FEASIBILITY ANALYSIS OF GRID-CONNECTED ROOFTOP SOLAR PV SYSTEM FOR THE INDUSTRY

A PROJECT AND THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF DEGREE OF BACHELOR OF SCIENCE IN ELECTRICAL AND ELECTRONIC ENGINEERING

BY

ANUP KUMAR MODAK
(ID: 171-33-389)

MD. DIDER MAIN
(ID: 171-33-390)

SUPERVISED BY

DR. ENGR. MD. ALAM HOSSAIN MONDAL
Associate Professor
Department of EEE

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

FACULTY OF ENGINEERING

DAFFODIL INTERNATIONAL UNIVERSITY

January 2021

Certification

This is to certify that this project and thesis entitled **"Feasibility analysis of Grid-Connected rooftop solar PV system for the industry ."** is done by the following students under my direct supervision and this work has been carried out by them in the laboratories of the Department of Electrical and Electronic Engineering under the Faculty of Engineering of Daffodil International University in partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical and Electronic Engineering. The presentation of the work was held on 31 January 2021.

Signature of the candidates

____

Name: **ANUP KUMAR MODAK**
ID: 172-33-520

____

Name: **MD. DIDER MAIN**
ID: 172-33-475

Countersigned

____

DR. ENGR. MD. ALAM HOSSAIN MONDAL
Associate Professor
Department of Electrical and Electronic Engineering
Faculty of Science and Engineering
Daffodil International University.

The project and thesis entitled **"Feasibility analysis of Grid-Connected rooftop solar PV system for the industry ."** submitted by **Anup kumar Modak ,** ID No:171-33-389 **and Md. Dider Main,** ID no 171-33-390, Session: Fall 2020 has been accepted as satisfactory in partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical and Electronic Engineering on 31 January 2021.

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List of Abbreviations

IEA	International Energy Agency
GHGs	Green House Gases
CFCs	Chlorofluorocarbons
BP	British Petroleum
BPDP	Bangladesh Power Development Board
GWh	Gigawatt hours
MW	Megawatt
PV	Photovoltaic

IRENA	International Renewable Energy Agency
SREDA	Sustainable And Renewable Energy Development Authority
HFO	Heavy Fuel Oil
IPP	INDEPENDENT POWER PRODUCER
SIPP	SMALL INDEPENDENT POWER PRODUCERS
COE	COST OF ENERGY
GDP	GROSS DOMESTIC PRODUCT
FIT	FEED IN TARIFF
NPC	NET PRESENT COST
IRR	INTERNAL RETURN RATE
NREL	National Renewable Energy laboratory
RE	Renewable Energy
HT	High Tension
MT	Medium Tension
LT	Low Tension
NASA	National Aeronautics and Space Administration
DC	Direct Current
AC	Alternating Current
A	Ampere
V	Voltage

NPC	Net Present cost
IRR	Internal Return Rate
USD	United States Dollar
CIS	Copper Indium Selenide
CIGS	Copper Indium Gallium Selenide
NEM	Net Energy Meter
NPC	Net Present Cost

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ABSTRACT

The growth of country development depends on industrial fast growth which fully stand on electric power. To ensure energy security and increase energy demand to decrease per unit electricity production and consumption cost for all the sector of Bangladesh especially in the industrial sector. PV system with on grid media to balance electricity production and consumption for commercial, industrial or any private or university. The proposed rooftop PV system under area of Egarosindur Cold Storage Ltd at Kishoreganj, Dhaka, Bangladesh. As basis of industrial power generation we are selected best PV power generation component as well as considered to the cost. For research analysis primary data using homer expert software. The aims of research not only reduce the cost and protect environmental degradation. We are try to obtain the value of NPC and COE for electricity production by using PV system. And analysis with sensitivity also optimization result with anymore for feasibility. To show the result of production cost as compare with grid rate to say beneficial. This study found COE is $0.0300 for $0.0669 for without and with battery system respectively . Net present cost for without battery system is $669956 and the COE is varies for different location is $0.0213 to $0.0315 . Simple payback period for this system is 4.94 year. This study measures the efficiency of the system and shows that the system is economically sustainable on the basis of actual net costs and energy costs.

Chapter 1

Introduction

1.1 Introduction

Energy demand increasing rapidly in the present world. Now world energy demand basically maintains by non-renewable energy like Natural gas, Coal, Oil, etc.[1]. The energy production cost by Oil is larger than the other sector. Natural gas and Coal is base Production cost is less[2]. According to IEA World Energy Outlook 2019, the maximum electrical energy is produced from coal. It's about 10 thousand TW. After that's the contribution of natural gas is larger. Most of the energy is used in the Industrial sector than in the residential sector[1]. All fossil fuels are the reason for environmental pollution. They produce Green House Gases(GHGs) especially CO_2, Chlorofluorocarbons (CFCs) [3]. Because of storage of fossil fuel is decreasing and environmental effect words now focused on renewable energy. Energy consumption by Coal is decreasing. Besides that energy consumption by Natural gas and Renewable is in increasing trend. It is predicted that by 2050, most of the energy will be generated through renewables[4] . In modern life, most of the energy is used in the industrial, residential, and transport sectors. For a rapidly changing economy, a large amount of electrical energy is required.

The economy of Bangladesh basically depends upon the industrial and agricultural sector[5]. Now the day's industrial sector is increasing. As a result, the power demand for the industrial and commercial sector is increasing rapidly. According to BPDP total energy Produced by natural gas is 55.26 % and it's about 0.17% by PV (On-grid). A large amount of electrical energy is import based. Now Installation Capacity is 20813 MW [6]. In Bangladesh, 94% of people have access to electricity[2]. About 3% of energy produce form renewable energy in Bangladesh [7, 8]. The government committed to ensuring affordable and reliable access to electricity for all citizens by 2021[9]. To meet large energy demand generation cost is increasing. The storage of natural gas is not enough for energy security. Renewable energy has a great chance to meet the demand in this situation[10]. For this reason, Renewable energy is becoming increasingly common in the world every day. In Bangladesh solar, wind, hydro, and biomass are the resource of renewable energy [7, 9] . Wind energy is more available in the coastal area. Wind speed is certain. Large hydro resource is limited. The average solar radiation status in Bangladesh is better for PV generation. The daily temperature of Bangladesh is reasonable for PV technology[11]. Solar energy is renewable. A lot of resource of solar energy is a solution to maintain future energy demand. Solar Photovoltaic(PV) can be a better solution for the energy security of Bangladesh.

1.2 World solar energy condition

To maintain its growing population and development activities, the world needs a huge amount of energy every day[12]. The Sun is a big source for the planet Earth of inexhaustible free energy (i.e., solar energy). New technologies are currently being used to produce electricity from collected solar energy sources[13].

