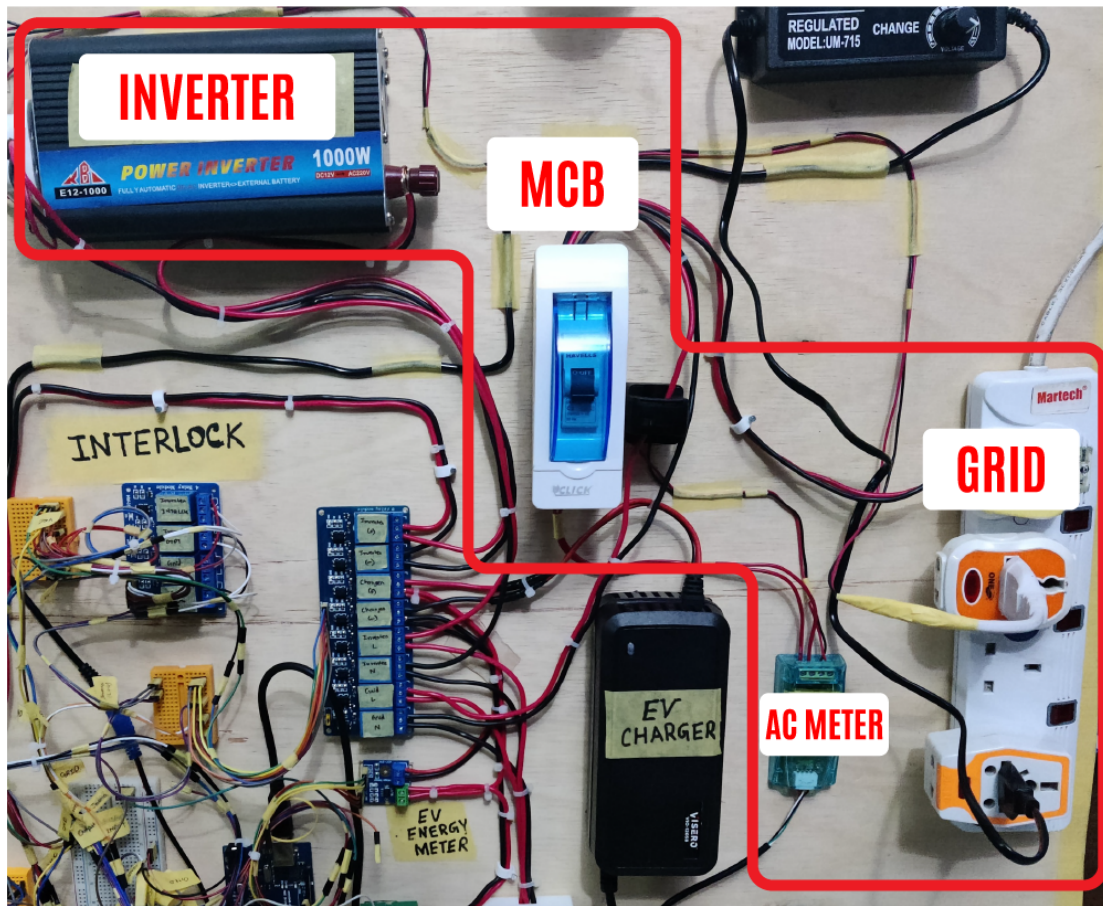


Fig. 5.2.8. Inverter and grid

Lastly, here is the part that is responsible for providing the EV charger with AC power. The inverter is connected to the EV charger during backup mode and the grid is connected to the EV charger during grid mode. The grid connection goes through a Miniature Circuit Breaker (MCB) as an overcurrent protection device. The grid is also connected to an AC meter (PZEM-004T) that monitors the energy taken from the grid. The AC meter can also monitor other parameters such as grid voltage, current drawn from grid, grid frequency and power factor. All the data is read by the Arduino and is transmitted to the web server via the NodeMCU.

5.3 Evaluate the solution to meet desired need

Once the hardware implementation was complete, we move on to testing and evaluating the performance of our prototype. For evaluating our prototype, we have proposed the following test cases:

- Solar subsystem charging battery
- Grid mode
- Inverter (backup) mode
- Export mode
- Switching between Grid mode and Inverter mode
- Real time data transmission to web server
- Demand Side Management (DSM)

5.3.1 Solar subsystem charging battery

We have drained the station battery for our test. The prototype was then placed on the roof in order to charge the battery using solar power. We have conducted this test for a week and calculated an average power generated. The sampling rate we have chosen to save the data was once every 30 minutes. We used the data to plot the following graph:

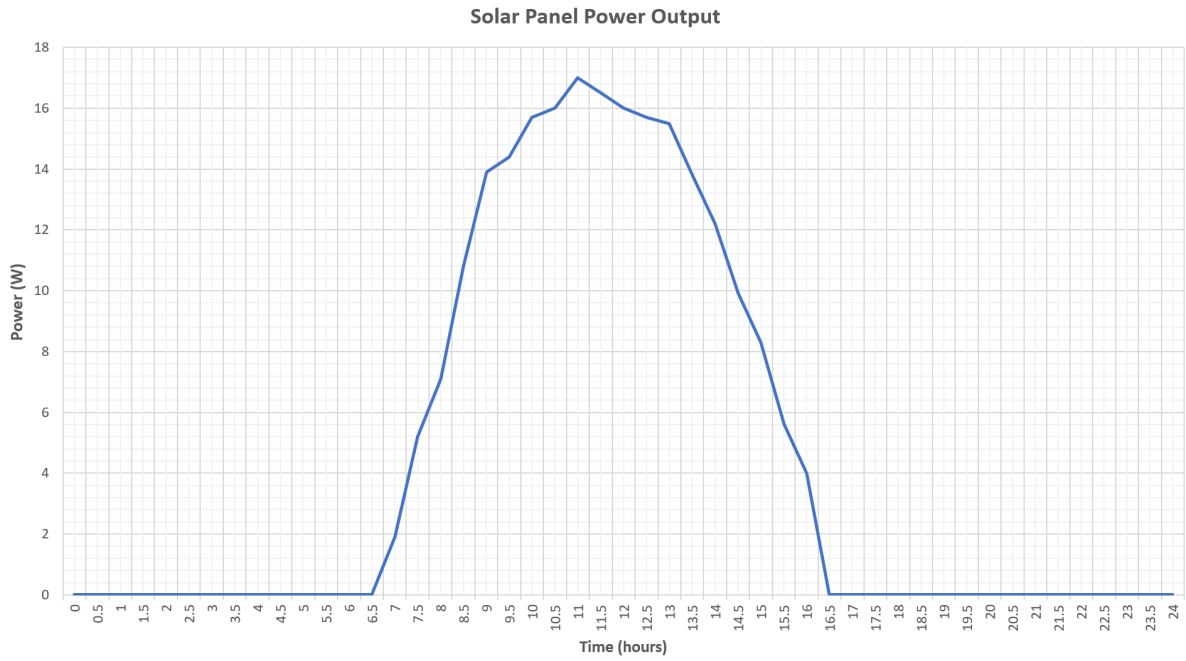


Fig. 5.3.1. Solar panel power output (7 day average)

From the area under the graph, we have calculated the total power generated by the solar panels is 108 kWh per day. This energy was sufficient to fully charge our station batteries. Thus, we concluded that our solar subsystem is working as expected.

5.3.2 Grid mode

For our charging during off peak hours, we use grid mode. Before charging is switched ON, we can see the load shedding LED is OFF (Fig: 5.3.2.), indicating that grid power is available. When the charging is switched ON, the grid mode LED turns ON along with the charging LED (Fig: 5.3.3.), indicating that charging has started. The EV charger gets power from the grid and charges the EV battery. When switched off, the system returns to normal state. Thus, we concluded that the grid mode is working as expected.

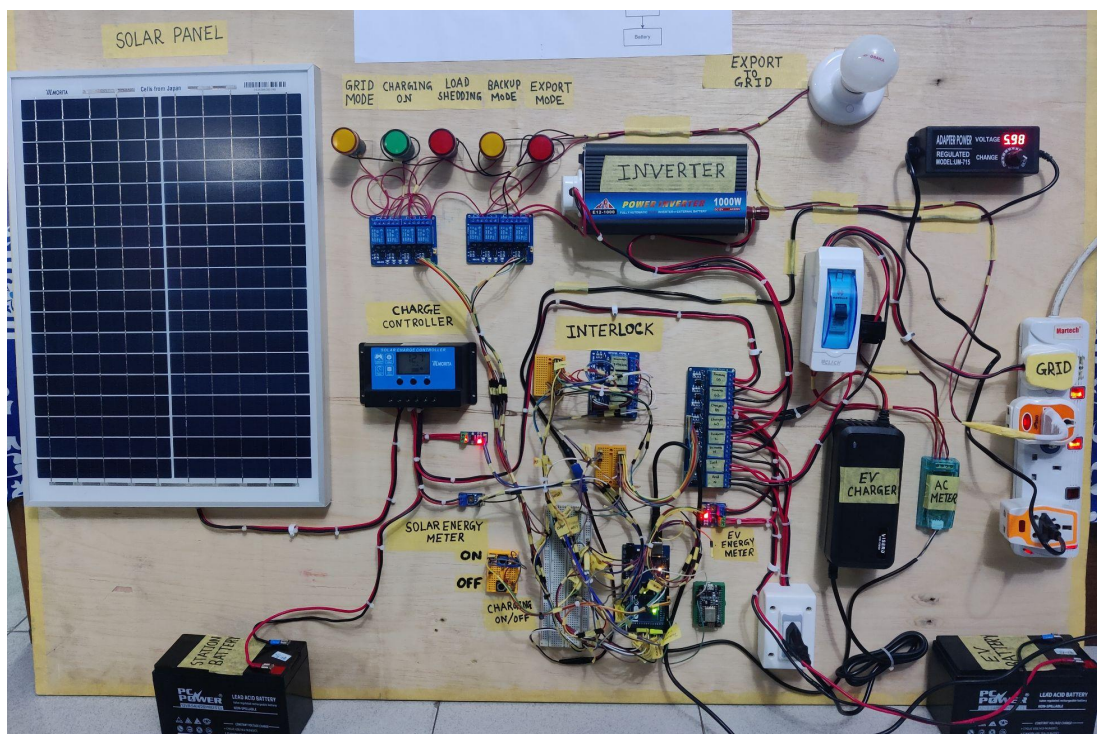


Fig. 5.3.2. Charging OFF, grid is available

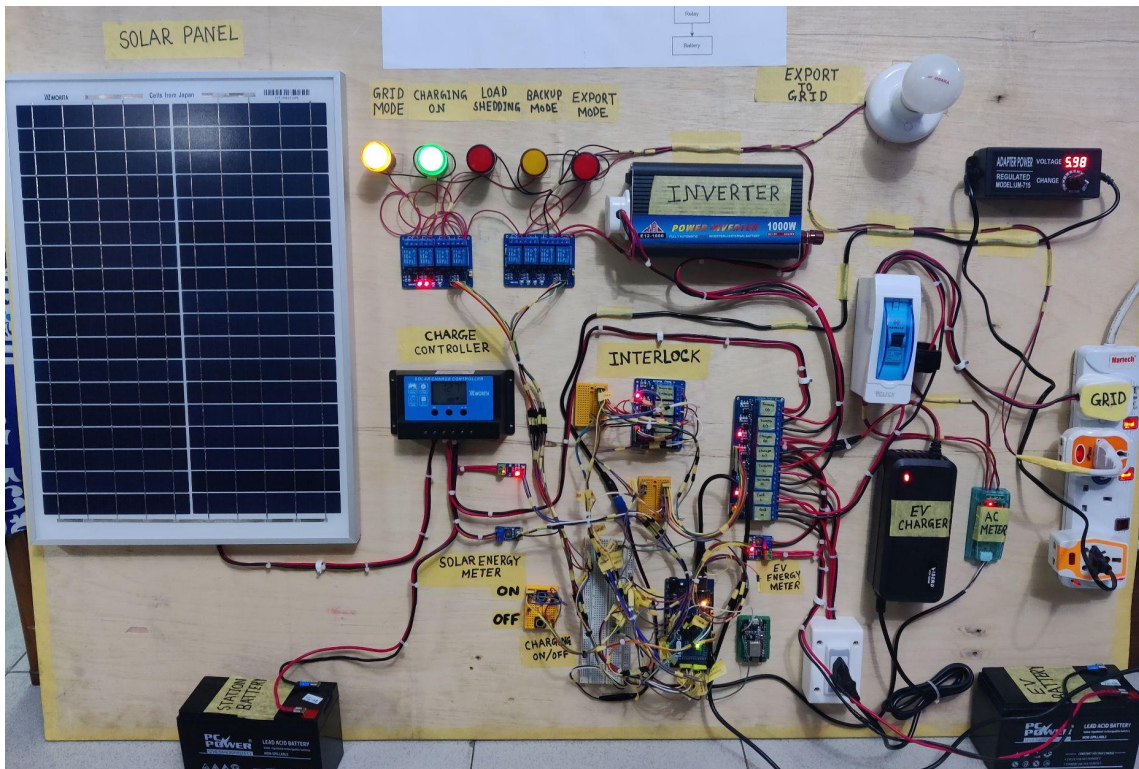


Fig. 5.3.3. Charging ON, grid is available, EV battery charges from grid power

5.3.3 Inverter (backup) mode

For our charging during peak hours or during load shedding, we use inverter (backup) mode. Here we have simulated a load shedding scenario by shutting off grid power. Before charging is switched ON, we can see the load shedding LED is ON (Fig: 5.3.4.), indicating that grid power is unavailable. When the charging is switched ON, the backup mode LED turns ON along with the charging LED (Fig: 5.3.5.), indicating that charging has started. The EV charger gets power from the inverter and charges the EV battery. When switched off, the system returns to normal state. Thus, we concluded that the inverter (backup) mode is working as expected.

