Design of a Photovoltaic Based Electric Vehicle (EV) Charging Station

By

Golam Rasul Riful (17121070)

Pronoy Sarker (18121135)

Sajjad Hossain Shawon (16321087)

Md Mahmudul Hasan (17121062)

A thesis 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

Electrical and Electronic Engineering

BRAC University

Summer 2021

Declaration

We hereby declared that

1. The thesis submitted is our own original work while completing our degree at BRAC University.
2. The thesis 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 thesis 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:

Golam Rasul Riful
17121070

Pronoy Sarker
18121135

Sajjad Hossain Shawon
16321087

Md Mahmudul Hasan
17121062

Approval

The thesis titled “Design of a Photovoltaic Based Electric Vehicle (EV) charging Station” submitted by

1. Golam Rasul Riful (17121070)
2. Pronoy Sarker (18121135)
3. Sajjad Hossain Shawon (16321087)
4. Md Mahmudul Hasan (17121062)

Of [Fall2020] has been accepted as satisfactory in partial fulfilment of the requirement for the degree of Bachelor of Science in Electrical and Electronic Engineering on 10 November, 2020.

Examining Committee:

Supervisor:

(Member)

____

Dr. Md. Mosaddequr Rahman

Professor and Chairperson, Dept. of EEE

Brac University

Program Coordinator:

____

(Member)

Dr. Abu S.M. Mohsin
Assistant Professor, Dept. of EEE

Brac University

Departmental Head:

____

(Chair)

Dr. Md. Mosaddequr Rahman

Professor and Chairperson, Dept. of EEE

Brac University

Abstract

Day by day electric vehicles like auto-rickshaw, Easy bikes are increasing in Bangladesh. In Bangladesh, easy bikes are charged using electricity from the national grid. This increasing number of electric vehicles creates a lot of pressure on the country's grid. Bangladesh is already lagging behind in the production of electricity. To reduce the pressure of the national grid and utilize renewable energy this study deals with the design of a photovoltaic (PV) based Electric Vehicle charging station. Easy bike charging by renewable energy is like solar offers a good solution from an economic and environmental point of view. The 3D model of the desired charging station has been included in this paper. This station is made for 15 easy bikes charging capacity which requires 21.6 kWh of energy daily on average. This design includes site selection, irradiation calculation, load estimation based on the vehicle survey, PV panel choosing, possible system loss, energy assessment, battery storage, cloud impact, grid dependency. In this study, a photovoltaic based easy bike charging station has been designed considering environmental impact. For this design total life cycle has been calculated. Additionally, carbon emission analysis has been done. The result shows that 16162.96 kg/kWh CO_2 per year can be minimized by the proposed design compared with fuel-based cars.

Keywords: Electric Vehicle; Photovoltaic; Easy Bike; Carbon Emission; Grid Connection; Cloud Impact; LCC;

Dedication

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

Acknowledgment

Firstly, all praise to the Great Allah for whom our thesis has been completed without any major interruption.

Secondly, to our supervisor Dr. Md. Mosaddequr Rahman whom we would like to thank for his assistance and guidance throughout the whole research. To our co-advisor Mohaimenul Islam sir for his kind support and advice in our work. He helped us whenever we needed help.

And finally, to our parents without their throughout support it may not be possible. With their kind support and pray we are now on the verge of our graduation.

TABLE OF CONTENT

Chapter 1: Introduction

Chapter 2: Theoretical Background

Chapter 3: Methodology

Chapter 4: Result Analysis & Discussion

Chapter 5: Conclusion

List of Tables

List of Figures

.

List of Acronyms

EV	Electric Vehicles
LCC	Life Cycle Cost
GHG	Greenhouse Gas

Chapter 1

Introduction

1.1 Introduction

Bangladesh is an energy-scarce country whose primary energy sources are natural gas and petroleum products. The transportation sector, which accounts for 46.46 percent of total petroleum consumption and 6 percent of total natural gas consumption, plays a crucial role in energy harvesting. Additionally, just 8 percent of total petroleum demand is met in Bangladesh, and 1.2 million tons of crude oil and 2.6 million tons of refined petroleum products must be imported each year [1, 2]. As a result, the government must spend a significant amount of money to import products from other countries [3]. Again, the emission of Greenhouse Gases (GHGs) from petroleum resources is a major environmental concern. Aside from this scenario, GHG emissions from the transportation sector are expected to increase dramatically [4].

According to the World Bank, conventional energy sources are used by 2.4 billion people, whereas 1.6 billion people do not have access to electricity [5]. Electricity consumption is predicted to double in 2020, with a projected global average growth rate of 2.8 percent. Electricity demand in emerging nations is expected to rise by 4.6 percent per year throughout this time. [6]. Bangladesh's power generating capacity is insufficient, therefore there is usually a large imbalance between demand and supply. Bangladesh is located between 20.30 and 26.38 north latitude and 88.04 and 92.44 east longitude, making it a good site for solar energy use. Solar radiation ranges between 4 and 6.5 kWh/m^2 on a daily basis. Solar photovoltaic (PV) technology is a promising new way to generate power. So, without utilizing any innovative technology, a highly populated tropical nation like Bangladesh may be electrified by a PV grid system using limitless and pollution-free solar energy. The use of solar energy sources for power generation on a large scale would compensate for the electricity shortfall and reduce CO_2 emissions.

The Bangladeshi transportation sector produces GHG emissions significantly. According to data published by the International Energy Agency, transportation vehicles account for roughly 23 percent of all GHG emissions [7]. Furthermore, the energy and agriculture industries are hastening CO_2 emissions [8]. The rapid increase in the number of transport vehicles needed to serve the country's massive population is a worrisome symptom of pollution and fuel consumption. Furthermore, the use of electric vehicles (EVs) such as auto-rickshaws and Easy Bikes is growing every day [9]. These electric vehicles emit fewer pollutants and emit no emissions. Though, the Bangladesh Road Transport Authority (BRTA) does not have any data on these types of electric vehicles. However, the increasing growth of electric vehicles necessitates about 500 MW of power each day taken from Bangladesh's national grid [10].

EVs are now charged in residential areas & paying residential customer’s electricity bills not business electricity bills. In such circumstances, charging those EVs does not generate any profit for the power sector. Moreover, these EVs are putting a lot of strain on Bangladesh's national grid [11].

The performance of an EVCS is determined by a variety of parameters, including power availability, load demand, battery capacity, charging cost, and charging time. The charge cost optimization in this study is done utilizing fuzzy logic while optimizing the use of renewable resources. Using fuzzy if-then logic, an energy management algorithm will be created. Although hybrid renewable energy-based EVCS optimization is a novel one, several studies have been conducted utilizing fuzzy logic. In Bangladesh, the price of power varies depending on whether it is used during peak or off-peak hours. As a result, the charging time, battery capacity, power consumption, and power availability are all inputs to the fuzzy system, with the charging cost being the only output. This sort of optimization will reduce charging costs while also ensuring that electric energy issued efficiently.

"Khulna city" was chosen as the focal point because of its popularity as an easy bike city. Furthermore, the planned site is adjacent to the "Sonadanga Bypass," which serves as the city's main entrance. Solar panels are divided into two categories. The difference between the two is that one is mono-crystalline and the other is polycrystalline. Mono-crystalline, on the other hand, has a higher efficiency rate of 15-20 percent, which means it generates more electricity per square foot, but polycrystalline is less expensive. They can produce 220 volts without the need for an external power source, as long as they are exposed to sunlight. This procedure is carried out with hybrid mono-crystalline a grade panels, which have a 21 percent efficiency rating and a diameter of 1.67225 meters square.

1.2 Background

A new field of study is the energy consumption sector, which has been influenced by the fast rise in the EV market penetration across the globe. This part of the chapter focuses on reviewing the difficulties and effects of current EV on the power grid, the use of renewable resources, and optimization methods, etc. The rapid surge in EV numbers is increasing the fragility of the power grid particularly during the peak hour. [12]. Meanwhile EV has several challenges; the biggest are inadequate charging stations, the current battery technology, longer charging times and increased cost. In contrast, a non-linear EV charger creates harmonics, voltage fluctuations, and power loss in the power supply. [13]. One of the environmental impacts of EV adoption is that, when EVs are charged by coal-based power, the carbon emissions are increased, while carbon emissions are decreased when EVs are charged by renewable energy. [14].

The fact is that the fossil fuel prices are rising globally and it is clear that this will bring problems for the power and transportation sectors. Aside from that, these manufacturing regions are the world's largest contributors to greenhouse gas emissions. [15]. It is now time to confront renewable energy resources rather than petroleum resources for Bangladesh's sustainable growth. The rising expense of fossil fuel and its limited availability introduces a grave threat for the transportation and power generation industries. To help meet the demand for energy, it is essential to encourage sustainable growth in both urban and rural regions. When the grid is not accessible, rural regions may be energized utilizing renewable resources like solar, biogas, and wind power. [16]. Bangladesh has access to renewable resources such as solar, biogas/biomass, and wind, which may be utilized to charge electric vehicles. [17].

Two major problems have been discovered in many studies: size and energy management. Chaudhari et al. have developed an optimization methodology to install an energy storage system in order to minimize EVCS PV operational costs using the real-time electricity pricing. [18]. Bhatti et al. proposed a particle swarm optimization (PSO)-based optimization model for sizing the PV and BESS in a grid-connected PBES, with the goal of minimizing the cost of the PV and BESS over time. [19]. Domínguez-Navarro et al. concentrated their efforts on the design of an EV fast-charge plant including the number of chargers, renewable energy installation power, storage of energy and the contractual grid electricity. [20]. One of the studies used a genetic algorithm to optimize the model and simulate the power requirements of an Erlang B queuing system. [21]. Baik et al. calculated the capacity of a PV and ESS system in power balancing energy storage (PBES) by employing an operator to optimize the net present value. [22]. Badea et al. used a genetic algorithm program to determine the optimum PV system design for an isolated PBES. [23]. Torreglosa et al. designed an energy management system to optimize the flow of energy among PV, BESS, and the grid in a PBES. [24]. Yao et al. used a mixed integer linear programming (MILP) model to control the charging/discharging pattern of electric vehicles (EVs) in a power battery exchange station (PBES). In their study, Hafez and Bhattacharya identified the optimum layout of an EVCS while using a variety of energy resources. [25]. Research published above either focused on size or energy management. However, this paper will concentrate on both of these problems. The model will explore the best energy management strategies by determining the best-sized PV and BESS systems in a grid connected PBES, and will examine the charging and discharging pattern of BESS as well as its interaction with the utility grid. Furthermore, most research has focused on the financial goal, and as a result, the objective function for this article will be to reduce the cost of electricity as the optimization objective function.

However, this paper contributes to all the possible problems, in term of energy management, station size, PV size, Energy storage, carbon emission etc. As the centre of focus, "Khulna city" has been chosen for its recognition as the city of easy bikes. Moreover, the proposed is beside the highway "Sonadanga Bypass", which is the gateway to the city. There are two kinds of solar panels. While one is mono-crystalline, the other is polycrystalline. However, mono-crystalline has a higher efficiency rate in the 15-20 percent range, which means it produces more power per square foot, yet polycrystalline is cheaper. There is another panel which is a hybrid panel. They can give 220 v output without external electricity connection direct from sunlight. For conducting this operation, hybrid mono-crystalline a grade panels are used, which provide around 21 percent efficiency and the diameter of a single panel is 1.67225 meters square.

Already a few solar charging stations have been set up by the Bangladesh Rural Electrification Board (BREB) and Bangladesh Power Development Board (BPDB). These charging stations are still not enough and solely depending on solar power that is lacking on rainy days and cloudy days. This research mainly focused on factors like solar irradiation, cloud impact and grid dependency. However, using the day time analysis as well as observing the movement of the clouds throughout the whole year, this research almost perfectly conducted the calculation and figured out the energy output, cloud impact and grid dependency for charging the 15 vehicles.