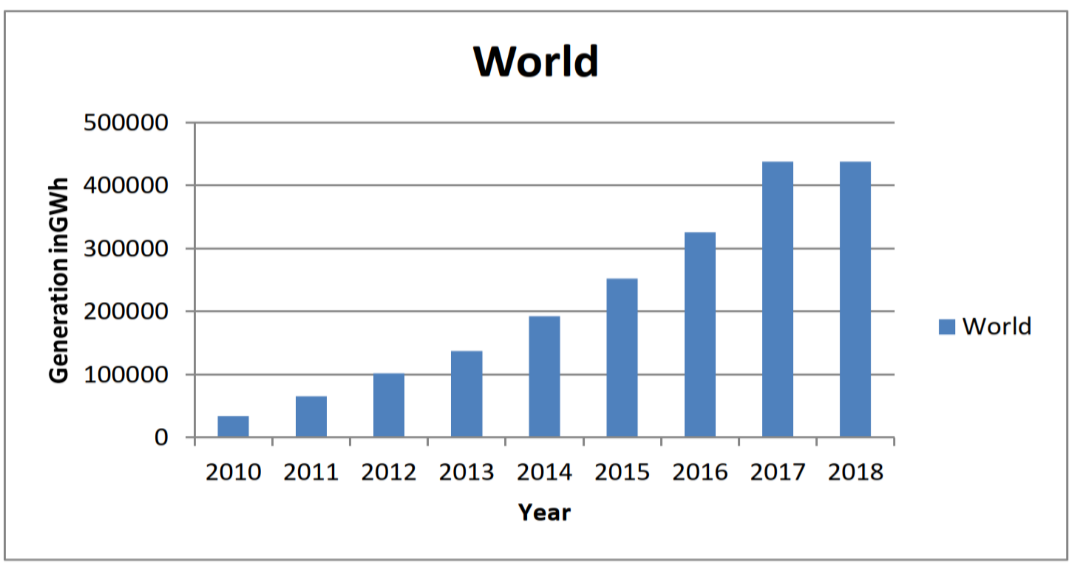

Fig.1. 1: Scenarios of global solar electricity production.

Solar energy installation is increasing(Fig.1.1) at a remarkable rate worldwide. According to Data of IRENA total solar energy generated 33813GWh in 2010. Within 2018 total energy production increases 438034GWh [14]. It shows that solar energy generation increases by 1295% within 8 years. Most of the solar panels are PV types.

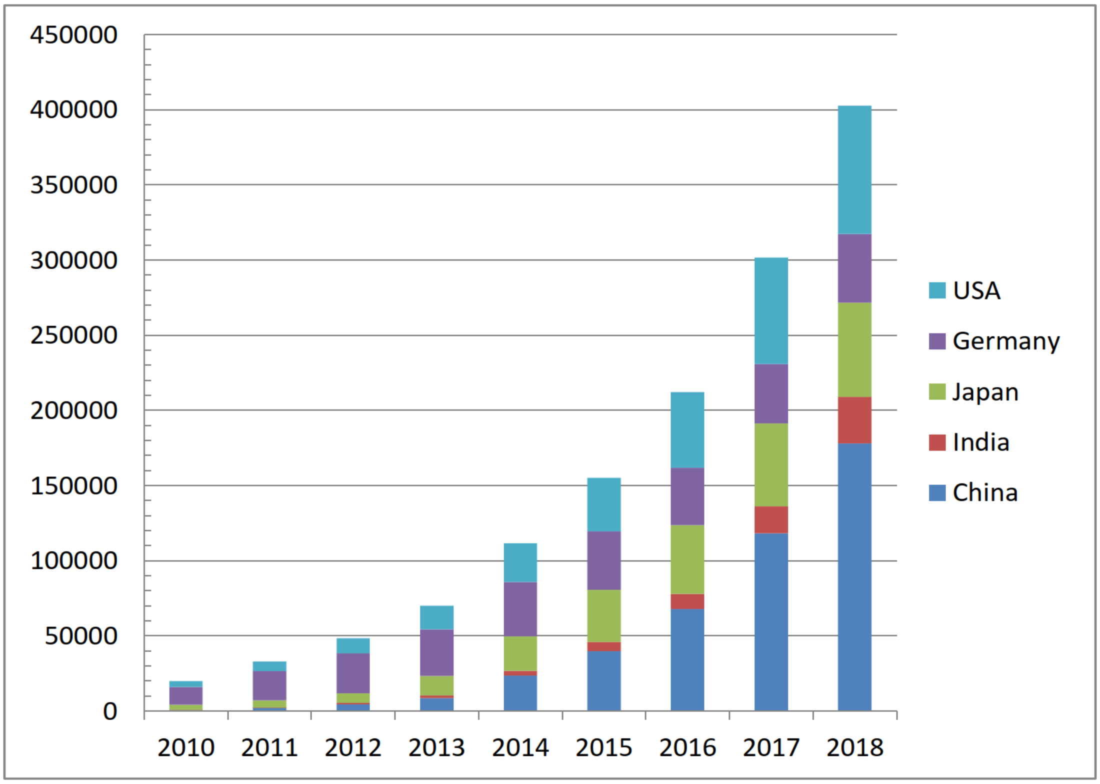

Fig.1. 2:Solar Generation increasing trend of USA, China, Japan, Germany, and India.

Data Source: Ref.[14]

Solar PV generation increased by 22% (+131 TWh) in 2019 and represented the second-largest absolute generation growth of all renewable technologies[15]. Despite decelerating growth due to recent policy changes and uncertainties in China (the largest PV market globally), 2019 was a year of record global growth in PV capacity. With this increase, the solar PV share in global electricity generation is now almost 3%[15].In solar energy generation China , USA, Japan , Germany and India is in leading position[14]. China is the largest producer of electricity and the largest producer of solar power(Fig.1.2). Beside china USA and Japan has larger share .Ten years ago, Germany was the largest producer of solar energy, which is still growing. India's solar power generation is an increasing trend. India is considering a future trade for solar generation. According to the Indian government, the target solar power generation is 100 GW within 2021-22[16]. On-Grid solar systems are getting popularity in the USA and Europe[17].India and China also focused on On-Grid solar system . The cost is relatively low as the grid-connected solar system does not require battery life. It is relatively easy to maintain. The user does not have to face any problem with the use of electricity and production conditions. So the world focused on it .

1.3 PV energy condition of Bangladesh

Along with increasing electricity demand in Bangladesh, the cost of power generation is also increasing. The average power generation cost per unit in Bangladesh is 5.95 Taka . The average Bulk energy supply cost is 6.06 Taka[2].