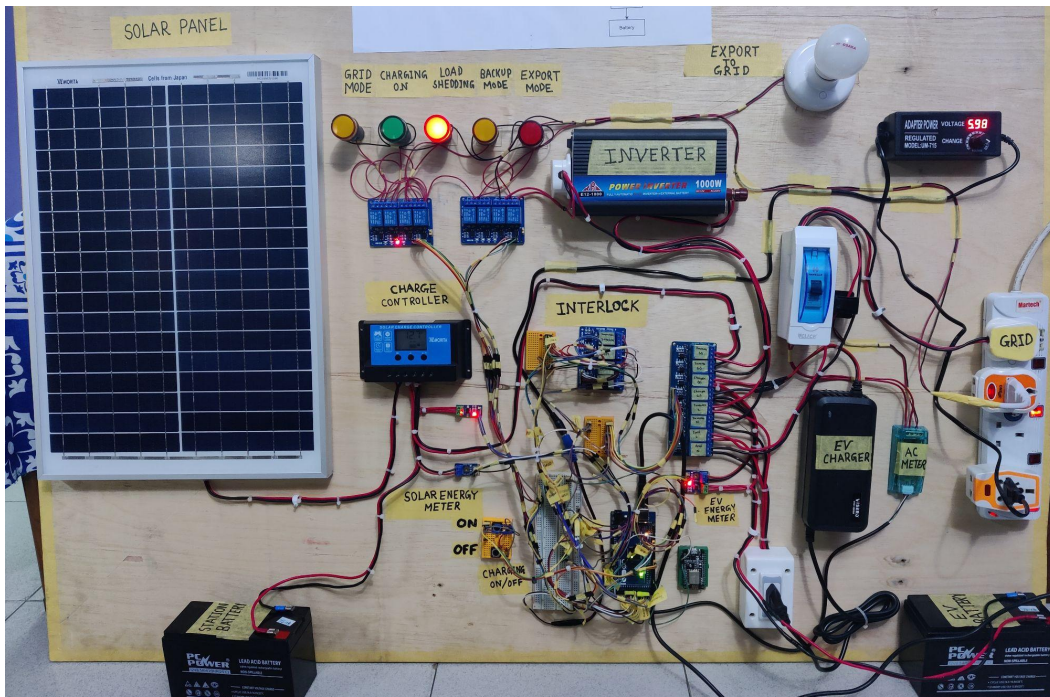


Fig. 5.3.4. Charging OFF, grid is unavailable, load shedding scenario

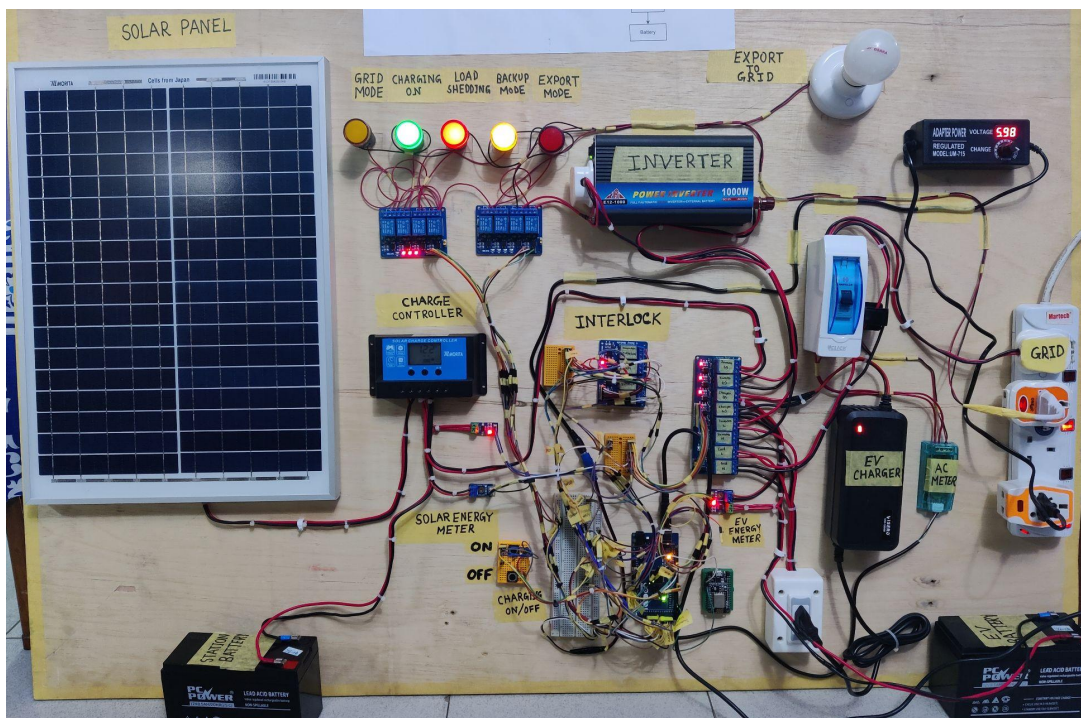


Fig. 5.3.5. Charging ON, grid is unavailable due to load shedding,
EV battery charges from inverter using station batteries

5.3.4 Export mode

When we turn on export mode, the export LED would turn ON and the inverter supplies power to the grid. The export bulb lights up, indicating that power is being exported to the grid, as seen below in Fig: 5.3.6. Thus, we concluded that the export mode is working as expected.

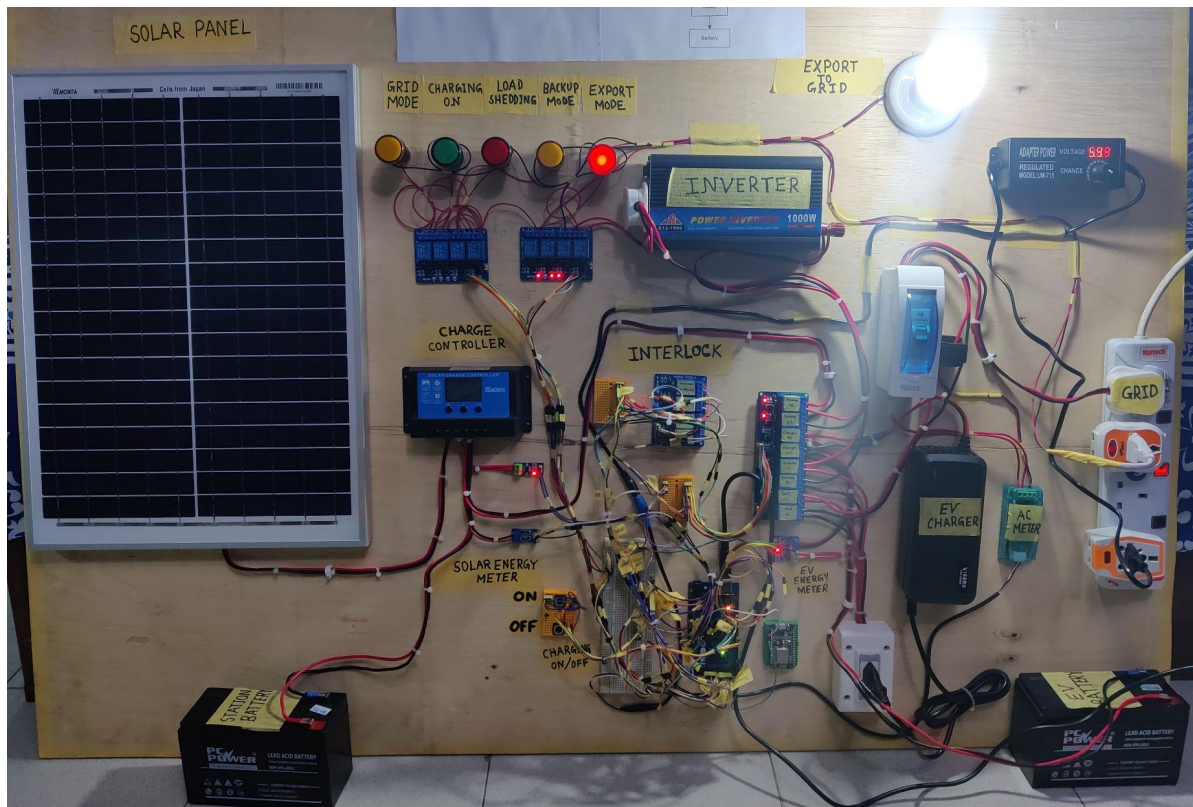


Fig. 5.3.6. Export mode ON, power is exported to the grid (shown via export bulb)

5.3.5 Switching between grid mode and inverter mode

To test the switching between modes while charging is active, we first charge the EV battery using the grid mode (Fig: 5.3.7.). Then the grid is switched OFF. The system responded by switching to the inverter mode (Fig: 5.3.8.). Once grid power is back, the system reverts back to the grid mode. Thus, we concluded that the switching between grid mode and inverter mod is working as expected.