For energy storage purposes, Tall Tubular Batteries are a perfect choice as they are especially designed with a compact and longer grid structure in a thicker tubular pack for positive plates and a flat type negative plate PE separator. They have an electrolyte volume increase of 30 percent thanks to their larger and thicker PP (Polypropylene) container, which also makes charging and discharging processes cooler. Moreover, its superior features have made it the most demanded inverter battery at current age. The tall tubular batteries are capable of functioning in extremely hot environments, and they can withstand deep cycle applications that include regular and long periods of power interruptions. It is ready to regulate power during a main failure or dipping voltage.

Solar energy has been in use since ancient times, beginning about the 7th century B.C. solar power was first used to light fires by focusing the sun's energy using a magnifying glass. Sunrooms were created in ancient times to catch sun energy and use it to provide natural warmth. The French physicist Edmond Becquerel discovered the photovoltaic impact during experimentation in a conducting solution using a cell consisting of metal electrodes in 1839. The first operational selenium solar cell was established by American inventor Charles Fritz in 1883, a forerunner of the technology utilized today. Although we use silicon for modern solar panels and cells, it has been an important precursor of today's technology.

In certain ways, several physicists have contributed to the invention of solar cells. Becquerel is ascribed to the finding of the photovoltaic effect potential and Fritz to the creation of all solar cells as an ancestor. However, this study also emphasized carbon emission data, yet using this modern solution, carbon emissions are reduced by up-to percent, as to some extent, they depend on the national grid.

1.3 Motivation

Bangladesh is a developing country with an increasing population. Many kinds of vehicles have been introduced for mobilizing this mass population. The quick growth of electric vehicles such as Easy Bike, Auto-Rickshaw and Electric bikes play a crucial part in the global energy problem. In Bangladesh, there are almost 900,000 easy bikes running on battery power. For charging batteries, all of them use national grid supply. Approximately 9,000 MWh of electricity is currently being consumed every day from the supply system to meet the easy bicycle charge demand. Due to the massive increase in the number of easy bikes, we are facing an electrical shortage which is resulting in problems like load shedding. For other important tasks, we do not get proper electricity. In addition, due to this massive pressure on the national grid, during peak hours the voltage level becomes so low that it damages our electronic equipment. Although in the transportation industry, electric vehicles are creating a new dimension with various benefits, such as the lowest method of transport and greenhouse gas emissions, it is not very easy to provide enormous battery power for batteries every day. To prevent this power crisis, alternative energy options can be adapted. For which, renewable energy is the best option.

The possible option to lower the pressure on the national grid is the "Solar Powered Battery Charging Station", which is a sustainable environmental approach to dealing with ongoing energy crises and to assisting existing vehicles operating on batteries. By adapting this approach, we can ease not all but most of the power crisis. This project can also be financially beneficial, which will also become the talented bachelor’s source of income.

1.4 Objectives

The main goal of this thesis is to design an Electric car charging station in “Sonadanga” in Khulna to reduce the pressure of the national grid and utilize renewable energy.

The following specific objectives will be taken into consideration in the present study:

1. Found out load estimation based on the vehicle survey, PV panel choosing, possible system loss, energy assessment, battery storage based on the collected data.
2. Carbon emission, effect on the Environment and grid dependency has been studied.
3. Irradiation has been calculated using MATLAB.
4. Analysing cloud impact data.
5. Completing Life Cycle Cost (LCC) analysis.

1.5 Organization of thesis/Outline:

The rest of the book is developed in a way for readers to understand more. The chapters are as follows: Chapter 2 talks about the theoretical background of the work, Chapter 3 contains methodology and design, Chapter 4 analyses the results and discusses economic and environment effects. Finally, Chapter 5 concludes presenting future scope.

Chapter 2

Theoretical Background

2.1 Solar Irradiation:

The following are the total components of solar irradiance: [26]

1. Beam,

2. Isotropic diffuse,

3. Diffusely reflected from the ground.

Liu and Jordan model

The proposed model of Liu & Jordan, published in The Interrelationship and Characteristic Distribution of Direct, Diffuse, and Characteristic Distribution Total Solar Radiation, stated that total solar radiation on a tilted surface can be considered beam radiation, reflecting radiation from the ground, and diffuse radiation on any collector panel. On a tilted collector panel, the educational representation can be derived based on the rate of hourly basis solar radiation of any sort. [27].

$$IT = IBRB + ID\ (1 + cos\beta\ 2) + IR\ (1 - cos\beta\ 2) \qquad (1)$$

IT= Total irradiance angle

IB= Beam radiance

ID= Diffusion irradiance

IR= Earth reflected radiation

Only half of the solar irradiance emitted by the sun reaches the earth's atmosphere in a solar year, and the direct or beam radiation (IBC), diffuse radiation (IDC), and reflected irradiance (IRC) are all equivalent to the solar radiation striking a Collector (IC) throughout this process. [26].

$$IC = IBC + IDC + IRC \tag{2}$$

[IC=Collector solar radiation]

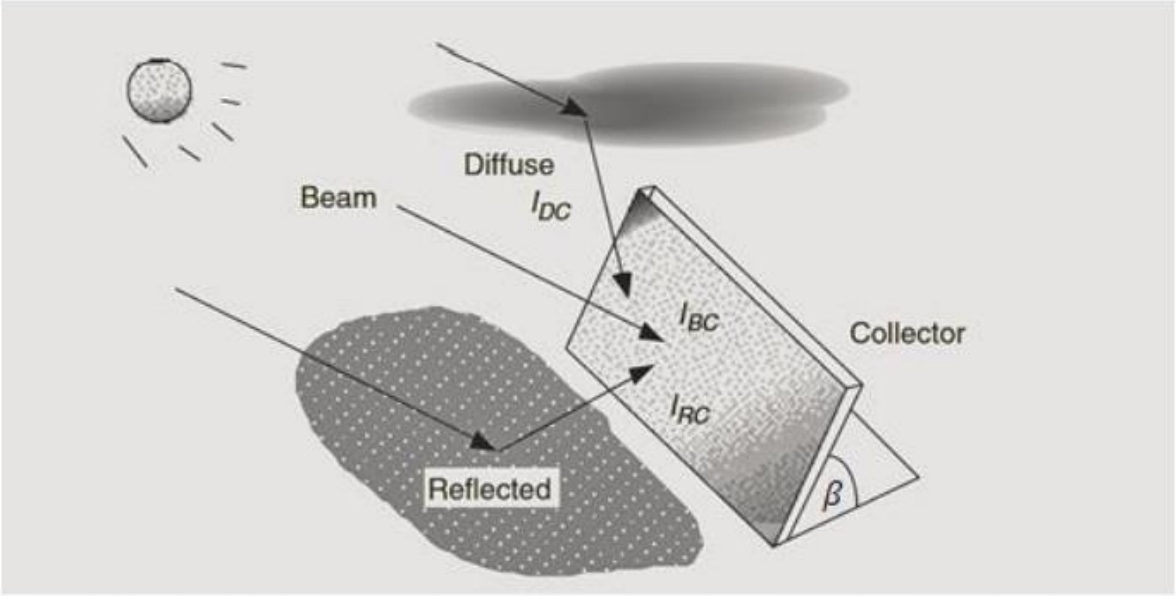


Figure 1: type of Irradiance [26].

2.2 Solar Calculation

Beam solar irradiance

The amount of energy that needs to travel through the atmosphere can be stated as beam solar irradiance, which is simple to calculate despite the fact that other factors in the atmosphere such as dust, cloud, pollution level, and weather humidity vary from location to place. A series of equations has been constructed to calculate the value of beam solar irradiance. [28]

$$I_B = Ae^{-km} \quad (3)$$

In the preceding equations, IB represents normal rays reaching the earth's surface, while A represents the apparent extra-terrestrial flux lost in space.

$$A = 1160 + 75 \sin [360\ 365\ (n - 275)] \quad (4)$$

Optical death termed as the dimensionless factor (K)

$$K = 0.174 + 0.035 \sin [360\ 365\ (n - 100)] \quad (5)$$

And the air mass ratio (m) Air mass ratio

$$m = 1\ sin\alpha s \quad (6)$$

Total solar beam irradiance IBC, will be calculated from the value of normal ray irradiation IB.

$$IBC = \ Bcos\theta \quad (7)$$

Surface tilt [4],

$$\beta = cos{-1}\ (cosHcos\beta a) \quad (8)$$

Surface azimuth,

17 $\gamma s = sin{-1}\ [nHsin\beta]$, for, $\beta \neq 0$, $-90° \leq H \leq +90°$

Here, solar azimuth angle (γ) is multiply of the declination angle (δ) and the

Hour angle divided by the surface tilt (β)

$$sin\gamma = cos\delta cosHcos\alpha s \quad (9)$$

Furthermore, the incident angle (θ) of the sun is determined using the altitude angle, surface azimuth, solar azimuth, and angle of the surface tilt associated with this system. The incident angle on the photovoltaic panel face is the normal ray angle, and the solar beam irradiance (IBC) is the solar beam irradiance (IBC). [28]

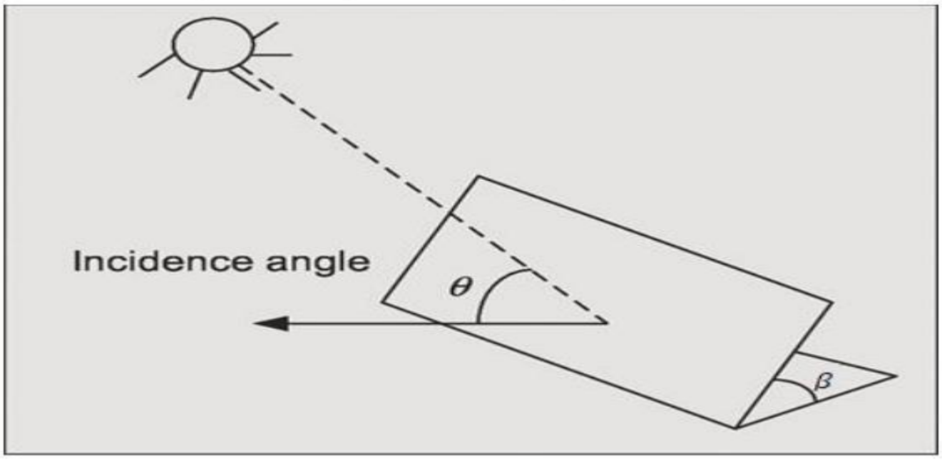


Figure 2: Incidence Angle.

To calculate solar energy first we need to know the declination angle, tilt angle of that place (tlt), sunrise (sr) & sunset time (ss) of that place, sunrise angle (ws) as well. Then we got Total day time (t) that will help us to find solar energy. Then we got hour angle (ws), solar altitude angle (A), zenith angle (za). 1st we got monthly solar energy then we average it because average monthly solar energy is more appropriate. We use a few formulas to find it that is given below for calculation.