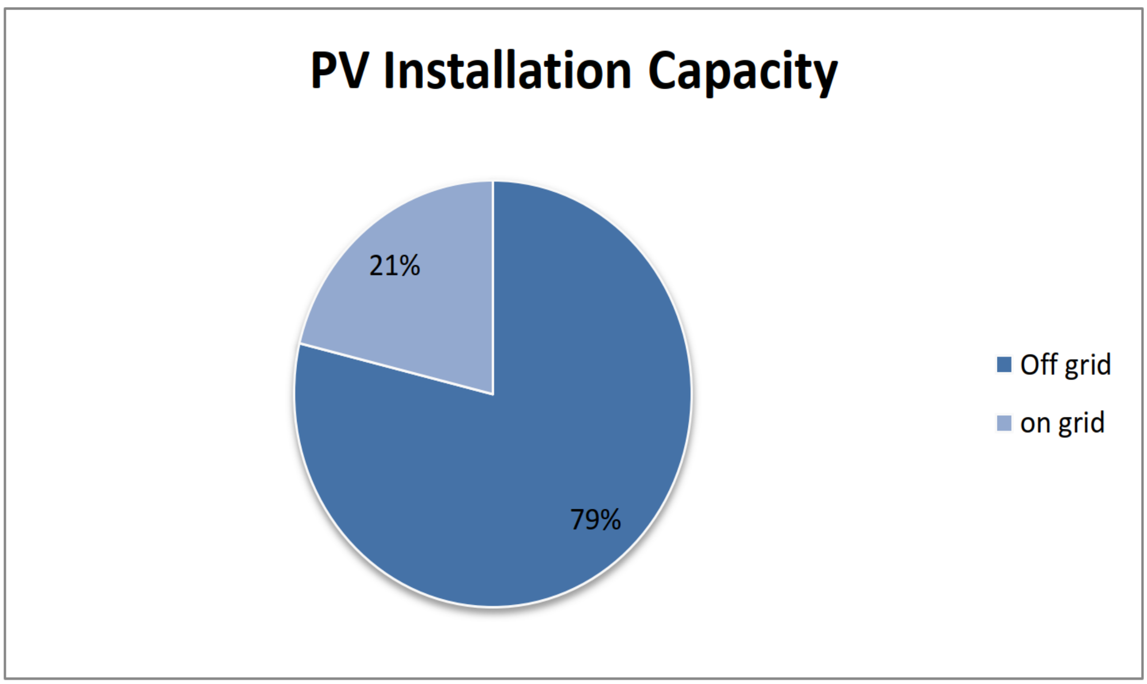

Fig.1. 3: On-Grid and Off-Grid PV Instaltion Bangladesh

For Increasing demand Bangladesh generate electricity from HFO. The government has to spend up to 22-83 Taka for electricity purchase from IPP and SIPP from HFO. But Purchase cost from solar is 12-16 Taka in the range[2]. Now production cost by PV is decreassing because efficiency of PV solar pannel is increasing . Solar production costs have dropped by 73% in 10 years[5].The government of Bangladesh had a goal to generate 5% from renewable within 2015 and 10% energy though renewable within 2020[12] . Solar generates 39% of electricity within total renewable energy generation [7]. According to Data of SREDA(Fig.1.3) total On-Grid PV installation is 88.06 MW and Off-Grid installation capacity is 327.48MW[18]Solar PV systems can make a significant contribution to the overall grid production being integrated into the grid through net metering. When a large PV system is integrated into the grid, it is needed to know beforehand the amount of power, the system can provide to the grid. On the contrary, optimization of self-consumption is required to increase profits and decrease energy exchanges with the grid in case of small system integration[19].

According to the BPDP annual report, a large number of On-Grid IPP is in under construction. These project are "200MW (AC) Solar Park on BOO basis" at Teknaf, Cox's Bazar by Sun Edsion Energy Holding (Singapore) Pvt Ltd, "200 MW (AC) Grid Tied Solar PV Power Project" at Sundarganj, Gaibandha by Beximco Power Company Ltd & TBEA XinJiang . "100 MW (AC) Solar Park" at Bora Durgapur, Mongla, Bagerhat by a Consortium of Energon Technologies FZE, UAE and China , "50 MW (AC) Solar Park" at Sutiakhali, Gouripur, Mymensingh District, Bangladesh by HETAT-DITROLIC-IFDC Solar Consortium, "30MW (AC) Solar Park" at Gangachara, Rangpur by Intraco CNG Ltd & Juli New Energy Co. Ltd, "32 MW (AC) Solar Park" at Dharmapasha, Sunamganj by Haor Bangla-Korea Green Energy Ltd, "35 MW (AC) Solar Park" at Manikganj by Consortium of Spectra Engineers Limited &Shunfeng Investment Limited,"5 MW (AC) Solar Park" at Patgram, Lalmonirhat by Green Housing & Energy Ltd (PV Power Patgram Ltd), and "5 MW (AC) Solar Park" at Sylhet by Eiki Shoji Co Ltd, Japan & Sun Solar Power Plant Ltd [2].

Now the day's government of Bangladesh focused on the On-Grid PV system. The cost of power generation in the on-grid system is low as the battery is not used in this system.

The Government of Bangladesh is emphasizing on the rooftop On-Grid solar system. They mainly focused on the rooftop area of office, industry or Building .The electricity demand can be met by generating electricity daily through an On-Grid system. Excess electricity can be sold to the grid. Again, electricity can be purchased from the grid if required. Electricity can be purchased from the grid at night when electricity is not generated. In this way, it is profitable to produce extra electricity during the day.

1.4 Research Significance

The Off-Grid system that is popular in Bangladesh, in current condition it is expensive and facilities are limited. So, the On-Grid power system is more appropriate for the present condition. It is time to reduce power generation costs as well as gain more facilities. At present solar conversion efficiency is more than 21% [20]. Solar cell prices are falling day by day as well as efficiency is increasing day by day. That increasing the possibility of on-grid solar power production and make it viable. This system reduces power loss. Because of the electric generator is located near to the electric load center[21]. There is no cost of battery as a result power production cost reduces quite a lot . There is no battery cost. So, power production cost reduces quite a lot. Besides that, no rooftop tiles are needed[21].

In this study techno-economical potential of the On-Grid solar system is analyzed . There has been less research about the On-Grid system in Bangladesh. Besides, the amount of research on net metering on industrial and commercial buildings is low. People know few about the benefits of net metering.

Through this study, one can get an overview of the financial benefit of the net metering system for industrial and commercial applications. It will also provide information on the cost of electricity production with and without batteries based on net metering. This study provides the variation of cost for different locations of Bangladesh by changing solar radiation and temperature.

1.5 Research Query

- Is the rooftop solar PV system is techno-economical viability for the industry?
- How are the components of the system performing?
- What is the difference between the production cost of the rooftop PV system and purchase cost from the Grid rate?
- What is the impact of solar radiation and temperature by different location on PV power generation?
- What are the advantages of the Net Metering Scheme for Industry?
- How is the rooftop solar PV system secured for the industry?
- What is the impact of the rooftop solar system with the net metering policy after installing it in the industry?

1.6 Research Objective

- To find out the techno-economical viability of rooftop solar PV system for the industry.
- To Determine the Per unit electricity generation cost in Net Metering with battery and without battery.
- To identify the impact of solar radiation and temperature on PV power generation.
- To determine Per unit cost for different locations of Bangladesh.
- To determine the overall benefit from the rooftop PV system.
- To ensure maximum PV production in a specific location within a reasonable price.
- To identify the sizing and specification of the rooftop solar PV component.
- To assure free emission electricity without polluting or damaging the environment.
- To ensure energy security by using empty rooftop spaces of industry.