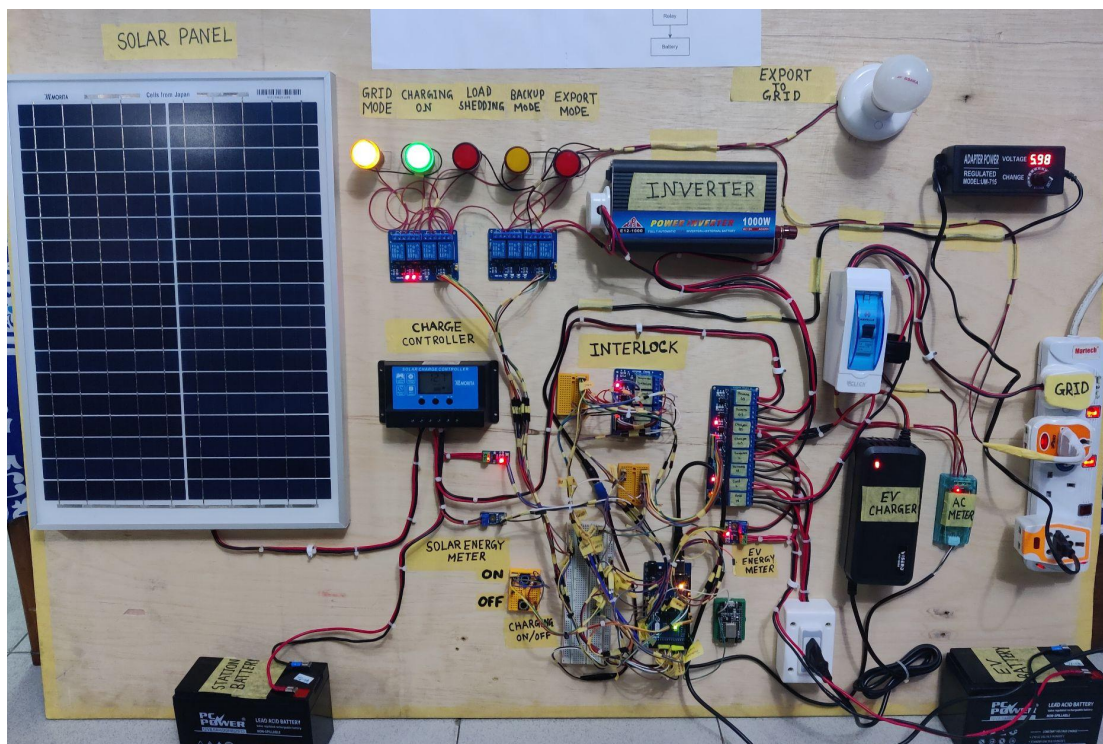


Fig. 5.3.7. Charging ON, grid is available, EV battery charges from grid power

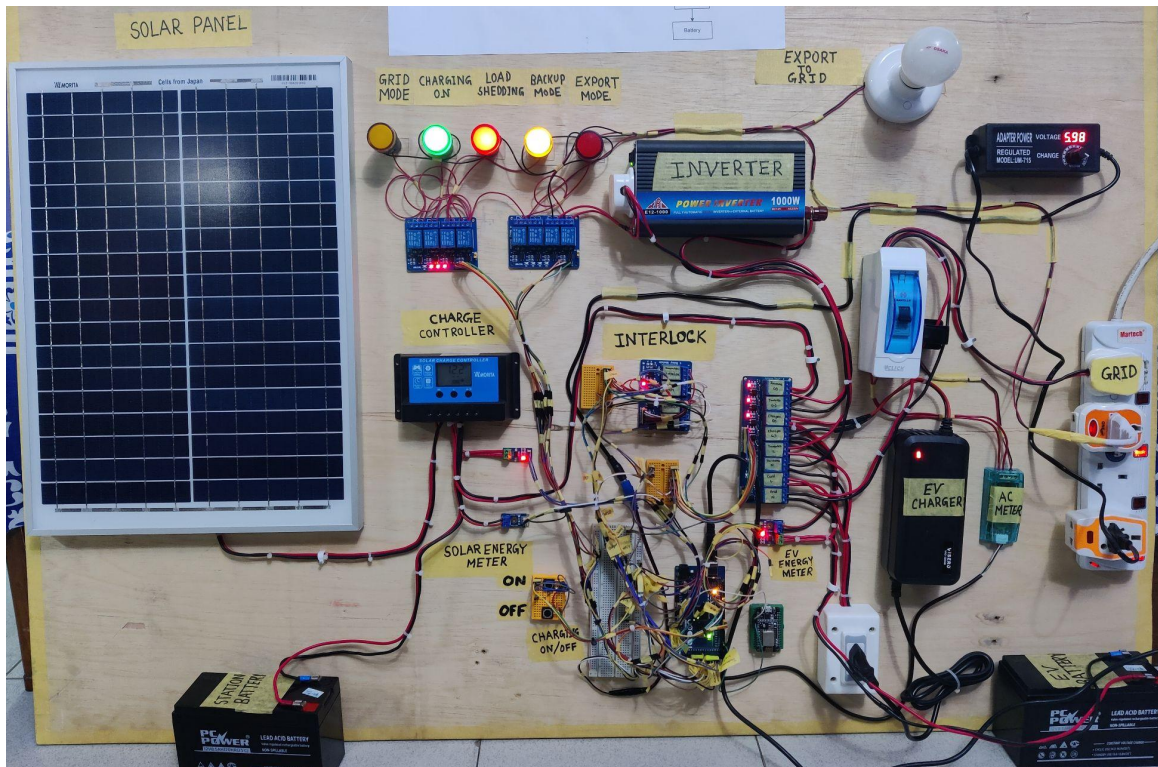


Fig. 5.3.8. Charging ON, load shedding trigger, system switches to inverter mode

5.3.6 Real time data transmission to web server

We connected the NodeMCU to the internet and observed that data is successfully transmitted to the web server, with a sampling rate of around 1 second. The data transmitted are: solar panel voltage and current, EV charging voltage and current, grid voltage, current, power, energy, frequency and power factor. In Fig: 5.3.9., we can see the web server showing the data, as well as the solar power output generated that day. Thus, the web server was working as expected.

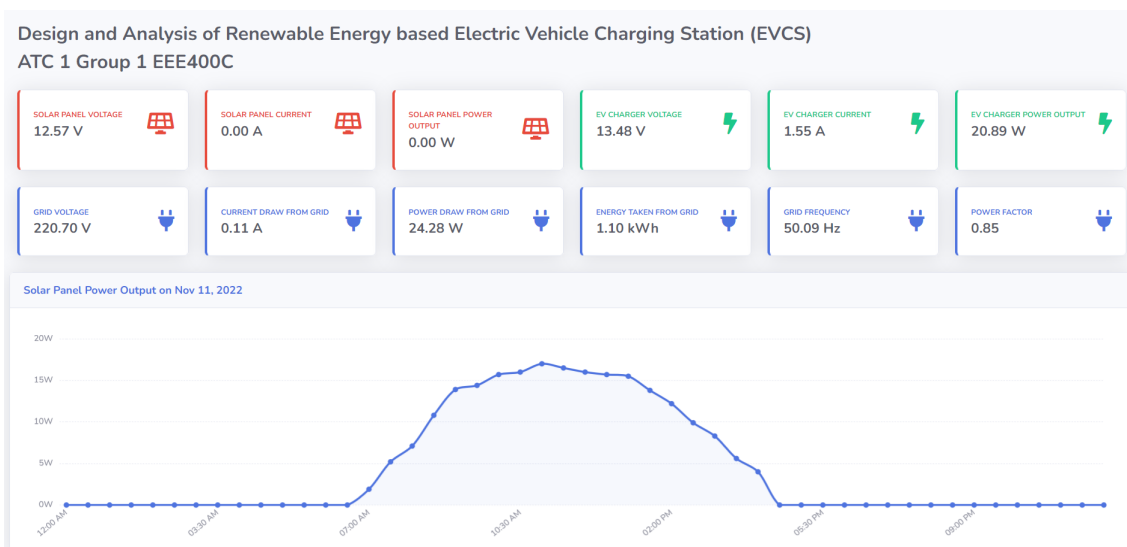


Fig. 5.3.9. Web server for real time data monitoring

5.3.7 Demand Side Management (DSM)

We have tested our system to see if the charging starts and stops at the off peak times. We set the start time to 12 am and the stop time to 6 am. The system turned on charging at 12 am and automatically turned it off at 6 am. Thus, we concluded that the Demand Side Management (DSM) is working as expected.

5.4 Conclusion

The prototype developed for this project demonstrated several key features that have the potential to contribute to the sustainability and reliability of electric vehicle charging stations. The use of solar power to charge the station batteries allows for a renewable energy source to be utilised, reducing the reliance on fossil fuels. The ability to charge easy bikes using the station batteries during periods of load shedding ensures that charging services can be maintained even in the event of power disruptions. The option to charge easy bikes from the grid during off peak hours allows for more efficient use of energy resources and can potentially reduce energy costs. The ability to upload data to a web server allows for remote monitoring and analysis of the charging station's performance. Finally, the ability to export power to the grid allows for excess renewable energy to be fed back into the grid, contributing to the overall sustainability of the energy system. Overall, these features demonstrate the potential for the prototype to be a valuable and innovative solution for electric bike charging

Chapter 6

Impact Analysis and Project Sustainability

6.1 Introduction

Every project, when it is first introduced has its share of effects that simultaneously make it strong and vulnerable. When we conducted an analysis of our project, we divided its effects into different categories such as societal, environmental, economical, health and legal that has been discussed in detail in the upcoming segment. Moreover, we have analysed our project in terms of SWOT (Strength, Weakness, Opportunities and Threats) analysis. The strengths of our project are it will significantly reduce air pollution and greenhouse gas emission when people will be shifting their fuel based cars to electric vehicles. Since this is an energy efficient transport system, and to run an electric vehicle charging station (EVCS) , low operation and maintenance costs are required so the need for EVCS will increase day by day. However, there are possible weaknesses as well which include supply and demand being unable to meet when there is load shedding, there are various EV charging fees which are growing annually and the duration that it takes to charge an EV is about 6-8 hours. Also, the number of accidents for the use of EVs, especially for easy bikes are also on the rise in Bangladesh [7]. On the other hand, building EVCS will lead to increased employment and people all over the world will be shifting to EVs. Foreign countries are already shifting their fuel-based cars to EVs [8]. Summing up, the drawbacks are few which cannot outweigh the advantages it has over building an EVCS so we believe that it will be beneficial for not only the customers but also for the government in the long run as load on the grid will be reduced during peak hours.

6.2 Assess the impact of solution

A brief analysis on the impact of renewable energy based EVCS has been shown based on the societal, environmental, economical, health and legal issues.

6.2.1 Societal

People could have an easier transition from internal combustion engines to EVs if they had more convenient charging options, as more charging stations become available. This would allow them to travel longer distances in their EVs which previously they could not do due to lack of charging stations. Moreover, there would be less load shedding to an area due to low grid dependency of the EVCS, which would result in a higher quality of life for people. Finally, less unemployment in the society could be seen, as some manpower will be needed to maintain and operate the EVCS.

6.2.2 Environmental

Electric vehicles (EVs) offer a number of environmental benefits, such as reduced greenhouse gas emissions and air pollution. This is because they are powered by clean and renewable solar energy, and no fossil fuels are burnt to charge them. Additionally, as people start to use more EVs, less extraction of non-renewable fossil fuels is required. Thus, the use of EVs is an effective way of reducing the environmental impacts of transportation.

6.2.3 Economical

The introduction of electric vehicle charging stations (EVCS) has the potential to bring about a lot of positive changes in the economy. It will create employment opportunities, leading to an increased standard of living. Additionally, it will reduce the need for importing

non-renewable fossil fuels, saving our reserve of foreign currency. It is also more cost effective to travel with EVs, as it reduces transportation costs. Furthermore, the low grid dependency of EVCS means that less electricity needs to be imported from other countries. If successfully implemented, this project will provide a new dimension to the renewable sector in the industrial prospect.

6.2.4 Health

The use of renewable energy sources can help reduce emissions of harmful gases like nitrogen oxides, sulphur dioxide, and carbon dioxide. This, in turn, can lead to a reduction in the number of respiratory and cardiovascular diseases since no particulate matter is produced. Utilising renewable energy sources is a great way to help protect the environment and keep people healthy.

6.2.5 Legal

As more people start to use the proposed EVCS, the number of illegal charging stations will reduce, resulting in less electricity theft from the grid and lower system loss. To ensure that EVCS are established in a safe and responsible manner, distribution companies will create specific guidelines for the establishment of EVCS. This will help to ensure that EVCS are used correctly and safely.

6.3 SWOT Analysis

To monitor a situation or to do market analysis, SWOT analysis is an essential tool. SWOT stands for Strengths, Weaknesses, Opportunities and Threats. The internal factors are strengths and weaknesses while opportunities and threats are the external factors [8].The impact of renewable energy based EVCS are shown below upon SWOT analysis:

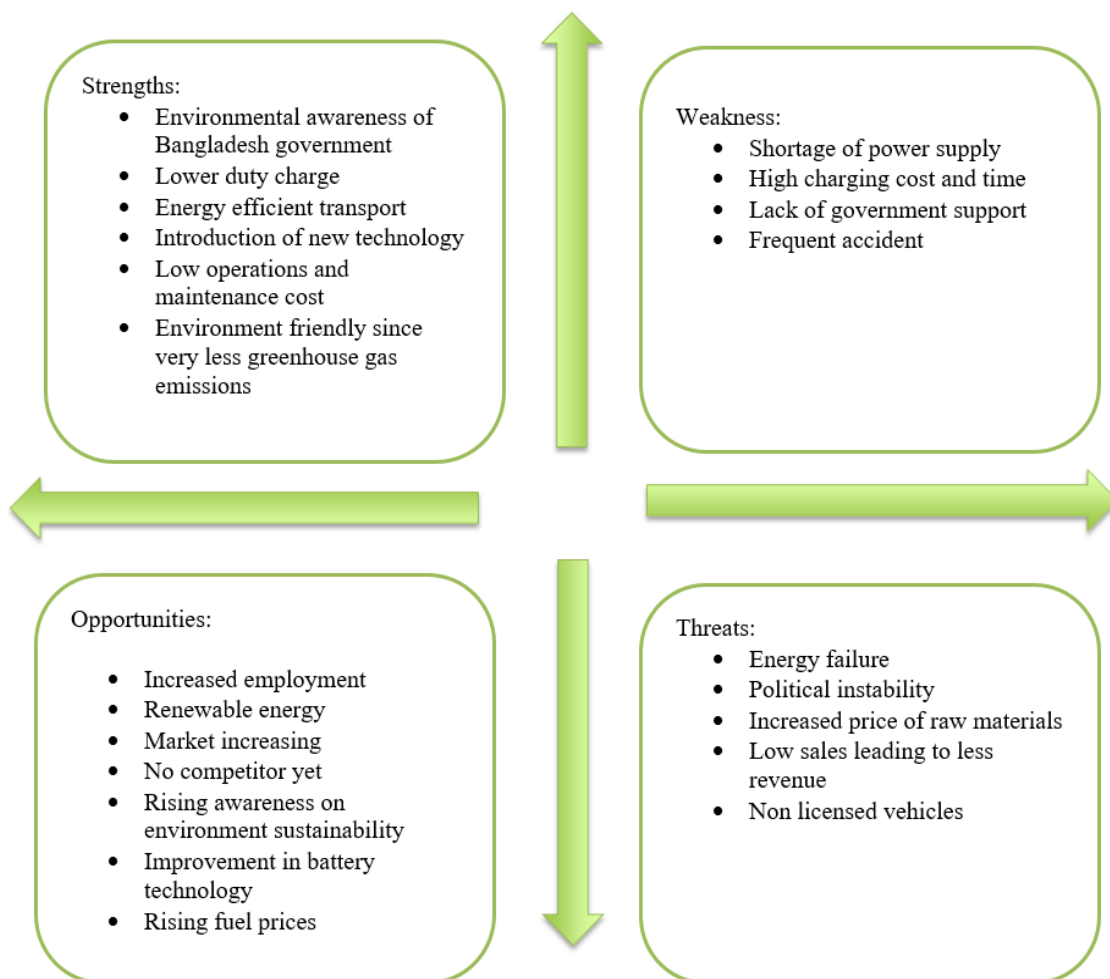


Fig. 6.3.1. SWOT Analysis

6.3.1 Strengths

Electric vehicle charging stations possess numerous potential strengths that would benefit not only the customers of Bangladesh but also the government as it will reduce air pollution by a significant amount once all the vehicles are electric-based. Bangladesh signed the Historic Paris Climate Agreement at the United Nations on 22 April 2016 [8]. Through its resources and international collaboration, the Bangladesh government has announced a number of efforts to adapt to climate change in a proactive manner. Moreover, Plug-in electric vehicles do not produce carbon dioxide. It contributes to keeping the globe clean and free of emissions, as well as reducing the greenhouse effect so the demand for the electric vehicle charging stations is high for all these electric vehicles. Foreign countries are already shifting their fuel-based cars to EVs. Every country's economy in the modern world is reliant on fossil fuel. However, the supply of fossil fuel is depleting on a daily basis. As a result, individuals are attempting to develop fuel-efficient technology such as electric vehicles (EVs). In an electric vehicle about 59–62 percent of the electrical energy from the grid is converted to power at the wheels [8]. The government of Bangladesh is supporting the use of electric vehicles. The charges for imported electric vehicles will be reduced by 15–50 percent. Because this technology is still new and Bangladesh is unfamiliar with it, the company that brings it here will have a higher chance of attracting clients and capturing the market [8]. So, the need for charging stations will be increasing rapidly in Bangladesh.