Declination angle,

$$a = 23.45 \times \left(sind \left((n + 284) \times \left(\frac{360}{365} \right) \right) \right) \text{(1 year=365days)} \tag{10}$$

Tilt angle, (tlt) = 20.70°

Sunrise time,

sr = Total month of the year $-\frac{1}{(middle\ day\ o/f\ the\ month)\times(acosd(-tand(l)\times tand(a))}$

Sunset time,

ss = Total month of the year + $\frac{1}{(middle\ day\ of\ the\ month)\times(acosd(-tand(l)\times tand(a))}$

Here, a= Declination angle

Sunrise angle,

$$Ws = acosd\ ((-tand(l)\times tand(a))) \quad (11)$$

Now we can find,

Day time, T= Ss-Sr

Hour's angle,

$$ws = -Ws + (\left(\frac{2\times Ws}{T}\right)\times(time(i) - Sr)) \quad (12)$$

For sky we use defect mf = $\frac{1+cosd(\beta)}{2}$

Solar altitude angle,

$$A = asind\ ((sind(a)\times sind\ (l)) + (cosd(a)\times cosd(l)\times cosd(ws))) \quad (13)$$

Zenith angle,

$$Za = 90-A$$

Monthly energy,

$$E = \sum_{Each\ month}^{12} = 1(\frac{each\ month \times Days\ of\ that\ month}{1000}) \tag{14}$$

2.3 Environmental Impact

Cloud impact is one of the major drawbacks for PV cells. Diffuse irradiation is isotropic, which means that the intensity of diffuse irradiation is uniform throughout the sky dome, according to the isotropic diffuse module. The presence of clouds has a negative impact on the efficiency of solar energy conversion. Because of the existence of clouds, a substantial part of the sun's rays may be unable to reach the earth's surface. The amount of radiation energy emitted by the sun and gathered on a surface may be quantified as solar insulation, which can be adjusted to account for cloud density, height angle of the sun's position, and other factors depending on a particular time period. [32].

Mathematical equations related to cloud impacts are;

$$E_{sunny} = \int_{TSR}^{TSS} (ISin\alpha + 0.1I)dx \tag{15}$$

$$E_{cloudy} = \int_{TRS}^{TSS} 0.2I\ dx \tag{16}$$

T_{SS} = Time of sunset

T_{SR} = Time of sunrise

Proposed Solar Panels Total Energy,

$$E_{Total} = x\ E_{sunny} + y\ E_{cloudy} \tag{17}$$

$x + y$ = total days for a particular month

2.4 Grid Dependency

Our research study is on the PV based grid dependent solar charging station for electric vehicles. We are getting energy from our solar panels. Yet, the energy we are getting is not enough to meet up our daily need which is 21.6 kWh. To meet up this need we need to depend on the grid to some extent. To calculate the grid dependency, first we calculated the produced energy by the station. Afterwards, we calculated month wise required energy. Finally, we subtracted the energy produced by the station from the monthly required energy. Finally, we will have our desired grid dependency. [33]

So, the energy produced by the station,

$$E_{station} = (G \times A \times (\eta \div 100) \times 12) - ((G \times A \times (\eta \div 100) \times 12) \times (\text{Losses} \div 100)) \tag{18}$$

G = Solar irradiation (Watt) A = Area of the panel (m^2) η

Again, the monthly required energy,

$$E_{required} = \text{Energy Demand} \times \text{Total days in a month} \tag{19}$$

Energy Demand = 21.6 kWh

Finally, Grid Dependency,

$$E_{Grid} = \text{the monthly required energy - the energy produced by the station} \tag{20}$$

2.5 Carbon emission

To find out the carbon emission from our system here we used two formulas.

$$\text{Station carbon emission } \left(\frac{\text{KG}}{\text{kWh}}\right) = \text{Grid dependency} \times \text{Carbon emission from grid connected station} \tag{21}$$

$$\text{Fuel car carbon emission } \left(\frac{\text{KG}}{\text{kWh}}\right) = \frac{\text{Grid dependency}}{\text{Required energy}} \times \text{Estimated path } \times \text{carbon emission per km} \tag{22}$$

About 0.417305 kg of CO_2 emissions per kWh from the grid-connected solar station (34) and 0.1204 kg of CO_2 emission per kilo-meter from fuel cars. (35).

2.6 Life Cycle Cost (LCC)

2.6.1 Inflation and discount rate

All of the costs associated with owning and operating anything for its entire useful life are included in a product's life cycle cost. Expenses for owning and running a product are incurred at different periods. Some costs are incurred when the product is purchased. The period of acquisition is helpful when comparing two identical products that may have had different costs at various times. As an example, a television may be purchased at a cheaper rate initially, but as time passes, it may end up costing more due to increased electricity use and maintenance. The extra expenses of electrical energy and maintenance may outweigh the reduced purchase cost by a significant margin. [36]

Over time, the value of money is affected by two factors. The inflation rate is denoted by i. When the inflation rate falls below a certain threshold, it indicates that money has lost value. Suppose the annual rate of inflation is 3 percent; an item will cost 3 percent more the next year at the same rate of inflation. Because it takes more money to buy the same amount of goods and services, the value of a unit of currency decreases as a result of this. It is important to note that the inflation rate for any particular item does not always reflect the overall inflation rate. In recent years, health-care prices in the United States have surpassed the overall inflation rate, while the cost of most technological products has dropped considerably below the normal inflation rate in recent years.

The discount rate is denoted by d, which represents how much interest may be made on saved capital. It is expected that the deposit would grow year after year if money is put in an account that earns a positive interest rate. Investments must be made at a discount rate higher than inflation in order to achieve success.

For example, suppose a producer surplus is invested annually at a rate of 100d percent, where d is the percentage rate represented as a fraction. Now after n years the value of the investment will be determined as,

$$N\ (n) = N_o\,(1+d)\ n \tag{23}$$

N (n) = Value of investment

N_o= Value of an item at the time of the investment was made d= Discount rate n= Number of years

When it comes to buying power, however, N (n) dollars will not be able to purchase the same quantity of goods and services that this amount of money would have been able to purchase at the time of investment. Keep in mind that if the cost of an item was Co at the time the investment was made, then its cost after n years if inflation is 100i percent per year will be

$$C\ (n) = C_o\,(1+i)^{\ n} \tag{24}$$

C (n) = Cost Of investment

C_o= Cost of an item at the time of the investment was made Inflation rate n = number of years

To put it another way, some people believe items should be bought as soon as their price rises outpace their ability to save money. Additionally, if the price of an item rises more slowly over time, or, in certain cases, even drops over time, it is wise to hold off on making the purchase since the price will be cheaper at a later date. Naturally, the drawback of this purchasing process is that the item being bought will not be available for use until it is purchased. So, the new computer that is becoming less and less costly while the amount of money spent increases continues to be unavailable for computing at the time when it should be bought. To put it another way, while making a purchase, the cost of the item may not be the only factor to consider. It's possible that individuals purchase something just because they want them.

Because d and i change with time, selecting values for them is like making predictions about the future. The average return may be constant or variable, depending on the savings method. There is no way to accurately forecast inflation.

2.6.2 Present Worth Factors:

Co = No and the ratio of C(n) to N(n) is transformed into a dimensionless number, Pr, which reflects the present value factor of an item that will be bought n years from now which can be represented as [36],

$$P_r = \left(\frac{1+i}{1+d}\right)^n \tag{25}$$

According to this definition, the present value of an object is defined as the amount of money that would need to be invested at the current time with a return of 100d percent in order to be able to buy that thing at some future period, assuming an inflation rate of 100i percent. If the item will be bought n years from now, the current value is calculated as follows:

$$PW = Co\,(P_r) \tag{26}$$

When a recurrent expenditure, such as gasoline, must be valued in the present, it is essential to do so. It is feasible to calculate the present value of a recurrent expenditure by adding the present values of all the individual expenses that make up the series in the future. Consider the case of a diesel generator that will consume a resource like diesel fuel for the duration of its useful life. To buy gasoline for n years, how much money must be invested now at a 100d percent annual interest rate, under circumstances of a 100i percent annual inflation. To calculate the present value of the fuel purchases, the first year's fuel supply must be bought when the system is placed into service, and each subsequent year's fuel supply must be purchased at the start of the year. The current value of the gasoline purchases is expected to be,

So, the cumulative present worth factor can be written as,

$$Pa = \frac{1-x^n}{1-x} \tag{27}$$

As you can see, the calculation assumes that you buy a year's worth of gasoline at a time when its current price is equal to what you paid for its last year. Afterwards, the fuel is bought on a yearly basis, with the final purchase happening one year before the system's lifespan expires. To put it another way, n fuel purchases are made, one at the start of each new-year.

If the recurrent purchase does not begin until the end of the first year, and if the final purchase is made at the end of the system's useful life, there will still be n purchases, but, using x again, the cumulative present worth factor is as follows [36],

$$xP_a = x\ (1 + x + x^2 + \ldots + x^{n-1}) \tag{28}$$

Since x is usually between 0.95 and 1.05, and since determining I and d are just educated estimates, either Pa or xPa will give a reasonable estimate of the present value of a cumulative spend. Purchasing a full year's supply of many items at the beginning of the year or at the end of the year is exceptional. The values of Pr and Pa are often recorded. Consistency of the values for these equations isn't necessary since most engineers use programmable calculators and computer systems. The present value of quantities may be computed after the variable values have been determined. Similarly, an engineer might use the same technique to calculate the current value of a quantity by assuming various values for d and I throughout time.

Chapter 3

Methodology & system design

3.1 Methodology

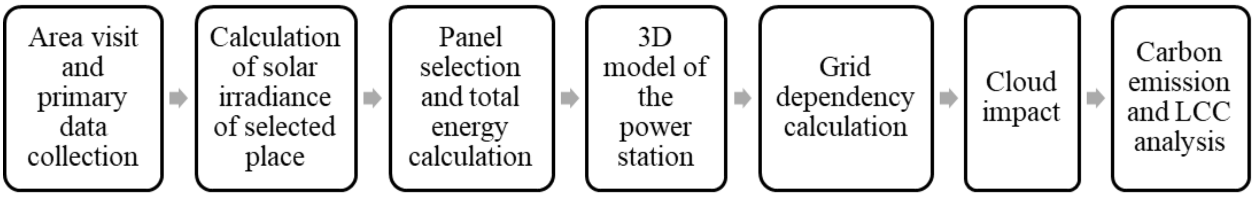


Figure 3: Flow Chart diagram of methodology

This chapter is about the mechanisms that were used in order to find relevant data and analyses them in order to carry out the charging station plan. These will include areas such as the location of the power station, size and measurement of the research design, data types and their collection method, strategies and management of the system.

The location selected for our power station was “Sonadanga Bypass” in Khulna division, Bangladesh as this city has one of the most growing populations in the country and its need for a sustainable energy source was never like this before because of the rising number of easy bikes. Another reason for selecting this place is, it is close to highway and building a charging station here will definitely help the people of this area.

Most of the data we used in our research was quantitative. For example, irradiation calculation, cloud impact consideration data, total loss and energy calculation, battery and panel power etc. However, we also had some primary qualitative data like importance of the location, panel quality, effects of the station on economy and environment. Almost all the data were collected from MATLAB simulation especially the irradiation part and energy calculation after considering cloud impact. Other data such as area, number of easy bikes in the area, battery and panel quality were taken from different papers, referred at the end and via primary research.

A 3D model of the charging station then was built. The intention of the design is to provide a basic idea about the physical view of the station. This design mainly focuses on the measurement of the panels and total area needed to carry out the operation rather than explaining the operation. We used software called

“Blender” in order to draw our design. Lastly environment and economical part was handled following LCC analysis.