1.7 Scope of On-Grid PV system Bangladesh

In Bangladesh, the industrial sector is a blessing for our modern-day economy. For most of the economic activities of the nation, electricity is the main source of power. Industry and the residential sector, commercial and agricultural industrial sector are the main energy users in Bangladesh. In Bangladesh, there are lots of government, nongovernment buildings, garments, and industries. All buildings are multi-storied. There has a more unused rooftop space. By using the rooftop area we can fulfill our energy demand. Besides, they can secure their own energy generation sector. Using modern technology in the industry, the grid-connected rooftop solar PV system which the distribution PV plant that can be fulfilling the own electricity demand as well as sold the electricity to the grid under the net metering policy when generation become more than the demand.

1.8 Net metering policy

Net metering is a process of utility billing system that offers a credit to residential consumer and business customers who are generating residual electricity from own solar generating station and sending it back to the grid. When there has a grid-connected solar system, the rooftop solar panel generates more electricity during day time. This solar system fulfilled the customer demand and excess electricity sent to the grid according to the net metering policy.Net metering is a bi-directional process that can export and import the electricity as well. Electricity bill is computed at the end of the billing period according to the energy recorded meter

1.8.1 Eligible criteria for Net metering policy

1. The Consumer of the utility must be active and current
2. The owner only can produce electricity from a renewable energy source.
3. The customer must have an available rooftop or free space to set up electricity generation stations using a renewable energy source.
4. The customer must consume electricity and export electricity to the utility grid at the point of power generation from renewable sources.[22]

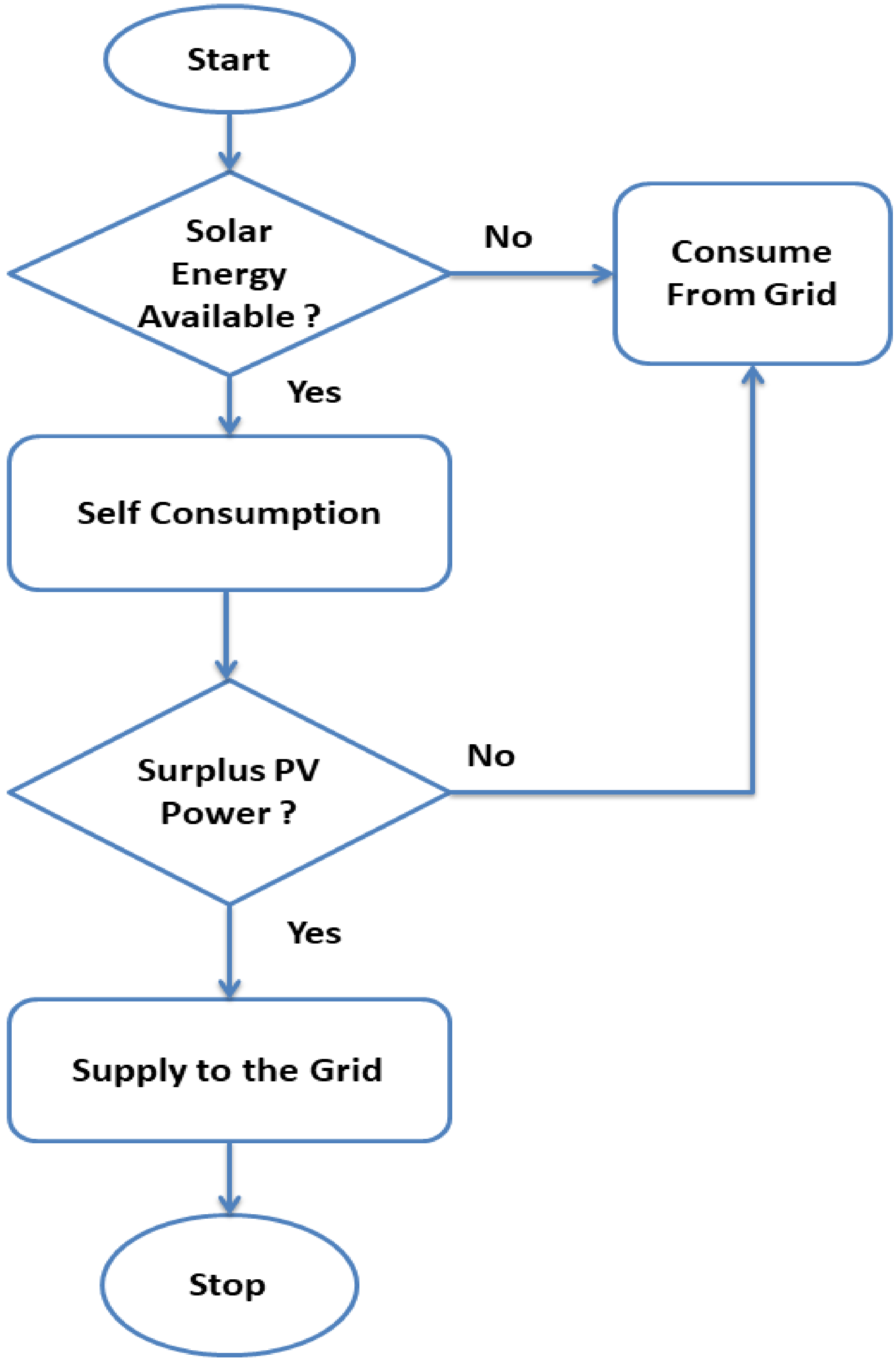

Fig.1. 4:Block Diagram of Net Metering System

1.8.2 Capacity, electricity export limit, and Conditions

According to the net metering guideline[23]:

- For the net metering scheme, every three-phase user would be considered eligible
- The output AC capacity of the renewable energy converter may be a maximum of 70 percent for the sanctioned load of the consumer.
- For net metering, the maximum AC output power of the installed RE system cannot exceed 10 MW.

Table.1. 1:Installation Capacity Limit Based On Consumer

Class of consumer	Voltage level
Residential	400V(LT)
Commercial/MT industry	11KV(MT)
Industry	33KV(HT)

For net metering, the steady-state voltage limit is -15% to +10, and trip time should not greater than 0.20 second. 50 HZ frequency is used in net metering. Maximum 1% frequency variation is acceptable though the inverter must be capable of operating properly within 4% frequency variation. The inverter must have the ability to detect low voltage, high voltage, under frequency, and over frequency.

According to the SREDA, the generation system component must be certified based on proven technology for under net-metering schemes. \Equipment standard for net metering are as follows- Solar Module/Panel- BDS IEC 61215, Grid Tied Inverter- BDS IEC 62109-1,BDS IEC 62109-2, IEC61727:2004, IEC 62116:2014[23]

1.9 Thesis Outline

This thesis is organized as follows:

Chapter 1 introduces the background of the solar PV power generation system, problem statement, objectives of the study, and literature review.

In chapter 2, this chapter includes the previous work and gird connected solar PV system worldwide and for Bangladesh.

Chapter 3 includes the proposed methodology for calculation and evaluation of the output of this thesis. Load data, solar radiation, to find an optimum model of on grid solar PV system for Industry .

Chapter 4 presents the result and simulation parts of the thesis with their significance.