6.3.2 Weaknesses

Load shedding happens in different parts of Bangladesh given the difference between maximum demand and supply. Around 9% of electricity is lost owing to auxiliary use at generating stations, transmission and distribution networks. As a result, supply and demand are unable to meet, and load shedding occurs [7]. The daily load curve of Bangladesh

demonstrates that during peak hours (5 p.m. to 11 p.m.), the load increases, and during off-peak hours (11 p.m. to 5 p.m.), the load decreases. However, the increased electrical consumption caused by electric vehicles puts additional strain on the system, particularly during peak hours. Therefore, the shortage of power supply is an obstacle for electric vehicle charging [7]. In Bangladesh, a complete charge of an electric auto-rickshaw/easy bike requires 120 to 150 BDT per day. There are also various EV charging fees, which are growing every year [7]. Furthermore, this charging takes 6 to 8 hours every day. The majority of electric vehicles in Bangladesh have a speed issue. People are anxiously anticipating technology that will fix these issues. In Bangladesh, the average speed of electric vehicles is 20 kilometres per hour. The usage of electric vehicles (mostly easy bikes and auto-rickshaws) is forbidden in Bangladesh, according to the government, and the use of these vehicles is discouraged. These electric vehicles use a lot of electricity, which puts extra load on the power grid. EV lacks a well-defined database and registration process. However, according to recent observations, the electricity industry is operating a number of EV charging stations in various parts of Bangladesh. As a result of the absence of government assistance, it is difficult to expand the use of electric vehicles. Nowadays, it is common to observe traffic accidents caused by electric EVs all throughout Bangladesh. Due to the lack of a dedicated road for these cars and the fact that EV drivers are mostly inexperienced, road accidents occur on a daily basis [7].

6.3.3 Opportunities

There is an increased employment opportunity for engineers, workers and experts from different fields for building and maintaining these electric vehicle charging stations. One of the most important aspects of EV is energy, specifically electricity. Bangladesh lacks energy security. However, there is reason to be optimistic because Bangladesh has already made

certain efforts and has a master plan in place to create renewable energy based power plants [8]. The global vehicle market is growing at a steady pace. Bangladesh has also experienced progress in recent years. A total of 4,68,706 automobiles were registered in 2017–2018. The next year, there were 5,24,016 automobiles. As a result, this is a positive sign for the vehicle industry of Bangladesh [8]. Yearly, the number of automobiles that are getting imported is increasing substantially and there is a high chance of more EVs to enter Bangladesh due to the increased demand of EVs. So to charge this huge number of EVs we need to implement more electric vehicle charging stations. Bangladesh is a large market with a lot of potential. There are around 160 million people living here. However, there is currently no potential firm in the EV industry. As a result, the market is completely unsaturated [8]. Through its resources and international collaboration, the Bangladesh government has announced a number of efforts to adapt to climate change in a proactive manner. So, Bangladesh is quite permissive to taking any supporting role for the environment's welfare, which means that any organisation can launch an electric vehicle business in Bangladesh [8]. Thus, it leads to increased awareness of environmental sustainability. Lead-acid batteries are popular in Bangladesh due to their relatively inexpensive cost. Although lead-acid batteries have a number of disadvantages, such as being unable to discharge more than 20% of their nominal capacity, having a low power density, being heavy, having a shorter life cycle, and so on. Lithium-ion batteries, on the other hand, have several advantages over lead-acid batteries, including high power density, extended life, and strong performance at higher temperatures. Therefore there is an opportunity to improve battery technology by means of using Li-ion batteries. Using Li-ion batteries will increase the range and decrease the charging time due to which people will be more keen towards usage of EVs and hence the demand of EVCS will increase. Lastly, the stock of fossil fuels is decreasing day by day so the price is increasing.

Hence, the use of electric vehicles is the alternative to replace all the current fossil fuel-based vehicles.

6.3.4 Threats

Bangladesh has a scarcity of power sources and charging stations due to its underdevelopment. Electric vehicles are fully reliant on electricity. Bangladesh has a single national grid with a total installed capacity of 25,514 MW. However, demand exceeds supply, and demand is increasing every day. Bangladesh has seen a lot of political violence since the 1971 independence struggle. It had a devastating effect on both the market and progress. Political instability has had a significant impact on the country's market, therefore it is a major source of concern for threats. Electric vehicles (EVs) represent a new era of technology in the worldwide globe. Because this technology is relatively new to the market, there may be a shortage of supply of parts. This technology is still in its early stages of development, therefore people might not feel comfortable owning electric vehicles, thus reducing the requirement to build EVCS [8]. In the BRTA (Bangladesh Road Transport Authority), there are no regulations for registering electric vehicles. However, there should be a regulatory framework in place to promote a sustainable environment through the usage of energy-efficient EVs [7].

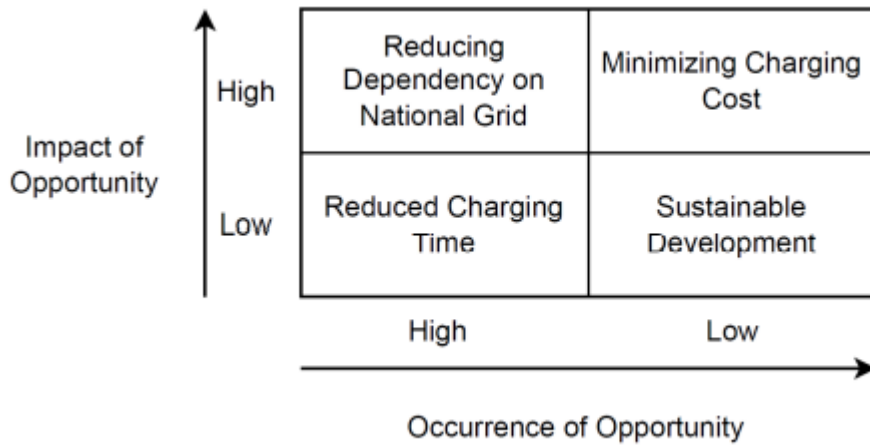


Fig. 6.3.2. Opportunity Matrix

6.4 Evaluate the sustainability

The charging stations system's actual implementation poses sustainability concerns that need to be thoroughly examined and assessed from a variety of angles. Several sustainability-related concerns have been assessed in terms of their effects on the social, environment, the economy, and society.

6.4.1 Social Aspects towards Sustainability

To address the social elements of sustainability, EVs provide a variety of activities, such as pleasant service providing, chances for social mixing, and increased mobility. The majority of passengers are content with the social features, particularly the mobility of the easy bikes. 88% of consumers value the function of simple bikes because of the greater service coverage and well-connected servicing facilities. In addition, the majority of passengers (56%) believe that easy-bike service is more pleasant than other forms of public transportation including buses, vans, and rickshaws, while just 37% believe that it is less comfortable since it can only

fit 6 people at a time. However, these easy bikes make it easier for people from different socioeconomic groups and genders to interact socially. Therefore, 48% of respondents believe it has a significant good influence on social mixing. However, the majority of passengers (51%) are dissatisfied with the safety features believing that frequent bike accidents result from unrestrained movement and poor administration. [9]

6.4.2 Economic Aspects towards Sustainability

According to our field survey the cost per full charge is about 120-150 BDT. The average cost for each trip varies within 20-40 BDT and in Khulna City Corporation (KCC) within the FCC's jurisdiction, the service fee for passengers is just, on average, 15-20 BDT each visit and 5 BDT per kilometre. (Field survey, 2017). [9] As a result, the majority of passengers are content with the service price that is being supplied and believe it to be fair and affordable. Our target audience is the people who use easy bikes for earning their livelihoods and it is our target to minimise the costing of 120BDT mark so that the charging becomes more affordable and hence the fare also reduces for passengers using the easy bikes. This project tends to be beneficial for the grid as well and hence helpful for the government in the process. As observed earlier, the grid's evening peak occurs between 9 p.m. and 12 a.m. Our survey revealed that the easy bikes are charged between the hours of 9 p.m. and 6 a.m., indicating that they are adding to the grid's burden during these times.

Bangladesh is well-suited for renewable energy sources like solar energy because of its geographical location. A BESS and renewable energy generation at the charging station will make the system grid-independent. It would ease the strain on the grid during peak hours as the simple bikes wouldn't need to be powered by the grid anymore. As found from the PVsyst

software analysis, the financial cash flow for an on grid system is positive in the long run and the cash flow increases exponentially.

6.4.3 Environment Aspects towards Sustainability

Easy bikes produce very little pollution compared to motorised vehicles that are powered by petrol or diesel. 83% of the passengers admire the contribution of easy bikes towards air pollution [9]. Since easy bikes contribute less to environment pollution, emit no greenhouse gases, the need for EVCS will be more, therefore our project will help in keeping a cleaner environment. Hence the harmful effects and diseases such as bronchitis, pulmonary disease, stroke and other related diseases will diminish. When lithium ion batteries lithium-ion has served their purpose, disposing of them properly raises serious environmental issues. By opting for an on-grid system rather than an off-grid or hybrid system, we were able to fully eliminate the usage of batteries in order to make our project ecologically friendly.

6.5 Conclusion

The extent to which a project is sustainable is a factor in determining its efficiency. It is not worthwhile to put time, effort, and money on something that will not last for a long time. In the same way, we carefully examined our project to see how much sustainability it exhibited. Thankfully, ours is very sustainable in all three areas: socially, economically, and environmentally. This is due to the fact that it would have no negative environmental consequences of any kind such as nuclear waste of any kind or air pollution caused by the discharge of gases like carbon dioxide.

Chapter 7

Engineering Project Management

7.1 Introduction

In order to successfully execute an engineering project, it is essential to understand the components of effective engineering project management. This includes efficient use of resources, reduction of waste, and quickly and effectively achieving project goals. Project management experts create practical and effective project plans by utilising cost estimates, project schedules, and project lifecycle. This helps them identify and mitigate the risks associated with a project such as financial limitations, time constraints, and access to resources. By understanding the components of high-quality engineering project management, it is possible to plan a successful project journey and minimise the risks involved.

7.2 Define, plan and manage engineering project

An engineering project manager has a wide variety of responsibilities to fulfil in order to ensure that their team completes projects on schedule and within allocated budgets. Engineering project management is the method used by managers to maintain control over their projects, aiming to make sure that team members can accomplish the project's ultimate goals as well as steer the scope of a project in the appropriate direction. To do this, project managers need to employ a variety of abilities, both general managerial abilities and those that are more particularly pertinent to someone working in the engineering industry. The work involved in an engineering project may be realistically completed by working group members, but the engineering project manager is tasked with assisting this work, as the

completion of an engineering project is a substantial undertaking that calls for a high degree of cooperation.

In the project, three main phases were identified; topic selection, designing, and prototype development. To cover these phases, three stages were allocated to EEE400P (problem selection), EEE400D (software development), and EEE400C (hardware implementation). Every step required the completion of specified tasks, which were depicted using Gantt charts to show the amount of time allocated for each step. A log book is also kept to track the development every time a peer discussion or a conversation with the project coordinator takes place. Initially, the Gantt charts for EEE400P, EEE400D, and EEE400C were created during the EEE400P course. The projected schedule and tasks in the Gantt charts were based on the one year projection. Subsequently, the EEE400P and EEE400D Gantt charts were updated, and the project progression in each course was assessed accordingly. The EEE400C Gantt chart was also updated to adhere to the timetable and monitor the project advancement of the implementation stage. Technical issues have caused some delays in the plans and tasks, but these were soon covered up when the drawbacks were mitigated.

7.3 Evaluate project progress

The following Gantt chart shows our plan for EEE400C and the actual workflow throughout the semester.