3.2 Station Design

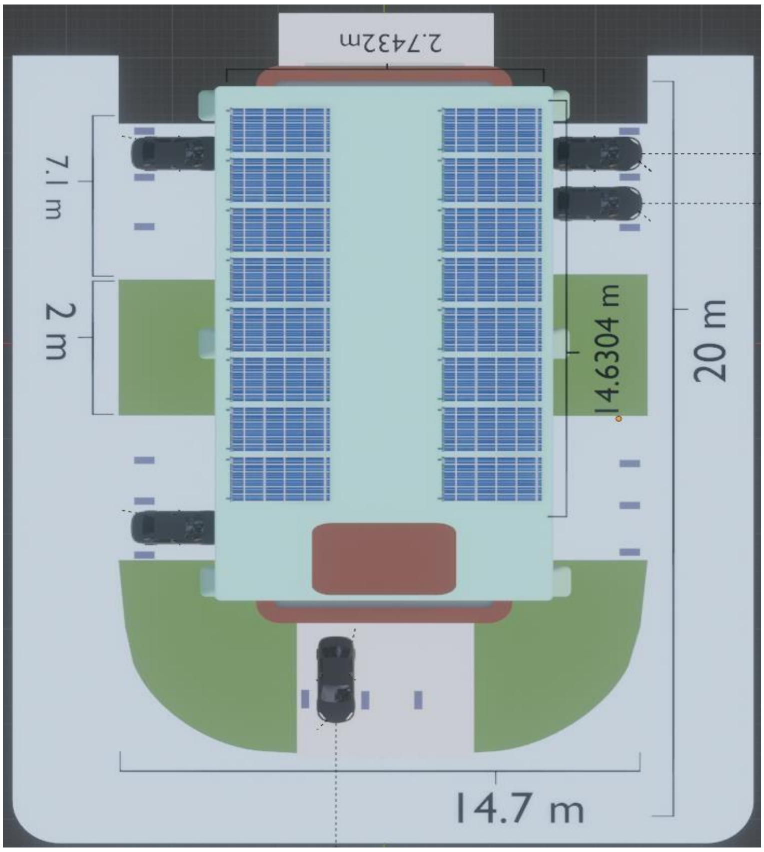


Figure 4: Top view of the station.

The solar panels are within a total area of 27.8 square meters where 8 panels in each row are parallel and the 2 rows are series to each other. The gap between two rows is 1.5 m. So, at the rooftop total length and width for 16 panels are 14.6304 m and 2.7432 m respectively. Now the corresponding value of length and width of our easy bike is 3.8 m and 1.7 m. Here we considered a 1m gap between two easy bikes charging space. Our design's east and west sides are identical along with 6 easy bikes on each side. Besides for 3 easy bikes, the space needed is 7.1 m. In addition, we contemplated a 2 m gap in the middle for landscape architects. South side of our station also has the capability to charge a total number of 3 easy bikes, designed in the same manner. Thus, our station's total length becomes 20 m and width 14.7 m. Hence it has an area of 294 square meters. Should be noted, pathways for vehicles to move around the station were ignored.

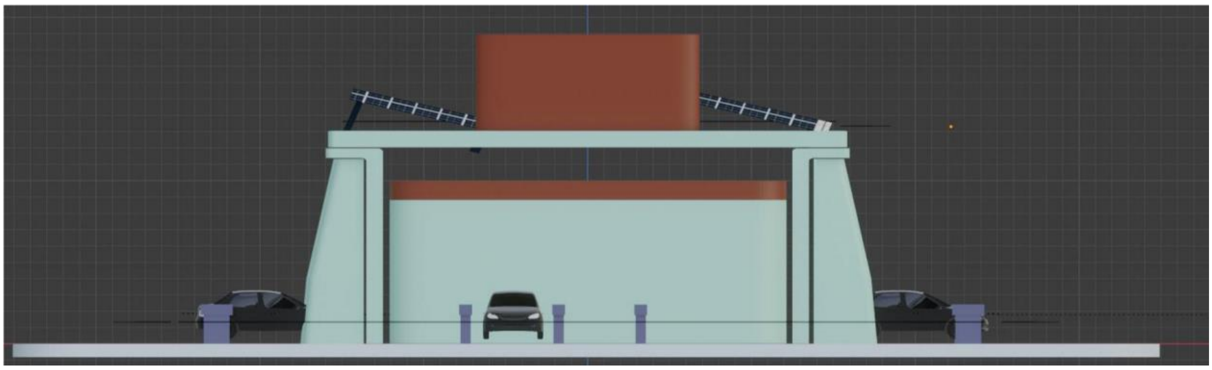


Figure 5: Rear view of the station.

Up to 3 easy bikes can be charged in the rear side. Same amount of space is considered here also.

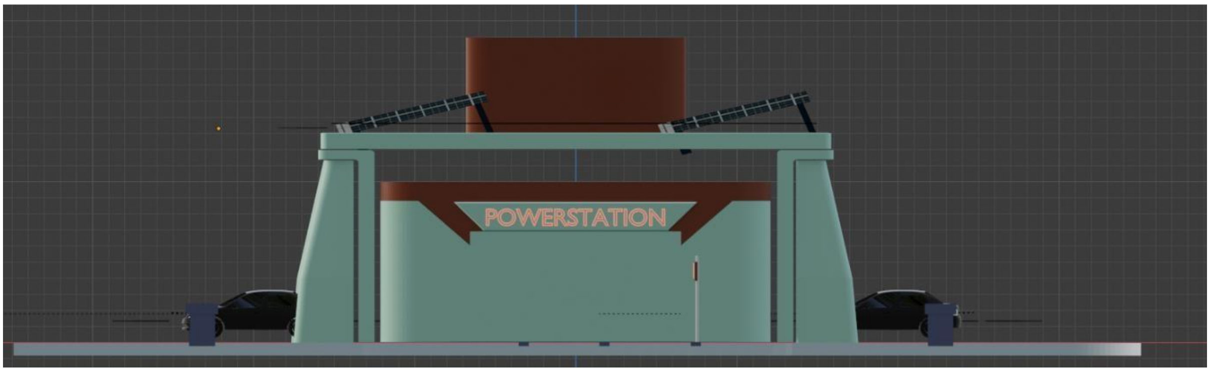


Figure 6: Front view of the station.

This is the opening gate. In order for the satisfaction of the customer a restaurant or mini hotel can be made. This will increase the yearly income of the charging station.

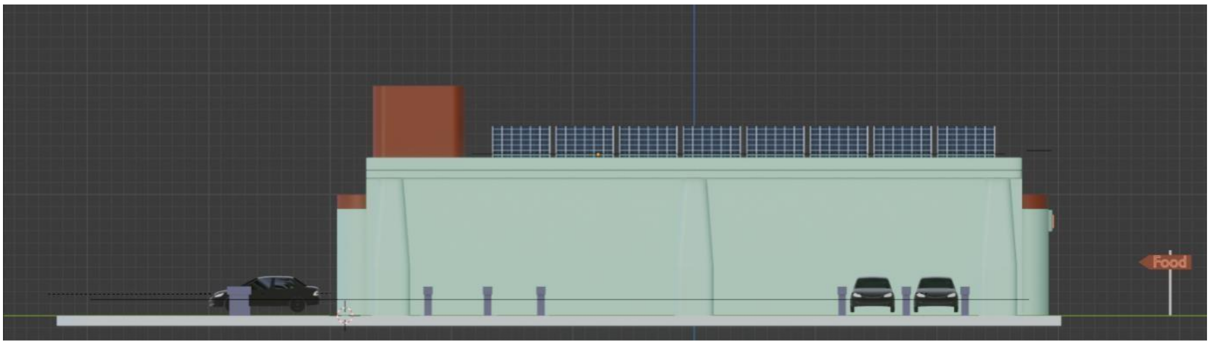


Figure 7: Right side view of the station.

On the right side the station can charge six easy bikes. The other factors like pathway length, decoration etc were ignored for convenience.

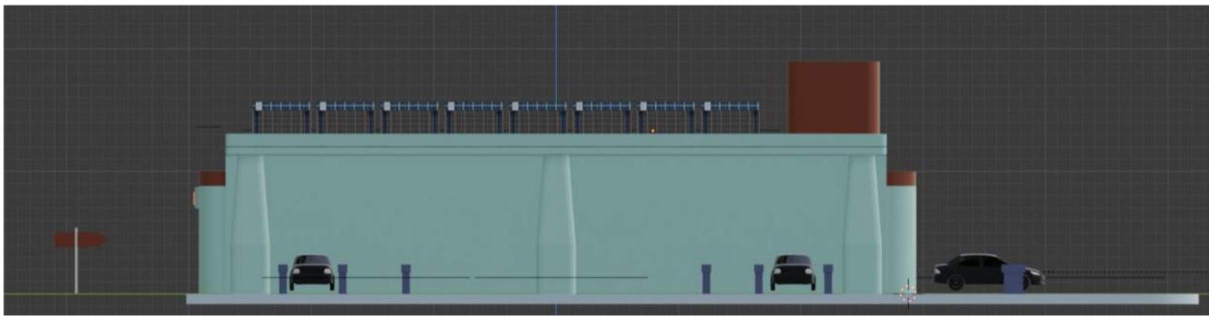


Figure 8: Left side view of the station.

Both the left and right side are identical. Here the number of cars doesn’t represent the number of charging ports.

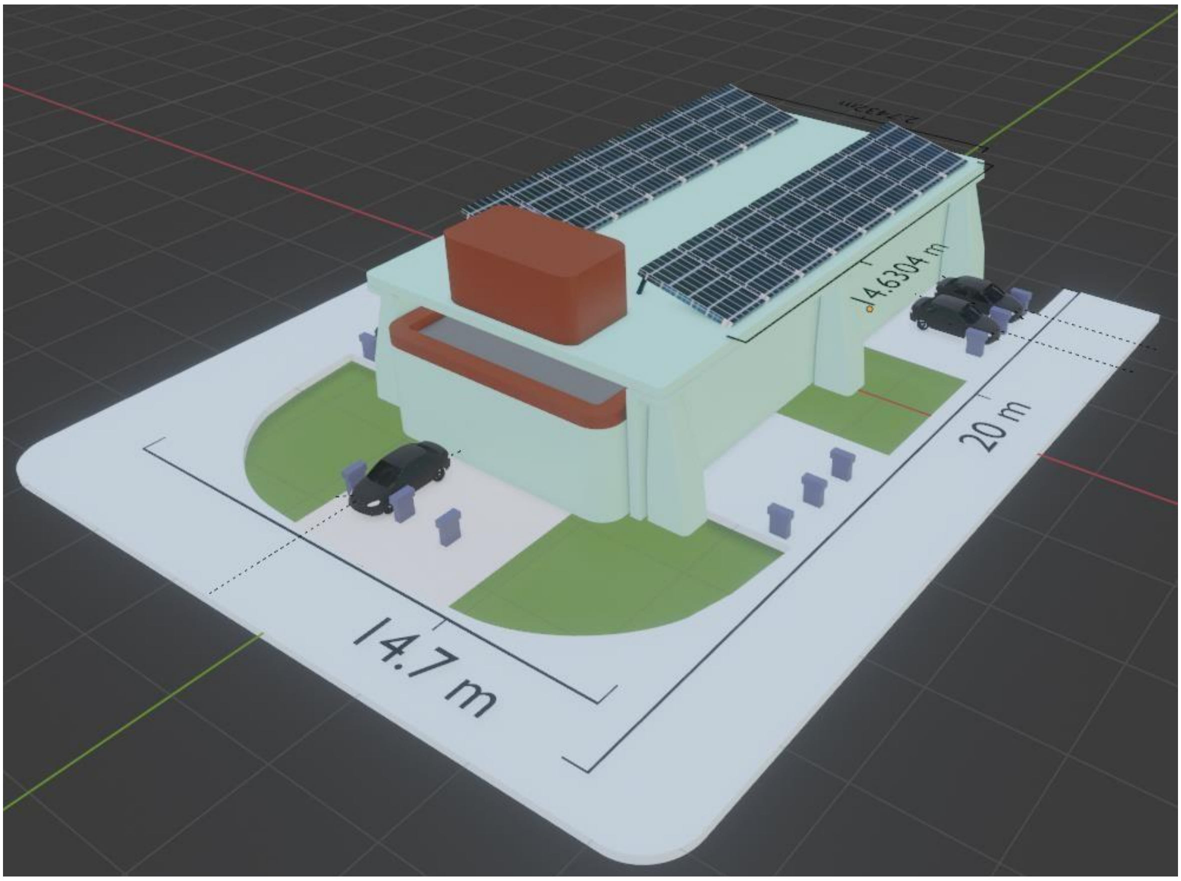


Figure 9: Charging station.