Chapter 5, conclusions are drawn and scope of the future studies are proposed

Chapter 2

Literature review

2.1 Introduction

The country's electricity demands continue to increase daily, endlessly, and the power crisis has become imminent. In 2004, 84.5% of electricity was produced by natural gas and the GDP growth rate was 5.5% [24]. In 2014, 62.39% of the total power generation capacity in Bangladesh was generated from natural gas[25].In 2014 GDP was 6.06%. Now 55.26% of energy is produced form natural gas .Storage of natural gas is decreasing in our country beside that electricity demand is increasing . Government and specialist try to move on an alternative way to fulfilling energy country demand to increase country Economy also increase country GDP. To overcome this energy problem, renewable energy is a preferred alternative energy source. The cost of electricity from solar photovoltaic(PV) has been decreased remarkably since 2010[5]. There have several studies on Off-Grid solar installation. It has been widely applied in rural areas of Bangladesh. Government now focused on On-Grid system . Because the cost of production reduce in this system and it is more comfortable for consumers.

However, the Bangladesh government is focusing on an On-Grid system through net metering. However, the amount of research on the economic benefits of the On-Grid system in Bangladesh is very few. Although they have some research on solar home, research is rare in Bangladesh on the grid system through net metering at industrial and commercial level.

Research on the economic benefits of PV installation through net metering in the industrial commercial sector can increase the interest of consumers in PV installation in this sector. As well as developing a new way to develop an On-Grid system under net metering. Sufficient Financial funding can be played a vital role in increasing the installation of the on-grid photovoltaic PV for the industrial sector. Government and nongovernment plans should give a hand in favor of fulfilling their financial demand at the initial phase. As a result of this, they will be inspired, which in the meantime will also be a positive for increasing energy security-related to installing solar photovoltaic PV.

2.2 Word wide On Grid PV system

Solar PV is booming all over the world. Cost of electricity production using available rooftop with grid-connected technology in the commercial and industrial level. All over the world like China, USA, Germany, and also India, they are mainly focusing on grid connected solar PV installation for ensuring energy security. China, Germany, and India are getting benefits using this technology. They are successful in reducing electricity generation costs. Also, they can sustain the production rate below the national grid rate. Solar-based generation increased at a remarkable rate in the last ten years. In 2014, the world's solar PV power generation capacity was 177 GW. 60% of the total solar PV generation is from Asian countries[11]. Solar PV Power generation system is mainly three types of; Residential PV system(2-10KW), Industrial and commercial(100-500KW), and utility (more than 1 MW)[26].

Most of the study about renewable energy is the combination study of Wind and solar. Very few studies were observed on grid connect PV systems. Monika et al. (2017) analyzed that PV power generation cost RS7.5($0.10) KWh, including taxes, and other fixed charges. The location of this study was India. In this study, they use RETScreen and PVWatts. The difference in results was negligible. Study shows that capital cost recovered within 5 years [16]. Research of Ghose et al. was about the Hybrid system for Georgia by Homer Pro Software.. The optimum result of the study suggests about PV production[27].According to the study by Ghose et al. (2017), PV production cost is $0.0618 KWh. This study use grid as well as battery. With battery, the NPC of solar energy generation is cheaper. Farias et al. (2019) found that the simple payback period in FIT is 4.1 years for Philippines [28]. However, recent studies indicate that NPC is decreasing every year.

Different software use to analyze the NPC, IRR, COE, and Simple payback period grid-connected system. Most of the use Homer Pro, RETScreen, MATLAB, and PVWatt, etc.

2.3 On Grid PV generation Background of Bangladesh

In Bangladesh, the Off-grid installation of solar photovoltaic on the rooftop is the most common form for all of us. On-grid solar photovoltaic is so far away from the off-grid. PV generation(Fig.2.1) of increased rapidly last nine years . Rooftop on-grid photovoltaic PV not only fulfills the electricity demand but also provides financial support. Only 21 percent of PV generation are grid-connected[18]. Per capita energy consumption in Bangladesh was 426 kWh in 2019[2]. In recent years, the Bangladesh government has focused on solar PV power generation. Bangladesh government commissioned 3 MW solar photovoltaic power plant in 2017 , 20 MW solar photovoltaic power plant in 2018 and, 8 MW solar photovoltaic power plant in 2019[2]. Under the private sector(IPP) 657 MW photovoltaic production is under construction and 150 MW is under planning[2] . The Bangladesh government is emphasizing on net metering.

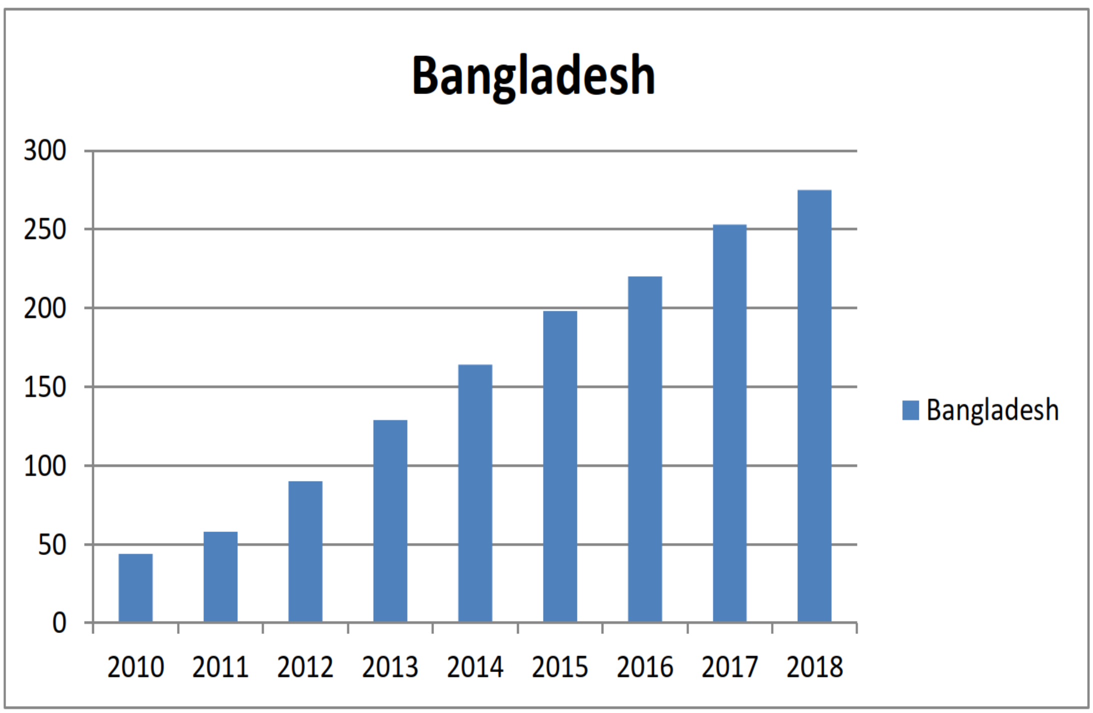

Fig.2. 1: Year-wise PV power generation .