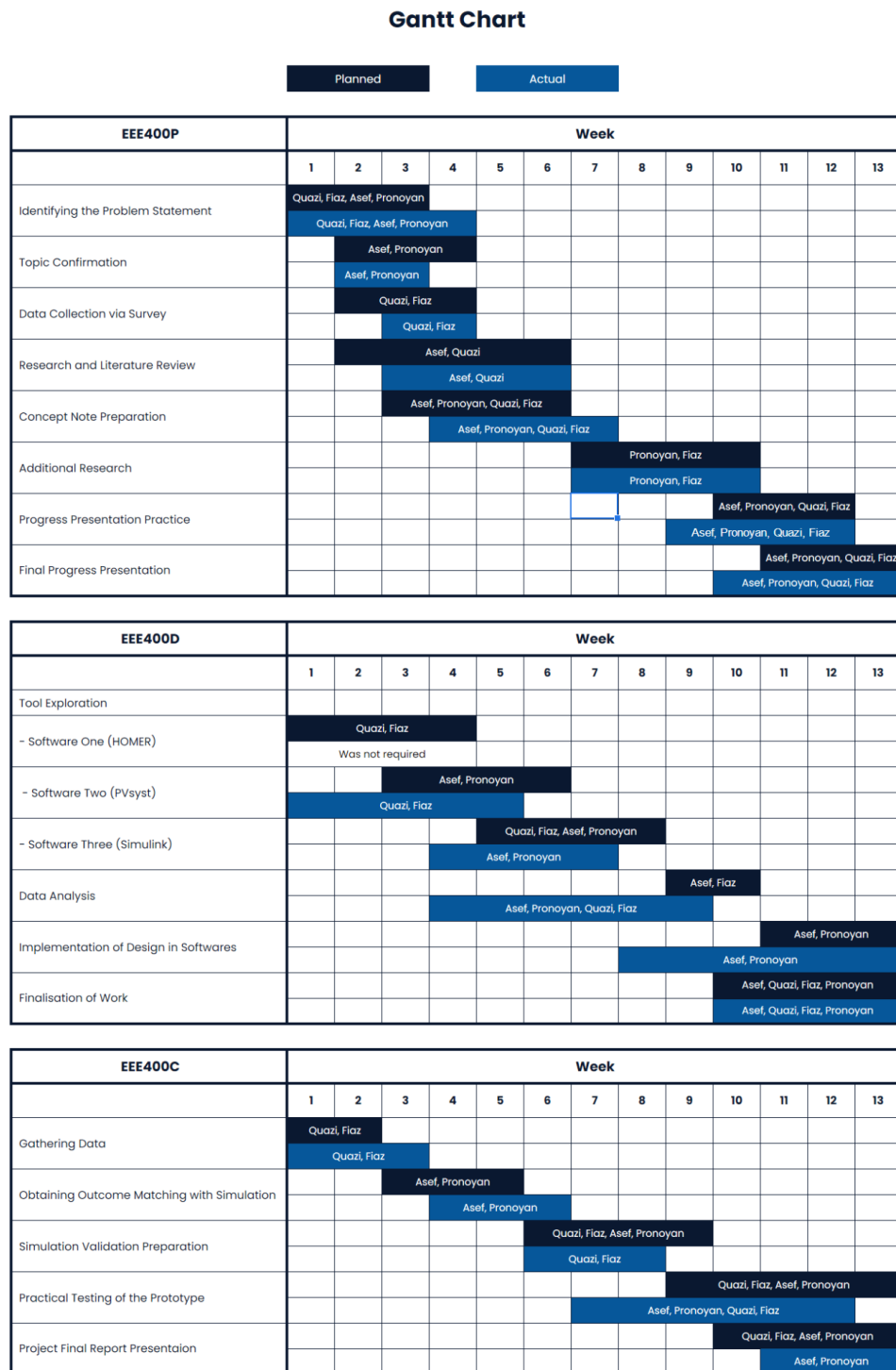


Fig. 7.3. Gantt Chart

From the Gantt chart, we can see that we were able to follow the timeline we have set and end the project in a timely manner. There were some delays every now and then caused by unforeseen events.

7.4 Conclusion

The successful completion of tasks in EEE400P, EEE400D and now EEE400C has been achieved due to the efficient management of the timeline and gantt charts distributed among members. The logbook has also played an important role in keeping track of the progress and ensuring that all tasks are completed in due time. Time management has been a key factor in the smooth completion of the project, as working as a team and supporting each other has proven to be essential in its development. With these factors in place, we have been able to achieve the desired satisfactory results in the timeline given.

Chapter 8

Economical Analysis

8.1 Introduction

Economic analysis is an important part of engineering projects, as it can provide an accurate representation of the cost and benefit associated with implementing a given project. Economic analysis can help to identify potential cost savings or inefficiencies associated with a project, and can also help to identify potential revenue streams that can be generated by the project. With economic analysis, engineers can better understand the financial implications of their projects, and make informed decisions about how to proceed. Additionally, economic analysis can also provide insight into the potential risks associated with a project, and can help to identify potential strategies for mitigating those risks. Ultimately, economic analysis is a critical tool for engineers that can help to ensure that their projects are implemented in a cost-effective and profitable manner. We have chosen to perform our economic analysis by analysing our real scenario budget in PVSyst to see whether the profit generated by the charging station would be enough to make it profitable feasible.

8.2 Economic analysis

TABLE 8.1. REAL SCENARIO BUDGET

Subsystem	Component	Model	Quantity	Cost per quantity	Total cost	Comment
Solar	Solar Panel	Longi Solar LR5-72HPH-545M	32.7 kWp	23,500 BDT for 545Wp	14.10 lac BDT	SREDA approved component and meets our requirement
	Grid-tied Inverter with MPPT Charge Controller	Huawei SUN2000-12 KTL-M2	2 x 12kW unit	2.10 lac BDT per 12kW unit	4.20 lac BDT	SREDA approved component and meets our requirement
	Battery Storage	Need to be custom made	40 kWh	11,500 BDT per kWh	4.60 lac BDT	Off the shelf Li-ion batteries do not meet our requirements. Average price per kWh was used for calculation.
Charging	Easy Bike Charger	Generic Charger	10 pcs	1,490 BDT	14,900 BDT	No reputed manufacturer was found
	NEMA 14-50 Receptacle	ENERLITES 50 Amp 125/250V	10 pcs	3,450 BDT	34,500 BDT	Has very good user reviews and is robust. Price is also competitive.
Safety & Protection	Overcurrent Protection	Siemens MCCB	5 pcs	8,500 BDT	42,500 BDT	Products manufactured by Siemens are reliable, robust and industry leading
	Ground Fault Protection	Siemens GFCI	10 pc	4,000 BDT	40,000 BDT	Have very accurate measuring capabilities, very short trip time
	Fire Extinguisher	ABC Dry Powder	5 x 2 kg	900 BDT per 2 kg cylinder	4,500 BDT	Relatively cheap and readily available. Most popular in the market.
	Fire/Smoke Alarm	Fire alarm system - 2 zone	5 pcs	5,000 BDT	25,000 BDT	Generic fire alarm system
Contingency Cost				10% of overall cost	2.45 lac BDT	To cover up potential costs that was not accounted for in initial stages
Total cost					27.00 lac BDT	

TABLE 8.2. PROTOTYPE BUDGET

Subsystem	Component	Model	Quantity	Cost per quantity	Total cost	Comment
Solar	Solar Panel	Morita 20W (12V, 1.5A)	1 pc	1,400 BDT	1,400 BDT	Generic 12V solar panel
	PWM Charge Controller	Morita (12V, 10A)	1 pc	650 BDT	650 BDT	Generic PWM charge controller
	Battery Storage	PC Power 12V 8.5Ah	2 pcs	1,500 BDT	3,000 BDT	Generic SLA battery
Charging	SLA Battery Charger	Visero VIO-1205B	1 pc	850 BDT	850 BDT	Accepts AC power at input to charge the EV
Export	Inverter	1000W	1 pc	1,500 BDT	1,500 BDT	
Control	Microcontroller	Arduino Mega	1 pc	2,600 BDT	2,600 BDT	It has 16 analog inputs
		ESP8266	1 pc	450 BDT	450 BDT	Connects Arduino to WiFi
	Voltage Sensor	Generic	2 pcs	160 BDT	320 BDT	Generic Voltage sensor
	Current Sensor	ACS712	2 pcs	250 BDT	500 BDT	Generic Current Sensor
	AC Meter	PZEM-004T	1 pc	3,300 BDT	3,300 BDT	Can measure AC voltage, current, frequency and P.F.
	8 Channel Relay Module	Generic	1 pc	450 BDT	450 BDT	Generic 8 channel relay module
	4 Channel Relay Module	Generic	3 pcs	280 BDT	840 BDT	Generic 4 channel relay module
	RTC Module	DS3231	1 pc	450 BDT	450 BDT	Has integrated temperature compensated crystal oscillator and crystal
	Push Button Switch	Generic	2 pcs	10 BDT	20 BDT	Generic push button switch
	Status LED	Generic 220V Circular Indicator	5 pcs	60 BDT	300 BDT	Glow brightly, has better visibility
Safety and Protection	SP Circuit Breaker	Havells 2A Type C	1 pc	350 BDT	350 BDT	2A of current was sufficient for our prototype
	Jumper Wire	Generic	6 set	80 BDT	480 BDT	Generic component
	Electrical Wire	1.5 mm	35 m	20 BDT	700 BDT	Generic component

Miscellaneous	2 Pin Socket	Superstar P-03	1 pc	40 BDT	40 BDT	Generic component
	3 Pin Plug	Generic 13A	3 pcs	100 BDT	300 BDT	Generic component
	Bulb	5W LED (E27)	1 pc	150 BDT	150 BDT	Generic component
	E27 Bulb Holder	Generic	1 pc	60 BDT	60 BDT	Generic component
	PVC Tape	Generic	1 pc	20 BDT	20 BDT	Generic component
	Wooden Board	4 ft. x 3.8 ft.	1 pc	800 BDT	800 BDT	Generic component
Contingency Cost				10% of overall cost	1,953 BDT	To cover up potential costs that was not accounted for in initial stages
Total cost					21,483 BDT	

These are the budget for both real scenario and prototype model. We input these parameters into PVSyst to conduct a cost benefit analysis.

8.3 Cost benefit analysis

We used PVSyst to evaluate the financial aspects of our real scenario project. In PVSyst, we have inputted the cost of the components as well as some additional parameters. The amount of energy produced by a PV system is directly linked to the amount of sunlight that reaches the solar panels. Soiling loss occurs when dust, dirt, and other debris accumulate on the panels, blocking sunlight. This loss can be significant, depending on the region the system is located in. Factors like wind, dirt, rain, bird populations etc. all have an effect on the amount of soiling loss. We set the soiling loss to 3%. The electricity production of solar panels degrades over time. For that, we set the module degradation to 0.4% per year. Solar panels are usually only rated for 30 years of operation, after which their efficiency reduces drastically. Therefore, we set the project lifetime to 30 years, since the solar panels, and batteries need replacing after that.

According to Bangladesh Bank, Bangladesh had an average inflation rate of 5.54% in December of 2021. Therefore, we set the inflation rate in PVSyst to 5.54%. From our survey, we have found that charging stations have a rate of around 150 BDT for charging one easy bike. Each easy bike has a battery capacity of 10 kWh. Therefore, the cost of electricity sold to the easy bikes is 15 BDT/kWh. In order to remain competitive with other charging stations, we have also chosen to fix the rate to 15 BDT/kWh. We have also set the depreciation rate for the equipment at a straight line method for 30 years.

After analysing the project in PVSyst using the above parameters, the payback period of the charging station came out to be 5 years. The return on investment (ROI) was 340%. Therefore the project is feasible.

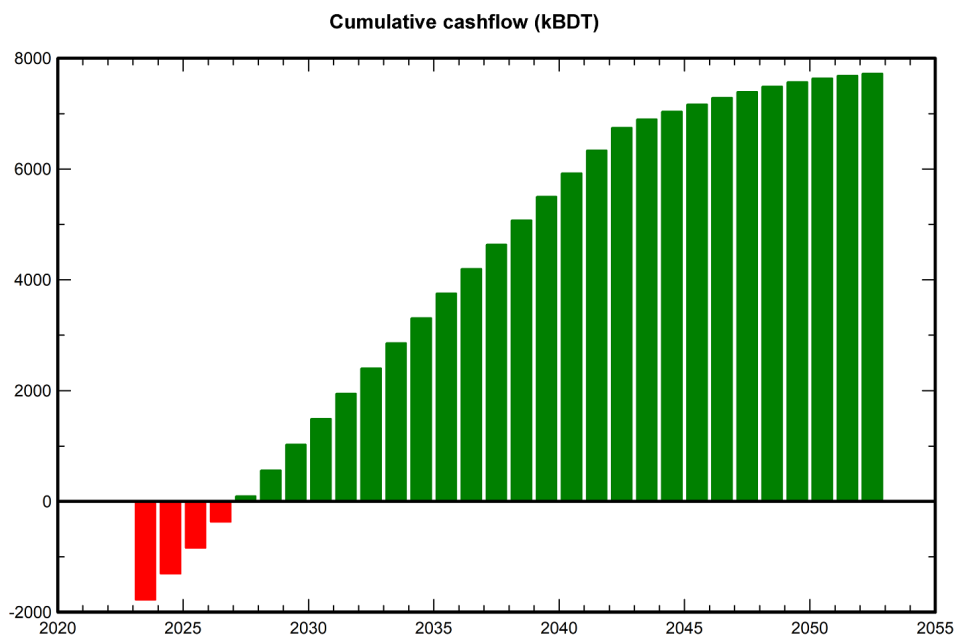


Fig. 8.3. Cumulative cash flow graph from PVSyst

8.4 Evaluate economic and financial aspects

While the initial investment of the project is high, we can see that after 5 years, the charging station is able to generate a net positive cash flow. It should be noted that the solar panels and battery degrade over time. We can see that after 20 years, the panels have degraded which caused the annual profit to decrease. After 30 years, the panels and batteries should be replaced as operating the charging station using degraded panels would result in a loss.