This is the final view of the charging station. The real-life station will be much like this one. The room on the rooftop is for the battery.

3.3 Station design Calculation

Table 1: Values for calculation.

Panel power	250W
Panel voltage	30.6V
Current through panel	8.17A
Panel efficiency	15.37 percent
Panel size	1.6 m^2
Solar insolation time	6.5hr
Battery voltage	12V

The solar charging station’s rooftop area for solar panel setup is considered to be, 300 ft^2 or 27.8 m^2 and calculated energy in December is 6500 Wh per square meter. So total energy we get from the rooftop area in December will be the multiplication of rooftop area and energy in December which is 180700 Wh.

Now, considering battery utilization efficiency as 90 percent; wiring efficiency 98 percent; temperature correction factor 90 percent; depth of discharge 80 percent and PV array degradation factor 90 percent, total output energy becomes (180700 × 90% × 98% × 90% × 80% × 90%) or 103276.5552 Wh. These factors are basically losses. For instance, for 90 percent efficiency the loss is 10 percent, for 98 percent the loss is 2 percent.

As for 15.37 percent efficient panel total output energy is (103276.5552 × 15.37%)

= 15873.60653 Wh.

However, single EV energy consumption is1440Wh.

Therefore, a Total of 15873.60653/1440 or approximately 11 EVs can be charged fully and perfectly.

Now for solar panel setup,

In the available 27.8 m^2 area, the highest possible number of panels can be set is 17 as each 250W panel size is 1.6 m^2. The battery storage system in the charge station is 48V.

So, the required number of panels in series will be the division of voltage of the battery storage system and panel voltage or $(\frac{48}{30.6})$V or approximately 2. Hence, the number of parallel panels will be, total number of panels divided by total number of panels in series $\frac{17}{2}$ or approximately 8.

As we overlook the value 2 in series connection, we set 8 for parallel so that our observation becomes more efficient and suitable.

Finally, we round with a total number of 16 panel setup organized with 2 series panels and 8 parallel panels. Now for battery storage to be set, solar insulation time and degradation factor must be onsidered.

Solar Panels are supposed to receive maximum energy only for 6.5 hr because solar insulation time is = 6.5 hr. Moreover, the Panel degradation factor of 90 percent

Hence the panel produces (8.17 × 8 × 6.5 × 90%) or 382.356 Ah where 8.17A is current through per panel.

Therefore, energy delivered to the battery by panel is panel production multiplied by panel's voltage and number of panels in series or (382.36 × 30.6 × 2) = 23400.1872 Wh.

In order to maintain 48V in the charging station, required number of batteries in series is 4 batteries, where each battery is 12V.

So, ($\frac{23400.1872}{48}$) V = 487.5039 Ah is required for charge storage and 150 Ah battery can store (150Ah × 90% × 80%) or 108Ah considering the losses. So, the required number of batteries in parallel is ($\frac{487.5039}{108}$) or approximately 5 batteries.

Here we get a total number of 20 batteries which will be required to be organized in 5 parallel and 4 series.

For validation,

Panel produces (8.17 × 8 × 6.5 × 90%) or 382.356 Ah.

When energy delivered to the battery by panel is (382.36 × 30.6 × 2) or 23400.1872 Wh.

Hence, battery ultimately store (487.5Ah × 90% × 80%) or 351Ah

And total energy stored by the battery is = 351 × 48 Wh or 16848Wh.

Lastly, the charging station actually delivers (16848Wh × 90% × 98%) or 14860Wh which can serve 10 EVs.

3.4 Solar Irradiation

Latitude & longitude of our selected place is: 22°48'31.1"N 89°31'47.5"E 22.808645, 89.529860. Again, the tilt angle of our project place is 20.70 degrees. Different types of solar angles are shown below in the figure where learned about tilt angle, horizontal surface, solar azimuth, solar altitude, sun line & vertical surface also.

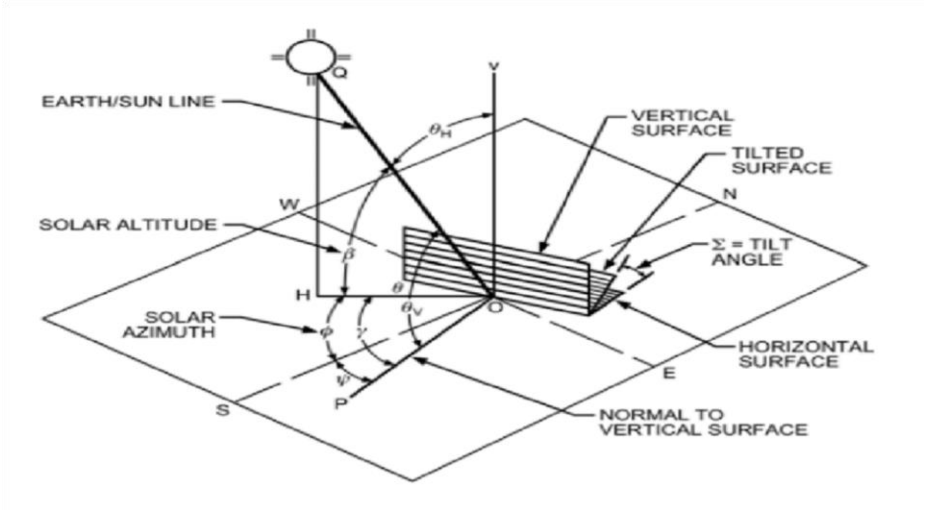


Figure 10: Solar Angles

Sunrise, Sunset, Day long time of the place

Table 2: Sunrise, Sunset, Day long time of “Sonadanga Bypass”.

Month	Sunrise With (Sunrise Angel)	Sunset With (Sunset Angle)	Day Long
January 2020	6:45(113ESE)	17:36(180s)	10:51
February 2020	6:35(104ESE)	17:56(256WSW)	11:20
March 2020	6:11(92E)	18:10(268w)	11:58
April 2020	5:42(79E)	18:21(281wnw)	12:39

May 2020	5:22(69ENE)	18:34(291wnw)	13:13
June 2020	5:17(64ENE)	18:47(296wnw)	13:29
July 2020	05:26(66ENE)	18:48(294wnw)	13:21
August 2020	05:39(74ENE)	18:32(285WNW)	12:53
September 2020	05:49(86E)	18:03(273w)	12:14
October 2020	05:59(99E)	17:35(261W)	11:35
November 2020	06:15(110ESE)	17:16(250wsw)	11:00
December	06:35(115ESE)	17:18(245WSW)	10:43

Place in ft^2: 720 x 10 = 7200 ft^2

So, our targeted suitable place is 7200 square feet which is enough. The power per unit area received from the Sun in the form of electromagnetic radiation, as measured in the wavelength range of the measuring equipment, is referred to as solar irradiance. The radiant energy emitted into the surrounding environment (joule per square meter, J/m^2) is commonly reported by integrating solar irradiance over a specific time period. Sun irradiation, solar exposure, solar insulation, or insulations are all terms for this combined solar irradiance. As we all know, In SI units, solar irradiance is measured in watts per square meter.

Table 3: Day number which we considered to calculate incident energy.

Month name (middle date of the month)	Yearly days
January (15)	15
February (14)	46
March (15)	74
April (15)	105
May (15)	135
June (15)	166
July (15)	196
August (15)	227
September (15)	258
October (15)	288

November (15)	319
December (15)	349

To calculate incident energy, need to middle day number & yearly days of that month. In table we can see that in January the middle of the month is 15 & the yearly days of that day is 15th. Again, in February middle of the day is 14 & the yearly day is 46th number day. In this way July middle of the day is 196th day & the day December middle of the moth belongs to 349th number day.

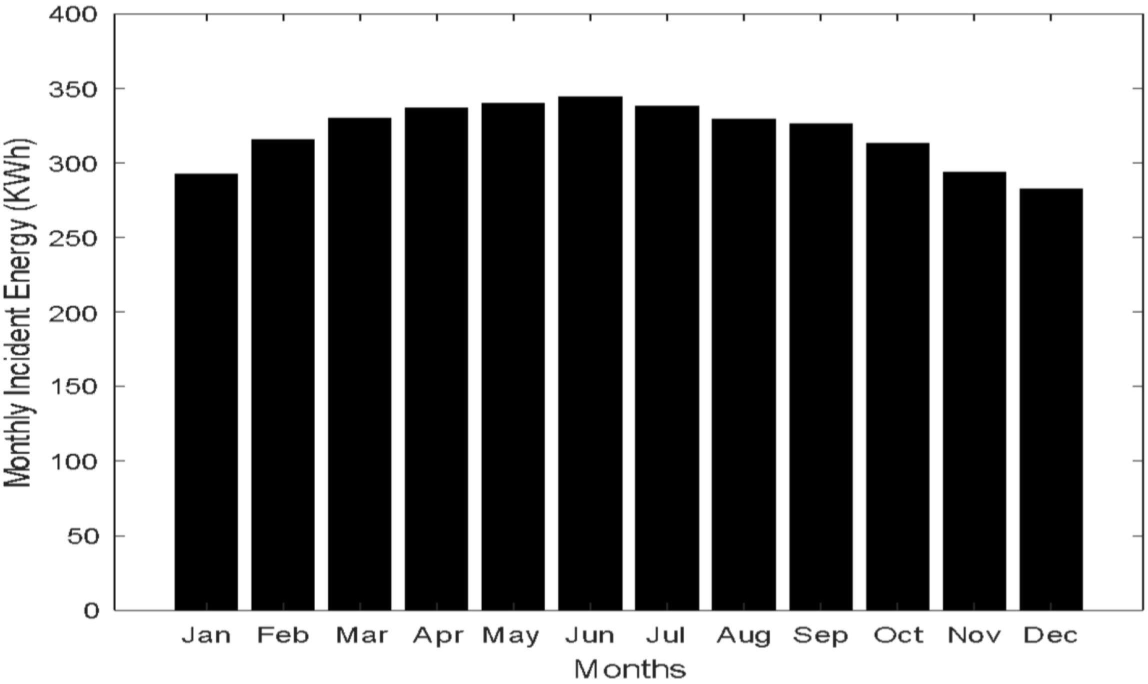


Figure 11: Average monthly incident energy graph.

Irradiation Model

Solar irradiance is the power per unit area received from the Sun in the form of electromagnetic radiation as measured in the wavelength range of the measuring instrument. The solar irradiance is measured in watt per square meter (W/m^2) in SI units. Solar irradiance is often integrated over a given time period in order to report the radiant energy emitted into the surrounding environment (joule per square meter, J/m^2) during that time period. This integrated solar irradiance is called solar irradiation, solar exposure, solar insulation, or insulation.

Initially, I attempted to model a device that could capture all of the radiation on a collector panel. The sun's irradiation is split into two parts: direct and reflected. Estimating the diffusion energy distributed by the atmosphere is more difficult because weather conditions and geographic location have an impact on diffusion rates. The ground reflected by irradiation by the earth's surface and any other surroundings make up the final component of the isotropic model. Liu and Jordan developed an anisotropic model. THRELKELD and JORDAN later produced a modified model that was included in the ASHRAE solar day clear flux model.