On grid PV generation cost under net metering is decreasing .According to the study of Moury et al. (2009), On-Grid PV COE is 0.568$/kWh. That's was designed by homer pro. [29].A study by Mondal et al. (2011) shows that COE varied between 13.25 BDT/kWh($0.156) to 17.78 BDT/kWh($0.210)[21]. This indicates that the solar PV COE decreasing at a higher rate. In recent years , The study of Nurunnabi el al.(2019) find that, On-Grid PV COE is 0.0037 $/kWh[30]. This result is lower than average electricity cost is lower than bulk energy production cost of Bangladesh[2] .

2.4 Summery

According to the reviews of the above studies, the grid-connected solar PV system is the most feasible. This study carried out about techno-economic analysis of an on-grid rooftop PV solar system for the industry that's name is Egaroshindur cold storage. This study uses primary data upon energy consumption. Feasibility analysis of grid-connected PV system for Bangladesh is performed in this study. To achieve the objective of this study like electrical load, solar radiation, electricity production, techno-economical analysis, and environmental issue, Homer Pro simulation software is used. Homer Pro simulation software is developed by the National Renewable Energy Laboratory ,USA (NREL). Besides that, for the different figures, we use Homer Pro, MATLAB, and Microsoft Excel.

Chapter 3

Method & Materials

3.1 Introduction

In this paper, as the perspective of the increasing industrial sector in Bangladesh due to that's reasons energy demand is a vital issue for fulfilling the requirement of an industrial generation of products.as matter of fact that, in this paper try to introduce the optimization result of energy production by using industrial rooftop solar generation plant as fulfilling the energy demand also sold to the grid as financial aspect .this study proposed an industry is Egarosindur Cold Storage Ltd. This study design can be applied to all the industrial rooftop grid-connected for their energy generation. Research Methodology is shown in Fig3.1. Homer software is used for techno-economical feasibility analysis which capable of both on-grid and off-grid analysis[31]. Its input is electrical load, and the technical data different power generation components like a solar panel, inverter, and battery. The mathematical model is it's a parameter, and the output of the software is financial analysis, sensitivity, and optimizing the simulated system, etc.

3.1.1 Study Design

Different information is necessary for the design of the study to address the research questions set out above. The types of information are classified into two categories.

1. Data and information that can be obtained by visiting an industry(Cold storage)
2. Information that can be obtained from various secondary sources

To find the financial viability of rooftop solar PV for different applications, data to be analyzed in the following case studies:

1) Installed rooftop solar PV instead of diesel power generating engine.
2) Introduced rooftop solar PV with grid-connected net metering policy.

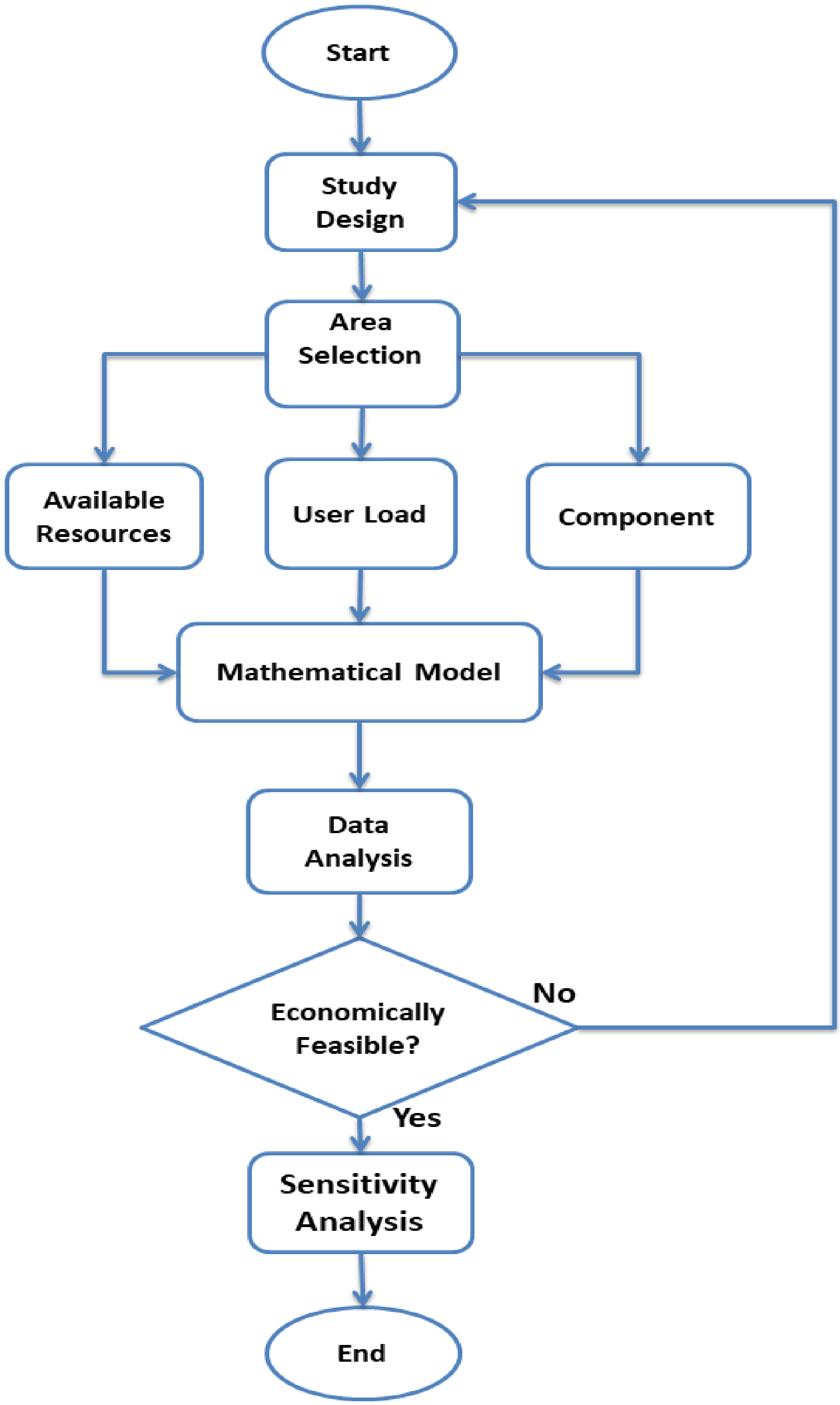

Fig.3. 1: Research Methodology.

3.1.2 Study Area

The proposed rooftop area is about Egarosindur Cold Storage Ltd at Kishoreganj, Dhaka, Bangladesh. It's geographical location is 24°21'21' North and 90°42'20 East(Google Earth Pro). Areas are first determined theoretically then finalized through practical observations and surveys. By using the Google Earth Pro software, showing the potential area of rooftop solar which was identifying this research. According to Google Earth Pro Software, the total rooftop area is 1300 square meters. For this study additional 1000 square meter area of Cold Storage is used, for required area determination RETScreen software is used. The fraction of the actual rooftop area has been evaluated from the total bright rooftop area in accordance with the research from Kabir et al. and that amount is 50%.[32]. The rooftop area of Egarosindur Cold Storage Ltd is shown in Fig.3.2.