8.5 Conclusion

After analysis, we can see that the project is able to generate profits based on the given parameters. Conducting the economic analysis allows the project team to make informed decisions regarding the cost and feasibility of a project, and to identify potential risks and opportunities. It helps to ensure that the project is financially viable and that it will yield the desired outcome. It also helps to identify ways to reduce costs and increase returns, while ensuring that the project is within budget. By taking an economic approach to engineering projects, project teams can ensure that their projects are successful and cost-effective.

Chapter 9

Ethics and Professional Responsibilities

9.1 Introduction

Ethics and professional responsibilities are the ethical principles and standards of behaviour that guide the work of engineers in the profession. They cover the duties of engineers to their employers, clients, the public, and the profession itself. They are based on the values of honesty, integrity, respect, responsibility, fairness, and concern for the public good. These principles are intended to ensure that engineers act with integrity, maintain public trust, and use their knowledge and skills for the betterment of society.

9.2 Identify ethical issues and professional responsibility

There are several ethical issues and professional responsibilities that may arise in the context of a renewable energy based electric vehicle charging station. Some of them are:

9.2.1 Environmental responsibility

As a provider of renewable energy solutions, the charging station has a professional responsibility to minimise its environmental impact and contribute to the transition to a low-carbon transportation sector. This may involve taking steps to minimise the use of resources, reduce waste, and protect natural habitats.

9.2.2 Consumer protection

The charging station has a responsibility to protect the interests of its customers and provide them with accurate and transparent information about the services it offers. This includes ensuring that customers are charged fairly for the electricity they use and that any fees or charges are clearly communicated.

9.2.3 Health and safety

The charging station has a responsibility to ensure that its operations do not pose a risk to the health and safety of employees, customers, or the general public. This may involve implementing appropriate safety measures and procedures, as well as providing training and resources to employees.

9.2.4 Data protection

As a provider of charging services, the charging station is likely to collect and process personal data from its customers. It has a responsibility to protect this data and ensure that it is used in accordance with relevant laws and regulations, such as the General Data Protection Regulation (GDPR).

9.3 Apply ethical issues and professional responsibility

The charging station should consider implementing the following measures to apply the ethical issues and professional responsibilities:

9.3.1 Environmental responsibility

The charging station can take steps to minimise its environmental impact by implementing energy-efficient technologies, using eco-friendly materials, and implementing waste reduction and recycling programs. It can also consider offsetting any carbon emissions that may be associated with its operations.

9.3.2 Consumer protection

The charging station can protect the interests of its customers by providing clear and transparent information about its pricing, terms, and conditions. It can also implement policies and procedures to handle customer complaints and concerns in a fair and timely manner.

9.3.3 Health and safety

The charging station can ensure the health and safety of its employees, customers, and the general public by implementing appropriate safety measures and procedures. This may include providing training and resources to employees, maintaining equipment and facilities, and implementing emergency response plans.

9.3.4 Data protection

To protect the personal data of its customers, the charging station can implement appropriate security measures, such as encryption and secure storage, to protect data from unauthorised access or misuse. It can also ensure that it is in compliance with relevant laws and regulations, such as the GDPR, which requires businesses to obtain consent from customers before collecting and processing their personal data.

9.3.5 Additional responsibility

Apart from the points mentioned above, the EVCS will be connected to the grid as a backup power option, and it is important to follow all necessary requirements set by the distribution company and SREDA before doing so. A net meter should be used for backfeeding to the grid, and it is important to ensure that it is properly maintained and operated in order to prevent unintentional losses for both the distribution company and the charging station.

The cost of the solar system and battery storage takes up a significant portion of the budget. To ensure that the budget is not exceeded and the return on investment time is not prolonged, it is important to make sure that the equipment is not purchased at a price higher than its market value. One way to do this is by inviting importers of such components to participate in a tender process, which allows for competitive pricing and the opportunity to secure the lowest purchase price. This is a matter of ethical responsibility, as it involves making financial decisions in a transparent and responsible manner.

Application template for setting up electric vehicle charging station:

To,
The Chairman
Sustainable and Renewable Energy Development Authority (SREDA)
IEB Building, Moulana Bhasani Rd, Dhaka

Subject: Application for net metering.

I, the undersigned, am applying in the prescribed form for setting up an electric vehicle charging station.

Full name of the applicant:	
Address:	
Nationality:	
NID No.:	
Present address:	
Permanent address:	
Trade licence No.:	
Address of the charging station:	

Mention the following details in a separate paper and attach relevant documents herewith:

1. Type of charging station
2. Probable date of completion
3. Probable date of going in operation
4. Utility companies involved
5. Committee members
6. Source of funding
7. Instrument cost
8. Land area with details
9. Technical details of electrical equipments
10. Technical details of safety equipments

I hereby declare that all the information given above is true and correct and undertake to comply with the provisions of the Electric Vehicle Charging Directives.

I hereby undertake that we shall not sell, mortgage, directly, indirectly or through association any right, benefit or liability to any other person without the prior approval of the Government.

The Government reserves the right to cancel the licence/electricity connection in case of breach of this agreement.

[Date]

[Applicant's name, Designation and Signature]

9.4 Conclusion

Ethics and professional responsibility are crucial considerations in the operation and maintenance of an EVCS. This includes following necessary requirements set by regulatory bodies, ensuring proper maintenance and operation of equipment, and making financial decisions in a transparent and responsible manner. In addition, it is important to prioritise environmental responsibility by minimising the impact of the EVCS on the natural environment. Consumer protection is also a key consideration, as the EVCS should provide a safe and reliable service to its users. Health and safety must be a top priority, as the EVCS can have potential risks for both workers and users. Finally, data protection is essential, as the EVCS may handle sensitive personal and financial information that must be kept secure. Failing to uphold ethical and professional standards in these areas can have negative consequences for the EVCS, its stakeholders, and the community it serves. It is important for those involved in the EVCS to prioritise ethics and professional responsibility in order to ensure the success and sustainability of the system.

Chapter 10

Conclusion and Future Work

10.1 Project summary

To summarise the entire project, we have conducted research and survey on our problem and set requirements based on the problem statement. Once the requirements have been identified, multiplied design approaches were found that could be used to solve the problem. The design approaches were compared to find the best one. Then we used different engineering tools and softwares to identify and analyse the best solution of our chosen design approach. A scaled down prototype hardware implementation was then created, which was then tested to see if the performance of the system is as required. Lastly, an economic analysis was performed to see if the project was feasible.

10.2 Future work

While the prototype is working as intended, there remains further work to be done to improve and develop the system even further. Development on the system would make the system more reliable, robust and convenient for users. It would also ensure a more stable profit generation for the EVCS.

Control from the web server: Web server could be developed further such as viewing past charging sessions, starting and stopping charging using the web and generating an automated invoice for the charging session. Other features could be included such as user tracking, payment through MFS (e.g. bKash, Upay) etc.

Daily solar prediction using Machine Learning: Daily prediction of solar output could help to ensure that the station batteries could be charged via solar power. If solar power is predicted to be insufficient for the next day, off peak power could be used to charge the station batteries.

Integration with other renewable energy sources: The EVCS could be further integrated with other renewable energy sources, such as wind, in order to increase the overall sustainability and reliability of the system.

Optimization of energy storage: The EVCS could explore different energy storage technologies and configurations in order to optimise the system's ability to store and use renewable energy effectively.

Integration with smart grid technologies: The EVCS could be integrated with smart grid technologies in order to optimise the use of renewable energy resources and improve the overall efficiency of the energy system.

Improvement of charging speed: Research and development could be conducted to identify ways to improve the charging speed of the EVCS, in order to make the charging process more convenient and efficient for users.

Expansion of the system: The prototype could be expanded to include additional components or capabilities, such as the ability to charge additional types of vehicles or to support higher levels of demand.

Chapter 11

Identification of Complex Engineering Problems and Activities

11.1 Identify the attribute of complex engineering problem (EP)

TABLE 11.1. ATTRIBUTES OF COMPLEX ENGINEERING PROBLEMS (EP)

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

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

Depth of knowledge required:

Engineering fundamental and specialisation knowledge was used to design the project. While planning the project a good amount of research literature was studied to gather relevant information.

Range of conflicting requirements:

Charging a higher number of vehicles will increase the establishment cost which might not meet the budget specified by stakeholders.

Depth of analysis required:

Data collected from field survey and research literatures were analysed and 3 alternate design approaches were proposed and compared.

Extent of stakeholder involvement and needs:

Field survey conducted on stakeholders to collect data (easy bike drivers).

Interdependence:

The charging system is heavily dependent on the solar system as it operates by taking stored energy from the station batteries. The station batteries are charged by the solar system.

11.3 Identify the attribute of complex engineering activities (EA)

TABLE 11.2. ATTRIBUTES OF COMPLEX ENGINEERING ACTIVITIES (EA)

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

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

Range of resource:

Met with one of the stakeholders (easy bike drivers) to know their requirements. Overall project plan is designed (including budget with contingency and work-flow) to be completed within the project timeline.

Level of interaction:

The budget specified by stakeholders might force components with lower specification to be used, bringing down overall performance of the charging station.

Consequences for society and the environment:

There will be significant reduction in GHG emissions and less pollution in the environment.

People will have a higher quality of life due to increased employment and less load shedding.

References

- [1] M. M. Rahman and M. Z. R. Khan, "Solar Energy based Net Metered Easy-Bike Charging Station in Bangladesh," 2021 International Conference on Information and Communication Technology for Sustainable Development (ICICT4SD), 2021, pp. 220-224, doi: 10.1109/ICICT4SD50815.2021.9396847.
- [2] A. Md, I. A K M and K.Md, "Bangladesh Power System Peak Demand Shaving through Demand Side Management of the Battery Operated Easy Bike Load," presented at Electrical Information and Communication Technology (EICT),Khulna, Bangladesh, Dec. 20-22, 2019.
- [3] S. S.M., A. Muhammad, H.Md, "Designing a Solar Powered DC charging Station for Easy Bikes: Bangladesh Perspective," in International Conference on Advances in Electrical Engineering (ICAEE), Sept 2019.
- [4] Person and C. S. Nick Carey, "EU proposes effective ban for new fossil-fuel cars from 2035," Reuters, 14-Jul-2021. [Online].
<https://www.reuters.com/business/retail-consumer/euproposes-effective-ban-new-fossil-fuel-car-sales-2035-2021-07-14/>
- [5] R. Md, I. A.K.M, B.Abdullah and M.Abdullah, "A techno-economic assessment for charging easy bikes using solar energy in Bangladesh," presented at IUT, Gazipur, Bangladesh, Jan. 5-8, 2016, Paper 10.1109/ICDRET.2016.7421487.
- [6] K. Ashish, H. Md. , K. Nallapaneni, J. Vishnupriyan, J. Arunkumar, R. Biplob, "Analysis of Using Biogas Resources for Electric Vehicle Charging in Bangladesh: A Techno-Economic-Environmental Perspective", Sustainability, 2020.

[7] A. Md, K. Ashish, "Challenges for Electric Vehicle Adoption in Bangladesh," presented at International Conference on Electrical, Computer and Communication Engineering (ECCE), Cox's Bazar, Bangladesh, Feb. 7-9, 2019.

[8] M. Suman, F. Chyon and M. Ahmmed, "Business strategy in Bangladesh—Electric vehicle SWOT-AHP analysis: Case study", *International Journal of Engineering Business Management*, vol. 12, p.184797902094148, 2020. Available: 10.1177/1847979020941487.