3.5 Cloud Impact

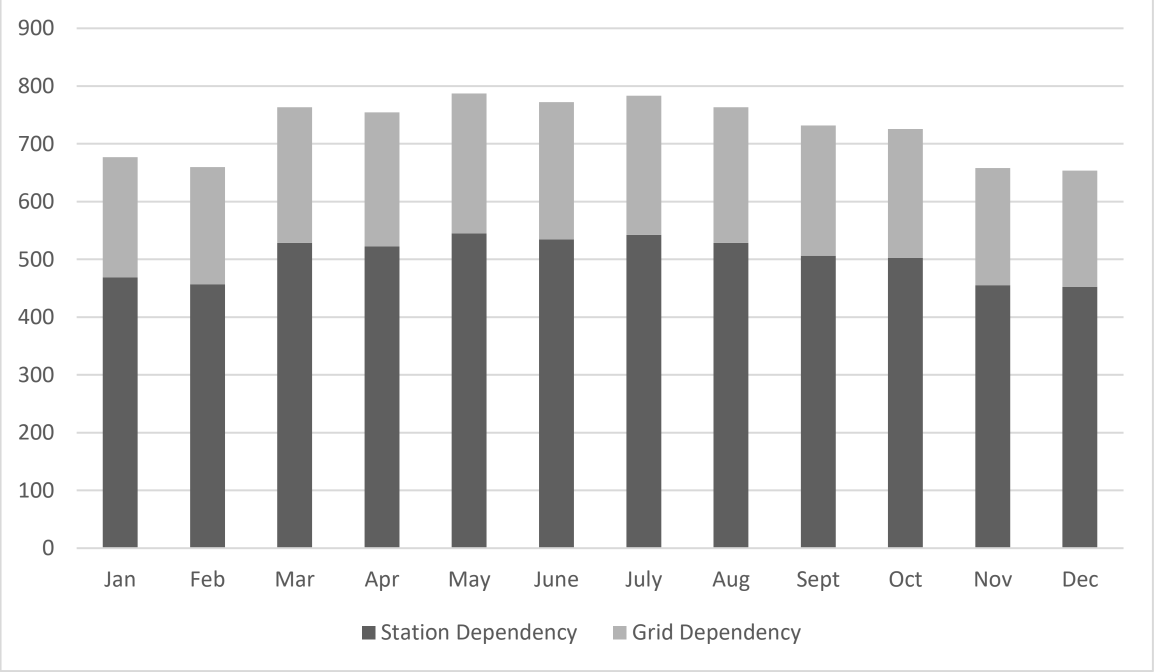


Figure 12: Station Dependency Vs Grid Dependency Considering Cloud Impact

The graph (Figure 12) intends to show a side by side comparison of how much energy our power station produces for its consumers and how much it relies on the grid after cloud impact consideration. It shows a full result of twelve months of a certain year. Here we can see, in March, the station produces most of its energy from solar panels depending less on the grid. However, in July, it mostly leaned on the grid and produced energy by the panels are not as much as other months.

Here it’s visible that on a sunny day the energy harvested in panels is 20 percent greater than on a cloudy day.

Table 4: Month wise cloudy day’s data

Month	Number of sunny days	Number of Cloudy days	Total Days
Jan	28	3	31
Feb	23	5	28
Mar	25	6	31
Apr	20	10	30
May	18	13	31
June	12	18	30
July	9	22	31
Aug	11	20	31
Sept	13	17	30
Oct	21	10	31
Nov	25	5	30

Dec	26	5	31
Total	231	134	365

Chapter 4

Results Analysis & Discussion

4.1 Case Analysis Based on Scenario

We have calculated grid dependency depending on different vehicles with different charge levels. Based on those results we plotted bar charts like Charge consume VS grid dependency, charge consume VS run path, Total output energy VS Grid dependency etc. We have also plotted charts based on the results from irradiation. An easy bike can run 110 km per day with 1.44 kWh energy. [1]. Now if we look at some scenarios, like Scenario 1 where every Vehicle runs 110km per day with 1.44kWh (Max battery health). So, the total Number of vehicle 15 and panel can produce 14.6165 kWh. So, the Grid Dependency = (15 × 1.44) – 14.6165 = 6.9835 kWh = 32.33 percent. Again, in scenario 2, suppose 15 vehicles ran 82.5 km in a day and came to charge. Total spend energy = (1.44 × 82.5)/110= 1.08kWh per vehicle. So, for 15 vehicles = 1.08 × 15= 16.2 kWh and our station produce 14.6165 kWh energy. So, the Grid dependency = 16.214.6165 = 1.5835 kWh. In percentage which is 9.77 percent. Now, in scenario 3, suppose 15 vehicles ran 55 km in a day and came to charge. So, Total spend energy= (1.44 × 55)/110= 0.72 kWh per vehicle and for 15 vehicles = 0.72 × 15 = 10.8 kWh but our station produces 14.6165 kWh, which is greater than we need so the grid dependency is 0 percent. Finally, scenario 4, suppose 15 vehicles ran 27.5 km in a day and came to charge. So, Total spend energy = (1.44 × 27.5)/110 = 0.36 kWh per vehicle and for 15 vehicles = 0.36 × 15 = 5.4 kWh as our station produces 14.6165 kWh so our Grid dependency is 0 percent. Now if we look at table 6, every scenario will be clear to understand.

Table 5: Data from different scenarios.

Run Path (Km)	Consumed Energy (kWh)	Grid Dependency (kWh)	Grid Dependency (Percent)
110	21.6	6.9835	32.33
82.5	16.2	1.5835	9.77
55	10.8	0	0
27.5	5.4	0	0

Here it is noticeable, if the station is fully booked with its capacity of 15 vehicles and all of the vehicles uses all of its battery capacity which is 1.44 kWh, it can run up to 110 km. So, if 15 vehicles run 110 km it consumes 21.6 kWh energy. But our station produces 14.6165 kWh energy. For this reason, we need to depend on the grid for the additional required energy. Additional required energy is 6.9835 kWh for which our grid dependency is 32.33 percent. Again, if 15 vehicles run 82.5 km it consumes 16.2 kWh energy. But our station produces 14.6165 kWh energy. For this reason, we need to depend on the grid for the additional required energy. Additional required energy is 1.5835 kWh for which our grid dependency is 9.77 percent. Furthermore if 15 vehicles run 55 km it consumes 10.8 kWh of energy and if 15 vehicles run 27.5 km it consumes

5.4 kWh of energy. For both of these cases the consumed energy is less than out produced energy so it doesn’t require the grid dependency.

4.1.1 Grid dependency Versus Power station dependency (Considering as percentages)

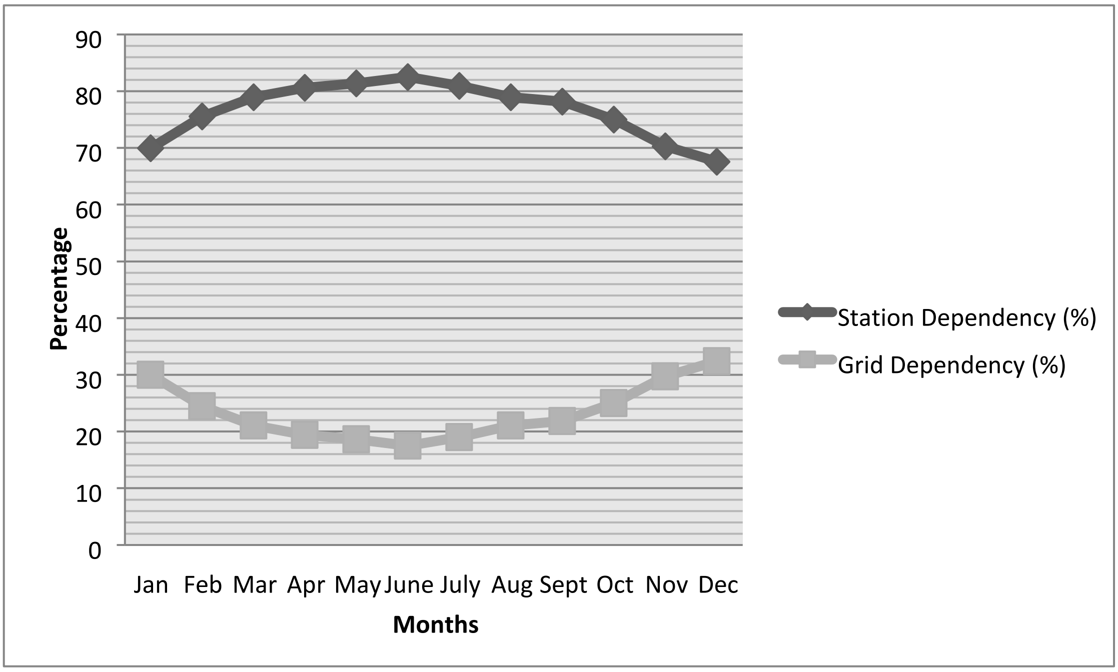


Figure 13: Grid Dependency VS Station Dependency in percentage.

There is a noticeable difference in percentages of grid & station dependency required throughout the year. The difference in dependency depends on the different weather conditions. As in summer the grid dependency is comparatively lower than station dependency as in this condition we can get enough sunlight for our cells. But during the rainy & winter season due to cloud impact and sun positioning grid dependency becomes higher.

4.1.2 State of Charge VS Run Path

Easy Bike Runs 110 km with 100 percent Charge

Easy Bike Runs 110 ⨯ 75/100 = 82.5 km with 75 percent Charge

Easy Bike Runs 110 ⨯ 50/100 = 55 km with 50 percent Charge

Easy Bike Runs 110 ⨯ 25/100 = 27.5 km with 25 percent Charge

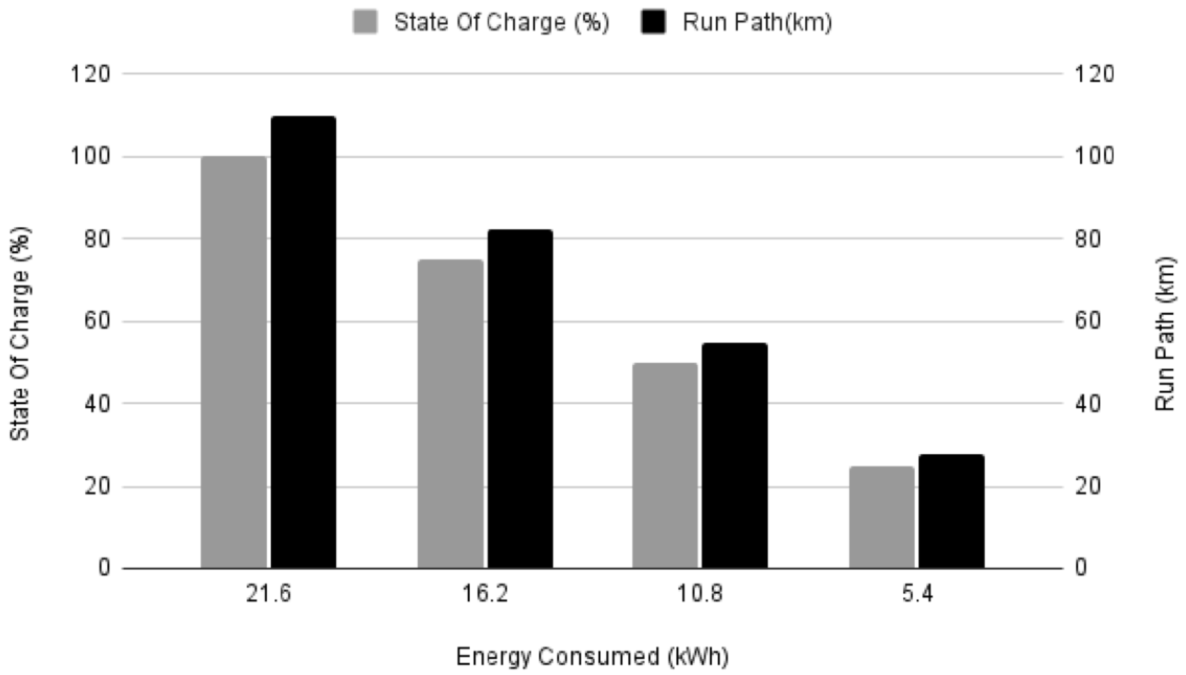


Figure 14: Run path and state of charge depending on energy consumed.