Fig.3. 2: Rooftop area of Egarosindur Cold Storage Ltd.

3.1.3 Information collection

The primary data has collected through Cold Storage Visit named Egarosindur Cold Storage Ltd located in Kishoreganj, Dhaka, Bangladesh. Among the primary data, daily, monthly, annual electrical load and electricity bills are worth mentioning. As well as the cost of per unit power production through diesel generators during load shedding and the amount of sanctioned load allowed for cold storage. Sanction load of cold storage 1 MW.

Most of the secondary data collected through the reports and guidelines of SREDA, and NASA. Air temperature and solar radiation data are collected from NASA. Besides that, information is collected from different publications like Journals, conference papers, books. Information was also collect from various websites like BPDP, IEA, NREL.

3.2 Energy consumption patterns

For an Industry like cold storage is used electric power 24 hours in a day and 8760 hours in a year. Load variation in cold storage is very low because the machine has to be kept running all the time. The load during the day is relatively high because the office of the cold store is open at this time. Several factors have been given priority for estimating the electrical load for every hour. These include the cost of purchasing electricity each month, what type of load is used in cold storage, and what type of load is on at what time period. Hourly load profile for peak season and off-season is given in Fig.3.3 and Fig.3.4. From these figures, it's clear that load in peak season is more than 110KW, where the load in the off-season is less than 40KW. Actually, the electrical load in peak season is more than double that of offseason.

According to Homer's simulations, the load variation within a month is less, because the load variation per hour is minimum . The daily load profile of a month is shown in Fig.3.5.

This is a potato-based cold store, so the electrical load is high from April to September. After the September , the total amount of stored products reduced, so power consumption is also reduced. Within November to December, potato storage becomes empty. In this period, a little amount of vegetables is stored in a specific way, and the temperature is reduced significantly. In Fig.3.6. Monthly load is shown. Homer simulation shows that daily average load is 1,972.78 KWh/day and load factor is 0.44. Average load in KW is 82.2 and Maximum load in KW.

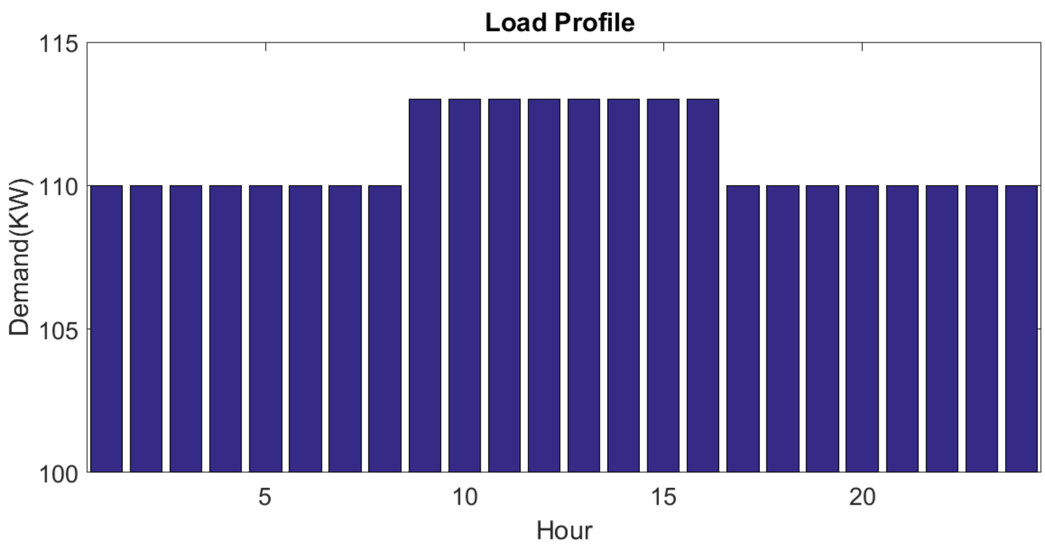

Fig.3. 3: Daily load profile for Peak season.

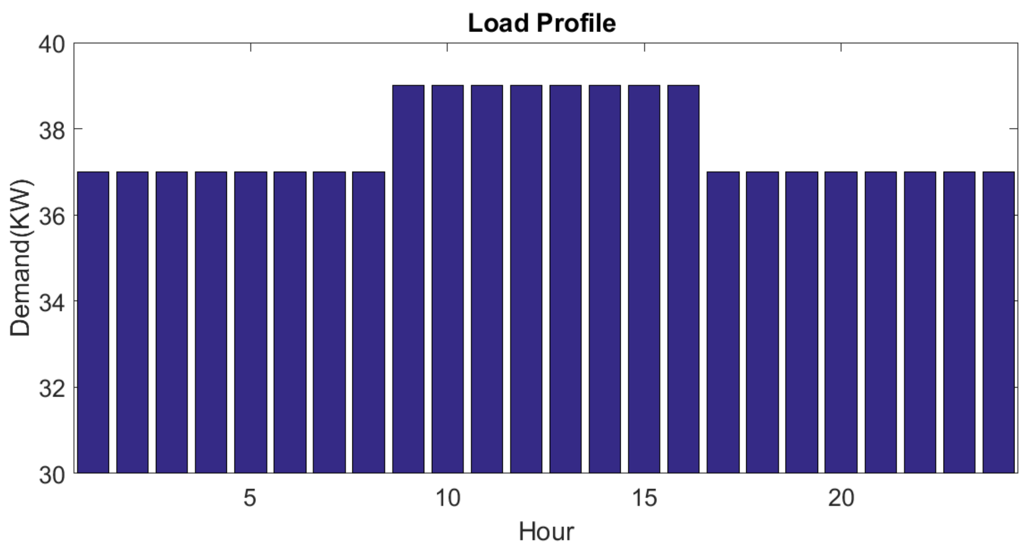

Fig.3. 4: Daily load profile for off-season.