[9] N. Anjum, "Emerging role of Easy Bike in Khulna City: Contribution towards Sustainability," *ICACE, 4th International Conference on Advances in Civil Engineering*, 23-Dec-2018. [Online]. Available: https://www.academia.edu/en/38029779/EMERGING_ROLE_OF_EASY_BIKE_IN_KHULNA_CITY_CONTRIBUTION_TOWARDS_SUSTAINABILITY. [Accessed: 28-Oct-2022]

Appendix

Arduino Mega Code

```
#include <Wire.h>
#include <DS3231.h>
#include <PZEM004Tv30.h>

PZEM004Tv30 pzem(11, 12);

RTCLib myRTC;

#define output_V A0
#define output_I A1

#define PV_V A2
#define PV_I A3

#define inv_input 26
#define inv_output 32
#define grid_output 30
#define charger_output 28
#define export_output 34

#define charging_LED 38
#define loadshedding_LED 40
#define grid_LED 42
#define backup_LED 44
#define export_LED 46

int c = 0;
int prevc = 0;

int l = 0;
bool prevl = -1;

int in = 0;

float v_out;
float i_out;
float p_out;

float pv_v_out;
float pv_i_out;
float pv_p_out;
```

```

float grid_v;
float grid_i;
float grid_p;
float grid_e;
float grid_f;
float grid_pf;

int debounce = 5000;
int lastTrigger = 0;
bool switchTrig = false;

String transmit = "";

void setup() {

    Serial.begin(115200);
    Serial1.begin(115200);

    Wire.begin();

    delay(500);

    pinMode(inv_input, OUTPUT);
    pinMode(inv_output, OUTPUT);
    pinMode(grid_output, OUTPUT);
    pinMode(charger_output, OUTPUT);
    pinMode(export_output, OUTPUT);

    pinMode(charging_LED, OUTPUT);
    pinMode(loadshedding_LED, OUTPUT);
    pinMode(grid_LED, OUTPUT);
    pinMode(backup_LED, OUTPUT);
    pinMode(export_LED, OUTPUT);

    pinMode(output_V, INPUT);
    pinMode(output_I, INPUT);

    pinMode(PV_V, INPUT);
    pinMode(PV_I, INPUT);

    digitalWrite(charging_LED, HIGH);
    digitalWrite(loadshedding_LED, HIGH);
    digitalWrite(grid_LED, HIGH);
    digitalWrite(backup_LED, HIGH);
    digitalWrite(export_LED, HIGH);

    pinMode(2, INPUT);

```

```

    pinMode(3, INPUT);

    full_shutdown();

}

void loop() {

    v_out = ((analogRead(output_V) * 5) / 1024.0) * 5;
    i_out = ((analogRead(output_I) * 5.0 / 1024.0) - 2.5) / 0.100;
    p_out = v_out * i_out;

    pv_v_out = ((analogRead(PV_V) * 5) / 1024.0) * 5;
    pv_i_out = ((analogRead(PV_I) * 5.0 / 1024.0) - 2.5) / 0.100;
    pv_p_out = pv_v_out * pv_i_out;

    grid_v = pzem.voltage();
    grid_i = pzem.current();
    grid_p = pzem.power();
    grid_e = pzem.energy();
    grid_f = pzem.frequency();
    grid_pf = pzem.pf();

    if(isnan(grid_v)) {
        grid_v = 0;
    }

    if(isnan(grid_i)) {
        grid_i = 0;
    }

    if(isnan(grid_p)) {
        grid_p = 0;
    }

    if(isnan(grid_e)) {
        grid_e = 0;
    }

    if(isnan(grid_f)) {
        grid_f = 0;
    }

    if(isnan(grid_pf)) {
        grid_pf = 0;
    }
}

```

```

transmit = "";

transmit += "outv=";
transmit += String(v_out, DEC);
transmit += "&";

transmit += "outi=";
transmit += String(i_out, DEC);
transmit += "&";

transmit += "pvoutv=";
transmit += String(pv_v_out, DEC);
transmit += "&";

transmit += "pvouti=";
transmit += String(pv_i_out, DEC);
transmit += "&";

transmit += "acv=";
transmit += String(grid_v, DEC);
transmit += "&";

transmit += "aci=";
transmit += String(grid_i, DEC);
transmit += "&";

transmit += "acp=";
transmit += String(grid_p, DEC);
transmit += "&";

transmit += "ace=";
transmit += String(grid_e, DEC);
transmit += "&";

transmit += "acf=";
transmit += String(grid_f, DEC);
transmit += "&";

transmit += "acpf=";
transmit += String(grid_pf, DEC);

Serial1.println(transmit); //Send data to NodeMCU

delay(1000);

//DSM

```

```

DateTime now = myRTC.now();
if(now.hour() >= 0 && now.hour() < 6) {
    Serial.println("Switch ON using DSM");
    c = 1;
    prevc = 1;
}

//Override using switch
if(digitalRead(2) == HIGH) {
    Serial.println("Switch ON");
    c = 1;
    prevc = 1;
}
else if(digitalRead(3) == HIGH) {
    Serial.println("Switch OFF");
    c = 2;
    prevc = 2;
}

//l = 0 means load shedding
//l = 1 means grid power is available

if(grid_v > 100) {
    l = 1;
}
else{
    l = 0;
}

if(prevl != l) {

    c = prevc;
    prevl = l;

    if(l == 0) {
        digitalWrite(loadshedding_LED, LOW);
    }
    if(l == 1) {
        digitalWrite(loadshedding_LED, HIGH);
    }
}

if(c == 1) {
    c = 0;
    digitalWrite(charging_LED, LOW);
    if(l == 0) {

```

```

        digitalWrite(grid_LED, HIGH);
        digitalWrite(backup_LED, LOW);
        backup_mode();
        //digitalWrite(export_LED, LOW);
        //export_mode();
    }
    else {
        digitalWrite(backup_LED, HIGH);
        digitalWrite(export_LED, HIGH);
        digitalWrite(grid_LED, LOW);
        grid_mode();
    }
}
if(c == 2) {
    c = 0;
    digitalWrite(changing_LED, HIGH);
    digitalWrite(grid_LED, HIGH);
    digitalWrite(backup_LED, HIGH);
    digitalWrite(export_LED, HIGH);
    full_shutdown();
}
}

void switchON() {

    if(millis() - lastTrigger > debounce) {
        lastTrigger = millis();
        switchTrig = !switchTrig;

        if(switchTrig) {
            Serial.println("Switch ON");
            c = 1;
            prevc = 1;
        }
        else {
            Serial.println("Switch OFF");
            c = 2;
            prevc = 2;
        }
    }
}

void switchOFF() {

    if(millis() - lastTrigger > debounce) {
        lastTrigger = millis();
        Serial.println("Switch OFF");
        c = 2;
    }
}

```

```

    prevc = 2;
  }
}

void full_shutdown() {

  Serial.println("Shutdown");

  charger_output_OFF();
  delay(100);

  grid_output_OFF();
  delay(100);

  inverter_output_OFF();
  delay(100);

  inverter_input_OFF();
  delay(100);

  export_OFF();

  Serial.println("Shutdown Complete");
}

void backup_mode() {

  Serial.println("Backup");

  grid_output_OFF();
  delay(1000);

  charger_output_ON();
  delay(1000);

  inverter_output_ON();
  delay(1000);

  inverter_input_ON();

  Serial.println("Backup ON");
}

void grid_mode() {

  Serial.println("Grid");
}

```



```

    inverter_output_OFF();
    delay(1000);

    inverter_input_OFF();
    delay(1000);

    charger_output_ON();
    delay(1000);

    grid_output_ON();

    Serial.println("Grid ON");
}

void export_mode() {

    Serial.println("Export");

    grid_output_OFF();
    delay(1000);

    charger_output_OFF();
    delay(1000);

    inverter_output_OFF();
    delay(1000);

    inverter_input_ON();
    delay(1000);

    export_ON();

    Serial.println("Export ON");

}

void export_ON() {
    digitalWrite(export_output, LOW);
}

void export_OFF() {
    digitalWrite(export_output, HIGH);
}

void inverter_input_ON() {
    digitalWrite(inv_input, LOW);
}

```

```
}  
void inverter_input_OFF() {  
    digitalWrite(inv_input, HIGH);  
}  
  
void inverter_output_ON() {  
    digitalWrite(inv_output, LOW);  
}  
void inverter_output_OFF() {  
    digitalWrite(inv_output, HIGH);  
}  
  
void grid_output_ON() {  
    digitalWrite(grid_output, LOW);  
}  
void grid_output_OFF() {  
    digitalWrite(grid_output, HIGH);  
}  
  
void charger_output_ON() {  
    digitalWrite(charger_output, LOW);  
}  
void charger_output_OFF() {  
    digitalWrite(charger_output, HIGH);  
}
```

NodeMCU Code

```
#include <ESP8266WiFi.h>
#include <ESP8266HTTPClient.h>
#include <WiFiClient.h>
#include <Arduino_JSON.h>

const char * ssid = "WIFI_SSID";
const char * password = "WIFI_PASSWORD";

const char * serverName = "SERVER_ADDRESS";
String serverPath;

String sensorReadings;
String rxData;

void setup() {
    Serial.begin(115200);
    WiFi.begin(ssid, password);
    Serial.println("Connecting");
    while (WiFi.status() != WL_CONNECTED) {
        delay(500);
        Serial.print(".");
    }
    Serial.println("");
    Serial.print("Connected to WiFi network with IP Address: ");
    Serial.println(WiFi.localIP());

    pinMode(LED_BUILTIN, OUTPUT);
    digitalWrite(LED_BUILTIN, LOW);
}

void loop() {

    //Check if data is sent from Arduino Mega
    //If data is received, transmit data to the server
    if (Serial.available()) {
        digitalWrite(LED_BUILTIN, HIGH);
        rxData = Serial.readString();
        Serial.println(rxData);
        httpSend(serverName, rxData);
        digitalWrite(LED_BUILTIN, LOW);
    }
}

void httpSend(String sName, String trx) {
```

```

WiFiClient client;
HTTPClient http;

serverPath = sName + "?" + trx;
Serial.println(serverPath);
http.begin(client, serverPath.c_str());

int httpResponseCode = http.GET();

if (httpResponseCode > 0) {
Serial.print("HTTP Response code: ");
Serial.println(httpResponseCode);
String payload = http.getString();
Serial.println(payload);
}
else {
Serial.print("Error code: ");
Serial.println(httpResponseCode);
}

http.end();
}

```

Server side code for receiving and storing the data

```

<?php

if ($_SERVER['REQUEST_METHOD'] === 'GET') {

    if(isset($_GET['outv'])) {

        define('DB_SERVER', 'localhost');
        define('DB_USERNAME', 'root');
        define('DB_PASSWORD', '');
        define('DB_DATABASE', 'fydp');

        $db = new mysqli(DB_SERVER, DB_USERNAME, DB_PASSWORD, DB_DATABASE);

        if ($db->connect_error) {
            die("Connection failed: " . $db->connect_error);
        }

        $time = time();

        $stmt = $db->prepare("INSERT INTO `datatable` (`time`, `out_v`, `out_i`,
`pv_out_v`, `pv_out_i`, `ac_v`, `ac_i`, `ac_p`, `ac_e`, `ac_f`, `ac_pf`) VALUES (?, ?,
?, ?, ?, ?, ?, ?, ?, ?);");

        $stmt->bind_param("ssssssssss", $time, $_GET['outv'], $_GET['outi'],

```

```
$_GET['pvoutv'], $_GET['pvouti'], $_GET['acv'], $_GET['aci'], $_GET['acp'],  
$_GET['ace'], $_GET['acf'], $_GET['acpf']);  
  
        $stmt->execute();  
        $result = $stmt->get_result();  
    }  
}  
?>
```

FYDP (P) Spring 2022 Summary of Team Log Book/Journal

Final Year Design Project (EEE400P) Spring 2022			
Sl.	NAME & ID	EMAIL ADDRESS	PHONE
Student Details Group 10			
Member 1	Quazi Rian Hasnaine 19121126	quazi.rian.hasnaine@g.bracu.ac.bd	01829431009
Member 2	Asef Jamil Ajwad 19121040	asef.jamil.ajwad@g.bracu.ac.bd	01619346789
Member 3	Fiaz Sadid 19121133	fiaz.sadid@g.bracu.ac.bd	01860280579
Member 4	Pronoyan Saha 19121131	pronoyan.saha@g.bracu.ac.bd	01708521256
ATC Details ATC 1			
Chair	Prof. Dr Md. Mosaddequr Rahman	mosaddeq@bracu.ac.bd	---
Member 1	Mohaimenul Islam	mohaimenul.islam@bracu.ac.bd	---
Member 2	Aldrin Nippon Bobby	nippon@bracu.ac.bd	---

General Notes:

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

Date/Time/Place	Attendee	Summary of Meeting Minutes	Responsible	Comment by ATC
09/02/22 8 pm	All members	Ice-breaking session, introduction among group members and discussion about topics (60 Minutes)	All	Nil
12/02/222 7 pm	All members + ATC panel	Discussion about topics(related to EV vehicles), what to do in these three months and one year, how to progress in FYDP (35 minutes)	All (Individual Study)	Prepare a literature review, do background study
13/02/22 10 pm	Asef, Pronoyan	Topic Discussion	All	Nil
15/02/22 2 am	Rian, Asef	Topic discussion on smart grid, problem with EV charging, how car engine works	All	Nil
17/02/22 1 am	All members	Individual progress and revision of the topics studied/researched.	All	Nil
20/02/22 1 am	All members	Discussion	All	Nil
25/02/22 12:30 am	All members	Contents, title and identifying complex engineering problems	All	Nil
26/02/22 8:30 pm	All members	Draft/ Concept note and presentation	All	Nil
28/02/22	All members + ATC Panel	Meeting with ATC	All	Simplify title. Give reference. Give title under graphs Be more specific.