In this case it’s visible that if the vehicle's battery is fully charged it can cover up to 110 km of path while to charge the battery fully it is required 21.6 kWh of energy. Again, if the vehicle's battery is 75 percent charged it runs up to 82.5 km path. To charge the 75 percent of the battery consumes 16.2kWh of energy. Furthermore, the vehicle can cover up to 55km of path with 50 percent of battery power. To run 55 km 10.8 kWh of energy is required. Lastly again if the vehicle left with 25 percent of charge it can cover up to 27.5 km path for which 5.4 kWh of energy is consumed.

4.1.3 Charge Consumed VS Grid Dependency

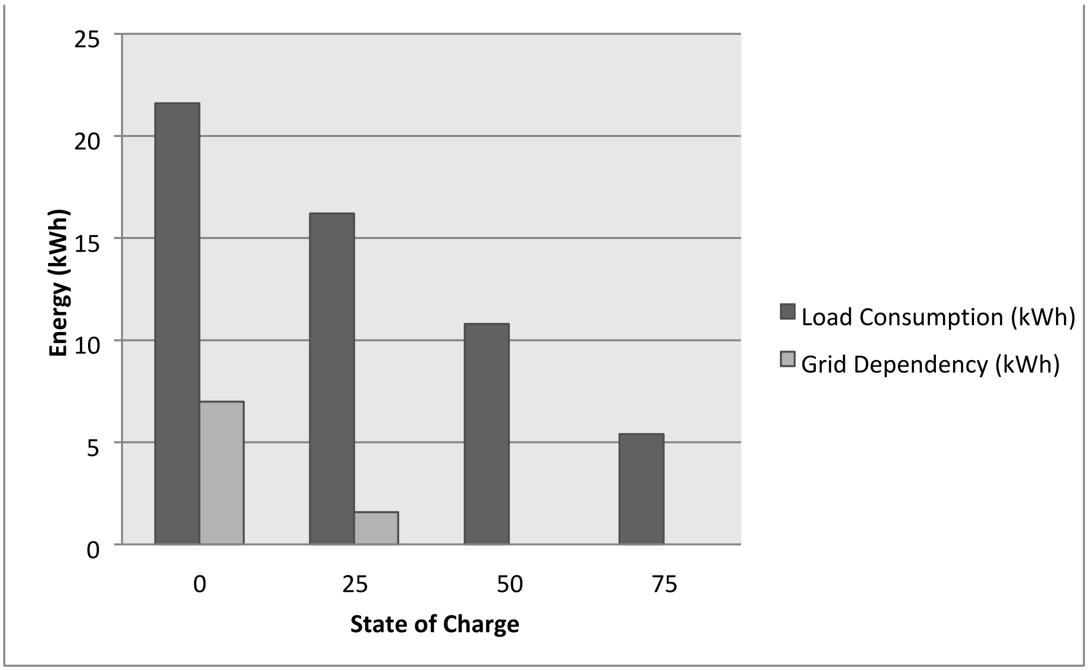


Figure15：Grid Dependency and Load consumption based on state of charge.

In this scenario if all of the 15 vehicle's energy usage is 25 percent then it'll consume 5.4 kWh and if the energy usage is 50 percent then it'll consume 10.8 kWh of energy. In both cases the station can manage without help of the grid therefore the grid dependency becomes zero. However, if all 15 vehicle's energy usage is 75 percent it'll consume 16.2 kWh of energy. Yet in this case, the station has to depend on the grid for additional 1.5835 kWh of energy. Finally, if all of the 15 vehicle's energy usage is 100 percent then it'll consume 21.6 kWh. For that reason, it surpasses the stations capacity and it requires additional 6.9835 kWh of energy.

4.1.4 Total Output Energy VS Grid Dependency

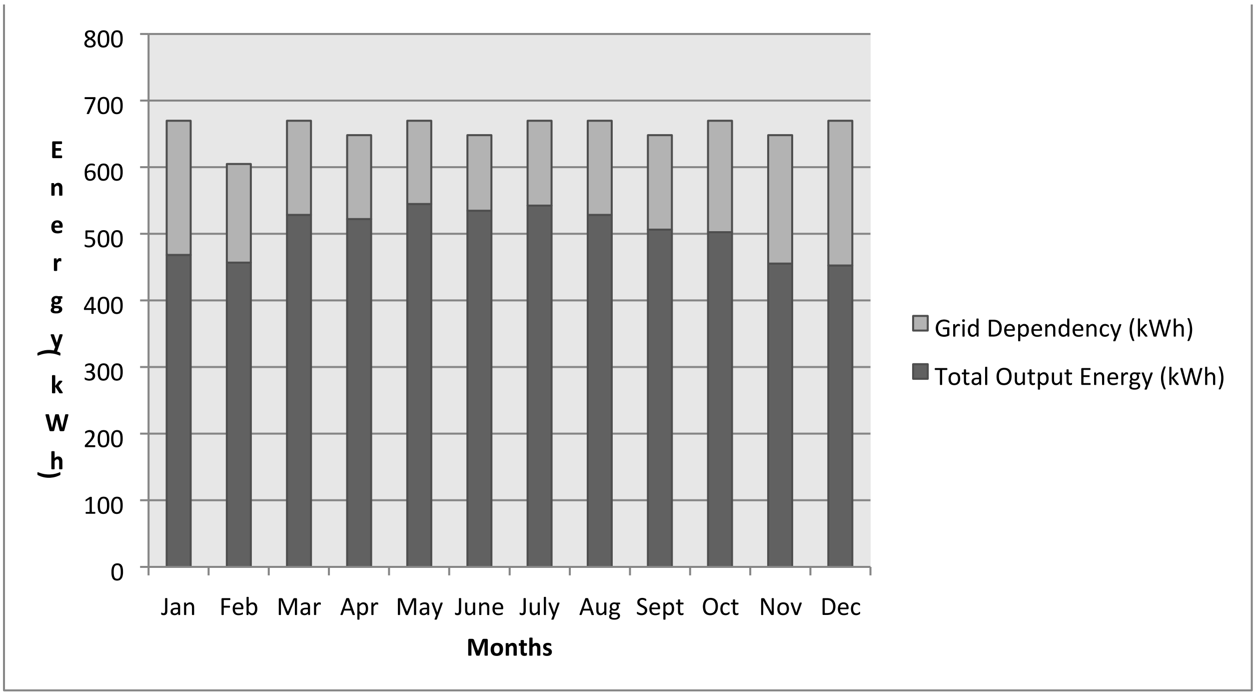


Figure 16 ：Output energy of the station and Grid dependency through-out the year.

4.2 Carbon Emission analysis

This is equal to about 0.92 pounds or 0.417305 kg of CO_2 emissions per kWh.

Our station will be dependable on-grid electricity. So, from our station, the amount of carbon emission is dependent on our grid dependency.

Station carbon emission (KG/kWh) = Grid dependency × 0.417305 fuel car carbon emission (KG/kWh) = [(Grid dependency /1.44) × 110] × 0.1204 In total our station will save from 16931.17 - 768.2169 = 16162.96 Kg/kWh CO_2

These calculations are based on table 10 information.

Table 6: Comparison on carbon emission between station and fuel car.

Months	Grid dependency (kWh)	Station carbon emission (Kg/kWh)	fuel car carbon emission (InKg/kWh)
January	201.0578	83.9024	1,849.1733
February	147.9824	61.7538	1,361.0270
March	141.0354	58.8548	1,297.1339
April	125.7527	52.4772	1,156.5755
May	124.7115	52.0427	1,146.9994
June	113.3477	47.3006	1,042.4840
July	127.4795	53.1978	1,172.4573
August	141.0583	58.8643	1,297.3445
September	141.5897	59.0861	1,302.2319
October	167.3598	69.8401	1,539.2453

November	192.5049	80.3332	1,770.5103
December	217.0210	90.5639	1,995.9904

Here, we compared the fuel car's carbon emission with carbon emission from our station. Firstly, we made a bar chart and secondly, we made an area chart for this analysis.

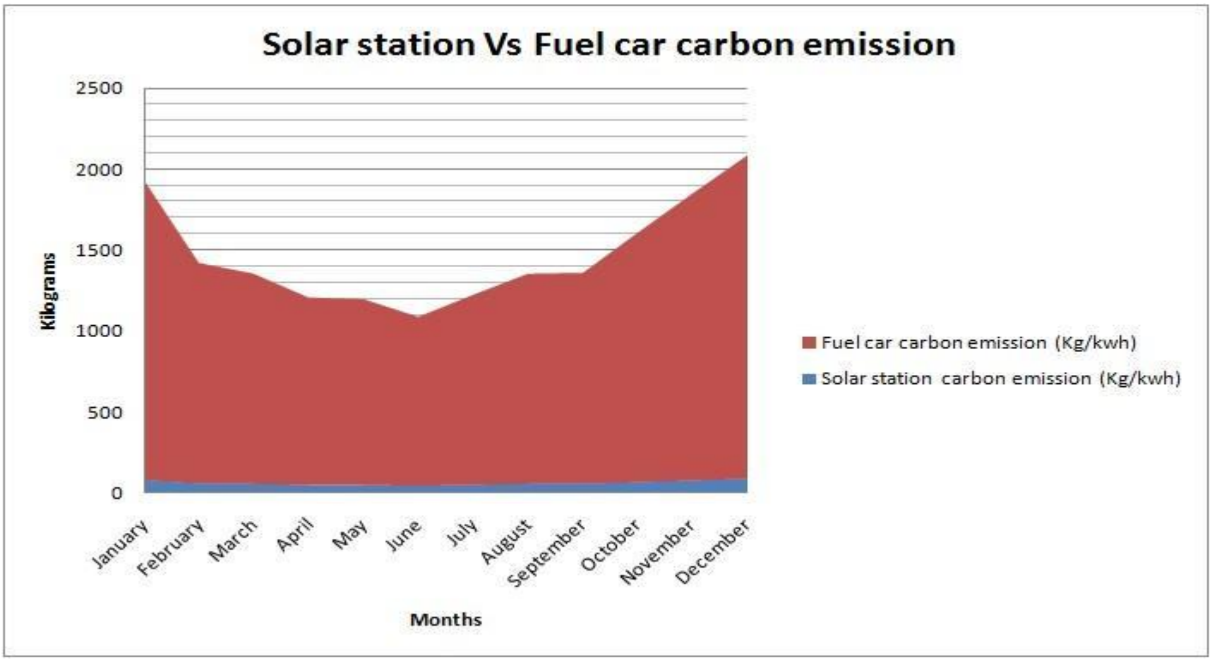


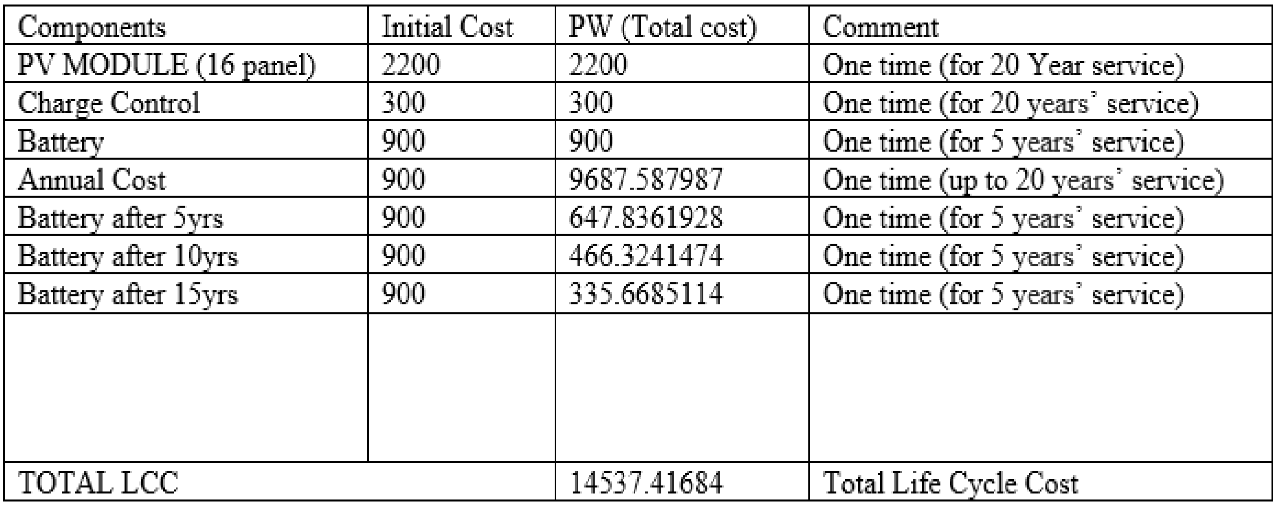
Figure 17: Station VS fuel car carbon emission area chart.