				<p>Collect data and then show(for example, PDB, DESCO)</p> <p>Has to be relevant to current problems. Solve problems related to the BD community.</p> <p>The proposed solution to the problem must have demand.</p>
01/03/22	Rian, Fiaz	Discussion with Mohaimenul Sir at campus about the project as a whole	All	Decided a topic that matches with our area of interest. Figured out a relevant problem and a feasible solution we could work on.
01/03/22	All members	Discussing what Mohaimenul Sir told us with the group	All	Nil
02/03/22	All members	Discussion on the things to collect	All	Nil
02/03/22	Asef, Pronoyan	Data gathering	Asef, Pronoyan	Nil
04/03/22 11 am	All members + Mohaimenul Sir	Finalisation and showing progress	All	<p>EV charging station design</p> <p>Area survey</p> <p>Per car how many batteries</p>

04/03/22 2 pm	Rian	Field survey of the electric easy bikes	Rian	Nil
04/03/22 1 pm	Asef, Pronoyan	Planning on how to progress with the topic	Asef, Pronoyan	Nil
05/3/22	Fiaz, Asef	Discussion on project proposal report	All	Nil
06/03/22 4 pm	Fiaz, Asef, Rian	Note taking, brainstorming, discussion on project proposal report	All	Nil
06/03/22 1 am	All members	Distributing work	All	Nil
07/03/22	Rian, Asef, Pronoyan	Concept note finalisation	All	Nil
08/03/22 3 pm	All members + Mohaimenul Sir	Finalisation of progress Presentation and tips to improve	All	Title finalisation, bits and pieces of concept notes information, add block diagram
08/03/22 6:30 pm	All members + ATC panel	Progress presentation update Final meeting before progress presentation	All	Minor changes in the slide and concept note
09/03/22	All members + ATC panel	Finalisation of progress presentation (20 minutes)	All	Nil
12/03/22	Asef, Pronoyan	Review of past work	All	Nil
14/03/22	Rian, Fiaz	Review of past work	All	Nil
16/03/22	All members	Fixing concept note	All	Nil
19/03/22	Asef, Pronoyan	Final touch up and submission of concept note (10 minutes)	Asef, Pronoyan	Nil

23/03/22	All members	Gathering more papers	All	Nil
25/03/22	All members	Regroup, planning ahead for future work	All	Nil
28/03/22 5:00 pm	Pronoyan, Asef + Mohaimenul Sir	Getting ideas to start writing from Mohaimenul sir (1 hour)	All	Shown the structure and how to progress on writing
03/04/22 1:04 am	All members	Group discussion on how to start writing (30 minutes)	All	Nil
07/04/22 10:30 pm	All members	Work division (1 hour)	All	Nil
09/04/22 10:30 pm	All members	Individual progress on the divided topics (3 hours)	All	Nil
11/04/22	Asef, Rian	Project Proposal Discussion	Asef, Rian	Nil
12/04/22	Pronoyan, Fiaz	Project Proposal Discussion	Pronoyan, Fiaz	Nil
15/04/22	Rian, Pronoyan	Project Proposal Discussion	Rian, Pronoyan	Nil
17/04/22	Fiaz, Asef	Project Proposal Discussion	Fiaz, Asef	Nil
20/04/22 5 pm	All members + Mohaimenul Sir	Discussion about Draft Project Proposal	All	Budget analysis, give consent form. Impact matrix, remove graph from SWOT analysis. In the Gantt Chart, include the responsibilities of all members. Bring fire and electrical safety and risk management. Include contingency costs.
21/04/22 10:30 am	Pronoyan, Asef	Project Proposal Discussion (30 minutes)	Pronoyan, Asef	Nil
21/04/22 11:00 pm	Pronoyan, Asef	Project Proposal Discussion	All	Nil

		(4 hours)		
22/04/22 10:30 am	All members	Project Proposal Discussion (1 hour)	All	Nil
23/04/22 01:00 am	Asef, Pronoyan	Project Proposal Discussion (3 hour)	All	Nil
23/04/22	Asef + Mohaimenul Sir	Draft Project Proposal Review	All	Add impact matrix in sustainability Add comments in the budget
25/04/22	All members + ATC panel	Draft Project Proposal Mock Presentation group work	All	Nil
25/04/22	All members	Draft Project Proposal Mock Presentation in front of ATC Panel	All	<p>Slide no 25 First few points vital Swot analysis not a major thing Environmental societal make better points Field survey : point out(make table) (Make them bigger) Problem statement : give reference Give importance based in CO'S MARKS</p> <p>Change problem statement slide (impact in what?)</p> <p>Functional requirement make stronger(charging time and no of cars to charge) Non functional give priority wise (Backup, monitoring will be at top)</p> <p>Specs dont give ss Reduce it voltage power etc dont give dimension.</p>

				<p>Constraint slide: multiple design approach 1 Then approach 2 Approach 3 Methodology not clear, make it clear Make the gannt chart bigger Make sure everything is visible (Gannt chart plus responsibilities in one slide)</p> <p>Budget decrease wordings</p> <p>Expected outcome: not under co So don't include in slides(not important) if you want to include this then give after impact.</p> <p>Don't include opportunity matrix</p> <p>Standard codes: reduce it , give one or two, include them in the report.</p> <p>Risk management:correction, its contingency plan And decrease fonts.</p>
26/04/22	Pronoyan + Mohaimenul Sir	Project proposal discussion	All	Minor changes
27/04/22	All members + ATC panel	Final Project Proposal Presentation	All	Nil

FYDP (D) Summer 2022 Summary of Team Log Book/Journal

Final Year Design Project (D) Summer 2022			
Student Details	NAME & ID	EMAIL ADDRESS	PHONE
Member 1	Quazi Rian Hasnaine 19121126	quazi.rian.hasnaine@g.bracu.ac.bd	01829431009
Member 2	Asef Jamil Ajwad 19121040	asef.jamil.ajwad@g.bracu.ac.bd	01619346789
Member 3	Fiaz Sadid 19121133	fiaz.sadid@g.bracu.ac.bd	01860280579
Member 4	Pronoyan Saha 19121131	pronoyan.saha@g.bracu.ac.bd	01708521256
ATC Details:			
ATC 1			
Chair	Prof. Dr Md. Mosaddequr Rahman	mosaddeq@bracu.ac.bd	---
Member 1	Mohaimenul Islam	mohaimenul.islam@bracu.ac.bd	---
Member 2	Aldrin Nippon Bobby	nippon@bracu.ac.bd	---

General Notes:

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

Date/Time/ Place	Attendee	Summary of Meeting Minutes	Responsible	Comment by ATC
02.06.22	All members + ATC panel	Intro to FYDP(D)	All members	Nil
08.06.22	All members + Mohaimenul Sir	Read research papers and literature reviews to gather knowledge needed to design and analyze the solutions	All members	Nil
10.06.22	All members	Update on individual progress and sharing collected papers	All members	Nil
12.06.22	Pronoyan, Asef	Exploring different simulation tools	Pronoyan, Asef	Nil
13.06.22	Asef + Mohaimenul Sir	Revising specification and requirements	All members	Advised slight modification to the functional requirements
17.06.22	Asef, Pronoyan	Exploring different modelling tools	Asef, Pronoyan	Nil
22.06.22	All members + Mohaimenul Sir	Discussion about multiple alternate solutions	All members	Nil
24.06.22	All members	Collecting research papers and literature reviews	All members	Nil
26.06.22	Rian, Fiaz	Discussion about alternate design solutions	All members	Nil
27.06.22	Pronoyan, Asef	Simulink simulation of multiple design approaches	Pronoyan, Asef	Nil
27.06.22	Rian, Fiaz	PVsyst simulation of multiple design approaches	Rian, Fiaz	Nil

28.06.22	All members	Progress presentation preparation	All members	Nil
29.06.22	Pronoyan + Mohaimenul Sir	Progress presentation update and slide showcase	All members	Add 3D model of the EVCS in slide and specific parts of simulation, not the whole report
29.06.22	Asef, Pronoyan	Prepared 3D model of the EVCS using SketchUp	Asef, Pronoyan	Nil
30.06.22	All members + Mohaimenul Sir	Update on progress presentation	All members	Approved the 3D model and slide
03.07.22	Pronoyan, Asef	Simulink simulation of design approach 2	Pronoyan, Asef	Nil
04.07.22	Pronoyan, Asef	Simulink simulation of design approach 3	Pronoyan, Asef	Nil
04.07.22	Fiaz, Rian	PVsyst simulation	Fiaz, Rian	Nil
06.07.22	Asef + Mohaimenul Sir	Identifying the optimal solution among the multiple design approaches	All members	Design approach 3: On grid system is the optimal solution
08.07.22	All members	Sharing simulation results and ways to improve them	All members	Nil
16.07.22	All members + Mohaimenul Sir	Different parameters to modify in simulation to obtain desired result and how to interpret the results	All members	Nil
17.07.22	All members	Simulation data sharing and analysing them	All members	Nil
21.07.22	All members + Mohaimenul Sir	Progress update	All members	Nil
26.07.22	Asef + Mohaimenul Sir	Progress on draft report	All members	Simulate in Simulink by altering some parameters

				and check if solar tracking is necessary
04.08.22	Asef + Mohaimenul Sir	Progress on draft report	All members	Nil
27.08.22	Pronoyan + Mohaimenul Sir	Suggestions on draft report	All members	Include 3D model, relevant graphs and Simulink block diagram
28.08.22	Pronoyan, Asef + Mohaimenul Sir	Contents to include in slide for final presentation	All members	Include all the major points from the draft report
29.08.22	All members + Mohaimenul Sir	Progress update on draft report	All members	Nil
30.08.22	All members + Mohaimenul Sir	Mock presentation	All members	Add reference in the slide. Mark graphs with proper labelling

FYDP (C) Fall 2022 Summary of Team Log Book/Journal

Final Year Design Project (C) Fall 2022			
Student Details	NAME & ID	EMAIL ADDRESS	PHONE
Member 1	Quazi Rian Hasnaine 19121126	quazi.rian.hasnaine@g.bracu.ac.bd	01829431009
Member 2	Asef Jamil Ajwad 19121040	asef.jamil.ajwad@g.bracu.ac.bd	01619346789
Member 3	Fiaz Sadid 19121133	fiaz.sadid@g.bracu.ac.bd	01860280579
Member 4	Pronoyan Saha 19121131	pronoyan.saha@g.bracu.ac.bd	01708521256
ATC Details:			
ATC 1			
Chair	Prof. Dr Md. Mosaddequr Rahman	mosaddeq@bracu.ac.bd	---
Member 1	Mohaimenul Islam	mohaimenul.islam@bracu.ac.bd	---
Member 2	Aldrin Nippon Bobby	nippon@bracu.ac.bd	---

General Notes:

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

Date/Time/ Place	Attendee	Summary of Meeting Minutes	Responsible	Comment by ATC
29.09.22	All members + Mohsin Sir	Intro to FYDP(C)	All members	Nil
01.10.22	All members + Mohaimenul Sir	Project plan and suggestions for prototyping	All members	Nil
10.10.22	All members	Tentative component list preparation	All members	Nil
13.10.22	Asef + Mohaimenul Sir	Tentative component list selection	All members	Update few components
14.10.22	Pronoyan, Asef	Tentative component list update	All members	Nil
16.10.22	Pronoyan + Mohaimenul Sir	Tentative component list finalisation	All members	Purchase components as soon as possible
17.10.22	All members	Component purchase	All members	Nil
21.10.22	All members	Tentative component connection and setup planning	All members	Nil
24.10.22	Pronoyan, Asef	Prototype setup	All members	Nil
25.10.22	Asef, Rian, Fiaz	Prototype setup	All members	Nil
26.10.22	All members	Prototype setup	All members	Nil
27.10.22	All members	Prototype setup	All members	Nil
28.10.22	All members	Prototype testing	All members	Nil
30.10.22	All members + Mohaimenul Sir	Progress update on prototype	All members	Nil
01.11.22	All members	Progress presentation slide preparation	All members	Nil
02.11.22	All members + ATC Panel	Mock progress presentation	All members	Update slides as per suggestion
02.11.22	All members	Progress presentation slide update	All members	Nil
03.11.22	All members + Mohsin Sir	Progress presentation	All members	Collect data for validation
12.11.22	All members	Update on prototype	All members	Nil
15.11.22	All members	Start data collection	Pronoyan	Nil

16.11.22	Pronoyan, Asef	Hardware side setup for data collection	All members	Nil
17.11.22	Pronoyan, Asef	Data collection update	All members	Nil
18.11.22	Pronoyan, Asef, Fiaz	Data collection update	All members	Nil
19.11.22	Pronoyan, Fiaz, Rian	Data collection update	All members	Nil
20.11.22	Pronoyan, Asef, Fiaz	Data collection update	All members	Nil
21.11.22	Pronoyan, Asef	Data collection update	All members	Nil
22.11.22	Pronoyan, Fiaz	Data collection update	All members	Nil
23.11.22	All members	Data collection update	All members	Nil
24.11.22	All members + Mohaimenul Sir	Discussion about collected data and how to present them	All members	Nil
26.11.22	Pronoyan, Asef	Server side setup for data processing	Asef	Nil
27.11.22	Pronoyan, Asef	Server side setup for data processing	Asef	Nil
28.11.22	Pronoyan, Asef	Server side setup for data processing	Asef	Nil
29.11.22	Pronoyan, Asef	Server side setup for data processing	Asef	Nil
30.11.22	All members + Mohaimenul Sir	Feedback on server side	Asef	Nil
01.12.22	All members	Report work distribution	All members	Nil
07.12.22	All members	Individual update on report writing	All members	Nil
08.12.22	All members + Mohaimenul Sir	Update on report writing	All members	Add block diagrams of multiple design approaches
12.12.22	All members	Final presentation slide preparation	All members	Nil
13.12.22	All members	Final presentation slide preparation	All members	Nil

14.12.22	All members + ATC Panel	Final mock presentation	All members	Update slides as per suggestion
14.12.22	All members	Progress presentation slide update	All members	Nil
15.12.22	All members + Mohsin Sir	Final presentation	All members	Nil
18.12.22	All members	Individual update on final report preparation	All members	Nil
20.12.22	All members + Mohaimenu Sir	Update on final report	All members	Nil