120.4 grams or 0.1204 kg or 0.2654 pounds of CO2 emission per kilometre from fuel cars.

4.3 Life cycle cost (LCC)

USD$ rate =85 taka

Table 7: LCC analysis of our designed charging station.



Components	Initial Cost	PW (Total cost)	Comment
PV MODULE (16 panel)	2200	2200	One time (for 20 Year service)
Charge Control	300	300	One time (for 20 years' service)
Battery	900	900	One time (for 5 years' service)
Annual Cost	900	9687.587987	One time (up to 20 years' service)
Battery after 5yrs	900	647.8361928	One time (for 5 years' service)
Battery after 10yrs	900	466.3241474	One time (for 5 years' service)
Battery after 15yrs	900	335.6685114	One time (for 5 years' service)
TOTAL LCC		14537.41684	Total Life Cycle Cost

Chapter 5

Conclusion

The geographical location of Bangladesh made it possible for this country to get solar radiation throughout the whole year. Thus, it makes half the work done of getting energy from the sun. By observing data from code, we learned about solar irradiance which clearly states about the energy received from sun in per unit area. This led to the determination of output energy of the station and how much it needs to depend on the grid to serve consumers. Carbon emission rate and a life cycle cost analysis was also done followed by cloud impact. We believe the fully functional power station will have a positive effect on the economy and the place we selected. Further work has to be done to make the station fully self-dependent.

In whatever way, this researched project opens various paths to explore more about PV panels and EV. One of them is fast charging. Right now, the goal is to work on the charging time of an easy bike and make the delay as small as possible. This will motivate people to switch to EV rather than using petrol vehicles. Though these projects are very much costly, a little focus and effort on this PV based power sector can bring a change to the country as well as to nature.

References

1. S. I. Sharif, M. A. R. Anik., M. Al-Amin, and M. A. B. Siddique, “The prospect of renewable energy resources in Bangladesh: A study to achieve the national power demand,” Energy and Power, 2019, 8(1), pp.1-6.

2. P. K. Halder, N. Paul, M. U. Joardder, M. Sarker “Energy scarcity and potential of renewable energy in Bangladesh,” Renewable and Sustainable Energy Reviews. 2015 Nov 30; 51: 1636-49.

3. D. F. Dominković, I. Bačeković, A.S. Pedersen, G. Krajačić “The future of transportation in sustainable energy systems: opportunities and barriers in a clean energy transition,” Renewable and Sustainable Energy Reviews. 2017 Jul 5.

4. H. Choi, S. Jungwoo, and J. R. Woo. “Effect of electricity generation mix on battery electric vehicle adoption and its environmental impact,” Energy Policy 121 (2018): 13-24.

5. World Bank, “Renewable Energy for Rural Development,” The World Bank Group: 1818 H Street, NY Washington, DC 20433, 2004.

6. M. Ibrahim, M.Anisuzzaman, S. Kumar, & S. C. Bhattacharya, “Demonstration of PV micro-utility system for rural electrification,” Solar Energy72(6), 521-530, 2002.

7. G. Santos, “Road transport and CO2 emissions: What are the challenges?” Transport Policy 59 (2017): 71-74.

8. Green House Gas emissions in Bangladesh. Available online:https://www.climatelinks.org/resources/greenhouse-gasemissions-factsheet-bangladesh (accessed on 10 December 2018).

9. M. Rahim, M. Abdur, M. U. H. Joardder, S. M. Houque, M. M. Rahman, and N. A. Sumon. "Socio-economic & environmental impacts of battery driven auto rickshaw at Rajshahi city in Bangladesh," In International Conference on Mechanical, Industrial and Energy Engineering, 2012 – 2013

10. Battery-run-three-wheelers need policy support. Available online: https://www.thefinancialexpress.com.bd/views/battery-run-threewheelers-need-policy-support-1530633388. (accessed on 10 December 2018).

11. PDB for bringing battery run vehicles under tariff regulations https://www.dhakatribune.com/bangladesh/powerenergy/2017/09/27/pdb-bringing- battery-run-vehicles-tariff-regulations/ (accessed on 5 December 2018).

12. Z.Y. She, Q. Sun, J. J. Ma, and B. C. Xie "What are the barriers to widespread adoption of battery electric vehicles? A survey of public perception in Tianjin, China," Transport Policy. 2017 May 1, 56: 29-40.

13. L. Durante, M. Nielsen, P. Ghosh "Analysis of non-sinusoidal wave generation during electric vehicle charging and their impacts on the power system," International Journal of Process Systems Engineering. 2017; 4(2-3):138-50.

14. J. P. Liu, T. X. Zhang, J. Zhu, and T. N. Ma, "Allocation optimization of electric vehicle charging station (EVCS) considering with charging satisfaction and distributed renewables integration," Energy. 2018 Dec 1; 164: 560-74.

15. S. Rashid, S. Rana, S. K. Shezan, S. A. B. Karim, S. Anower, "Optimized design of a hybrid PV-wind-diesel energy system for sustainable development at coastal areas in Bangladesh," Environmental progress & sustainable energy. 2017 Jan; 36(1): 297-304.

16. Das, A. Halder, R. Mazumder, V. K. Saini, J. Parikh, and K. S. Parikh

"Bangladesh power supply scenarios on renewables and electricity import," Energy155 (2018): 651-667. 87.

17. Mallik and A. Arefin. "Micro Hybridized Auto-rickshaw for Bangladesh: A Solution to Green Energy Vehicle," The Open Mechanical Engineering Journal, 2018 May 23; 12(1).

18. Chaudhari, K.; Ukil, A.; Kumar, K.N.; Manandhar, U.; Kollimalla, S.K. Hybrid Optimization for Economic Deployment of ESS in PV-Integrated EV Charging-Stations. IEEETrans.Ind.Inform.2018,14,106–116.[CrossRef].

19. Bhatti, A.R.; Salam, Z.; Sultana, B.; Rasheed, N.; Awan, A.B.; Sultana, U.; Younas, M. Optimized sizing of photovoltaic grid-connected electric vehicle charging-system-using particleswarm-optimization.Int.J.EnergyRes.2019,43,500–522.[CrossRef].

20. Domínguez-Navarro, J.A.; Dufo-López, R.; Yusta-Loyo, J.M.; Artal-Sevil, J.S.; Bernal-Agustín, J.L. Design of an electric vehicle fast-charging station with integration of renewable energy and storage systems. Int. J.Electr.PowerEnergy Syst. 2019, 105, 46–58. [CrossRef].

21. Baik, S.H.; Jin, Y.G.; Yoon, Y.T. Determining Equipment Capacity of Electric Vehicle Charging Station Operator for Profit Maximization. Energies 2018, 11, 2301. [CrossRef].

22. Badea, G.; Felseghi, R.-A.; Varlam, M.; Filote, C.; Culcer, M.; Iliescu, M.; Răboacă, M.S. Design and Simulation of Romanian Solar Energy Charging Station for Electric Vehicles. Energies 2019, 12, 74. [CrossRef].

23. Torreglosa, J.P.; García-Triviño, P.; Fernández-Ramirez, L.M.; Jurado, F. Decentralized energy management strategy based on predictive controllers for a medium voltage direct

current photovoltaic electric vehicle charging station. Energy Convers. Manag. 2016, 108, 1–13. [CrossRef].

24. Yao, L.; Damiran, Z.; Lim, W.H. Optimal Charging and Discharging Scheduling for Electric Vehicles in a Parking Station with Photovoltaic System and Energy Storage System. Energies 2017, 10, 550. [CrossRef].

25. Hafez, O.; Bhattacharya, K. Optimal design of electric vehicle charging stations considering various energy resources. Renew. Energy 2017, 107, 576–589. [CrossRef].

26. G.M. Masters, "Renewable and efficient electric power systems", 2004, New jersey: John Wiley & Sons, Inc.

27. Liu, B Y.H., & Jordan, R C. Interrelationship and characteristic distribution of direct, diffuse, and total solar radiation. United States. https://doi.org/10.1016/0038- 092X(60)90062-1.

28. Jakhrani, Abdul & Othman, Al-Khalid & Rigit, Andrew & Samo, Saleem&Kamboh, Shakeel. (2012). Estimation of Incident Solar Radiation on Tilted Surface-by-Different Empirical Methods. International Journal of Scientific and Research Publications. 2. 1-6.

29. Durusoy, B., Ozden, T. &Akinoglu, B.G. Solar irradiation on the rear surface of bifacial solar modules: a modeling approach. Sci Rep 10, 13300 (2020). https://doi.org/10.1038/s41598-020-70235-3.

30. Brock LeBaron, IngeDirmhirn, "Strengths and limitations of the Liu and Jordan model to determine diffuse from global irradiance",SolarEnergy,Volume 31, Issue 2,1983,Pages 167-172,ISSN 0038-092X,

31. Daut, M. Irwanto, Y. M. Irwan, N. Gomesh and N. S. Ahmad, "Clear sky global solar irradiance on tilt angles of photovoltaic module in Perlis, Northern Malaysia," International

Conference on Electrical, Control and Computer Engineering 2011 (InECCE), Pahang, 2011, pp. 445-450, doi: 10.1109/INECCE.2011.5953923.

32. Hoque, Sumaiya & Das, Bably& Al Askary, Md. Abu Hasan. (2019). Comparative Analysis of Dual and Single Axis Solar Tracker.

33. Infrastructure Development Company Limited (IDCOL), Available from: http://www.idcol.org/.

34. "Frequently Asked Questions (FAQs) - U.S. Energy Information Administration (EIA)", Eia.gov, 2021. [Online]. Available: https://www.eia.gov/tools/faqs/faq.php?id=74&t=11. [Accessed: 29- Sep- 2021].

35. CO2 performance of new passenger cars-in-Europe", www.eea.europa.eu, 2021. [Online].Available:https://www.eea.europa.eu/data-and-maps/indicators/average-co2emissions-from-motor-vehicles-1. [Accessed: 29- Sep- 2021].

36. R. Messenger and J. Ventre, Photovoltaic systems engineering, 2nd ed. Boca Raton: CRC Press, 2004, pp. 146-149.

Appendix:

Table 8: Station Dependency VS grid dependency considering cloud impact.

Month	Station Dependency (kWh)	Grid Dependency (kWh)
January	428.0103	241.5897
February	386.2576	218.5424
March	445.2882	224.3118
April	383.3135	264.6865
May	362.3777	307.2223
June	277.4449	370.5551
July	235.6586	433.9414
August	257.2239	412.3761
September	276.5550	371.4450
October	371.8996	297.7004
November	392.3254	255.6746
December	390.3633	279.2367