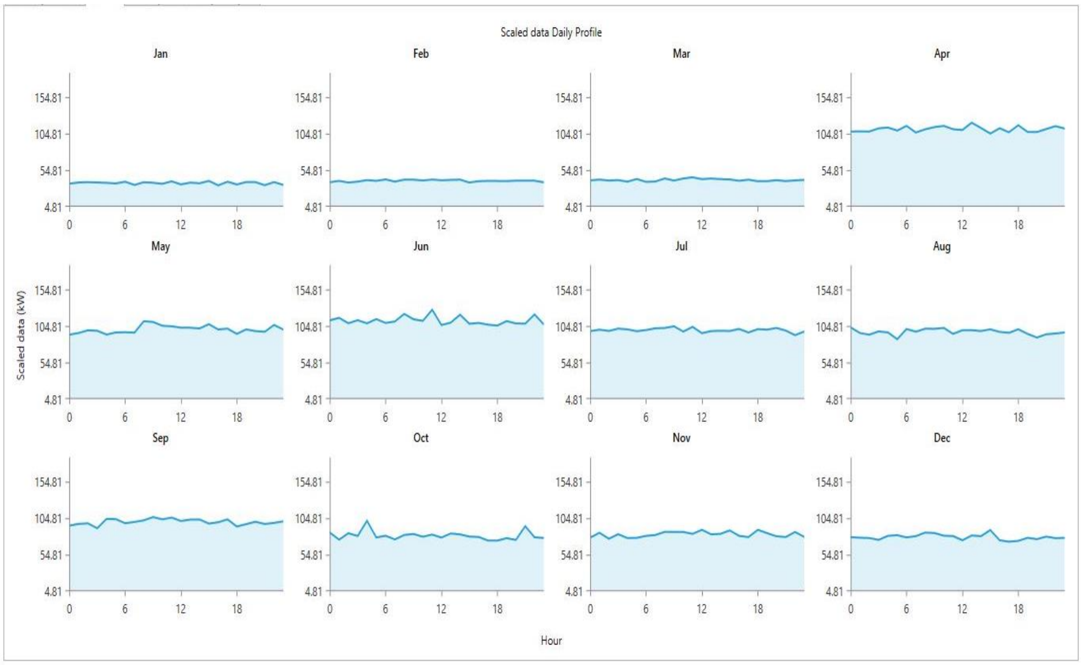

Fig.3. 5: Monthly load profile for each month .

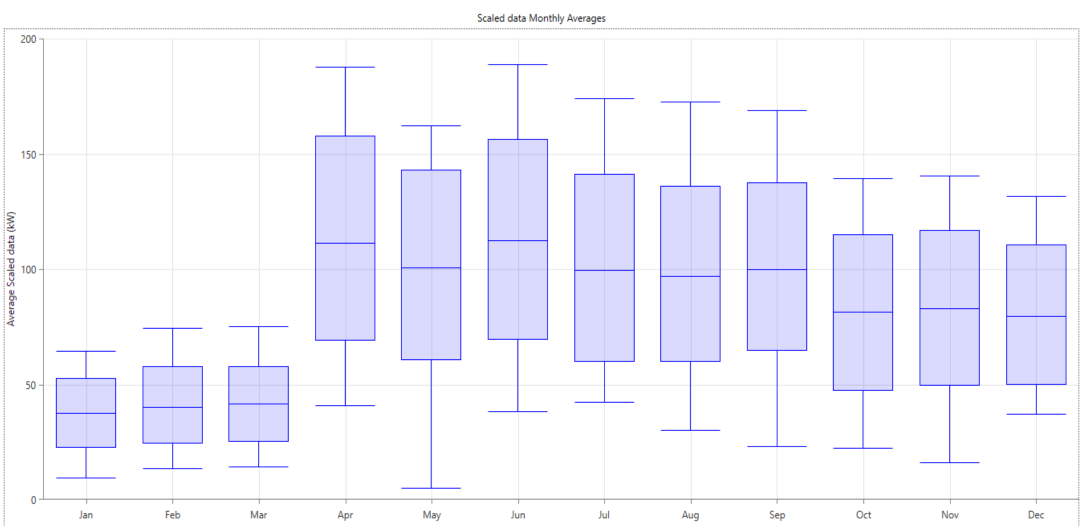

Fig.3. 6: Annual average load.

3.3 Solar radiation and clearance Temperature

Solar radiation theoretical data is collected by using Homer and RETScreen software for the location Dhaka, of 23.8103° North Latitude and 90.4125° East Longitude from National Aeronautics and Space Administration (NASA). To determine the relationship between solar radiation and the clearness index Homer software is used. And to know the relation between solar radiation and air temperature RETScreen software is used. The average solar radiation of Bangladesh is 4-5 Kwh/m^2 in 94% of the area of Bangladesh and practical solar radiation is 4-6.5 Kwh/m^2[7, 8, 21].

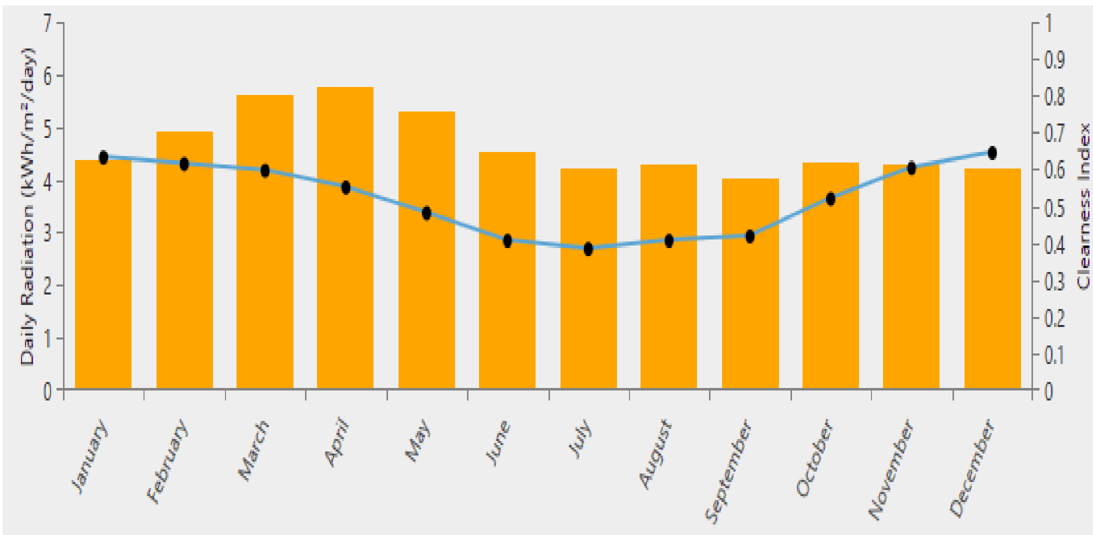

Fig.3. 7:Daily solar radiation and clearness index .

Fig.3.7 present the solar radiation and clearness index. The maximum amount of solar radiation available for the month of March-April and the minimum for December-January, and the clearness index(Clearness of atmosphere) is maximum for November to February. After April, Bangladesh receives a lot of rainfall, especially from June to August. As a result sufficient amount of solar radiation can't be obtained, besides that condition of the atmosphere is not clear as a result the clear index is also less. According to the database of NASA daily average solar radiation is 4.65Kwh/m^2 .

Monthly solar radiation, clearness index, and the temperature are shown in Table.3. 1. Fig.3.8 show the solar radiation and temperature relation. From June to September, solar radiation is low, but the air temperature is high. Temperature is inverse for solar PV power generation. From November to February air temperature is low, that's condition is better for PV power generation.

Table.3. 1: Daily average Solar Radiation , Temperature and Clearness Index

Month	Daily solar radiation -horizontal	Air temperature	Clearness Index
January	4.182	19.740	0.606
February	4.677	23.000	0.583
March	5.546	26.450	0.591
April	5.654	27.150	0.540
May	5.578	27.650	0.506
June	4.475	27.950	0.400
July	3.895	27.660	0.352
August	4.117	27.610	0.389
September	3.964	27.010	0.411
October	4.704	25.480	0.565
November	4.250	22.500	0.599
December	4.058	20.200	0.620
Annual average	4.592	25.200	0.514

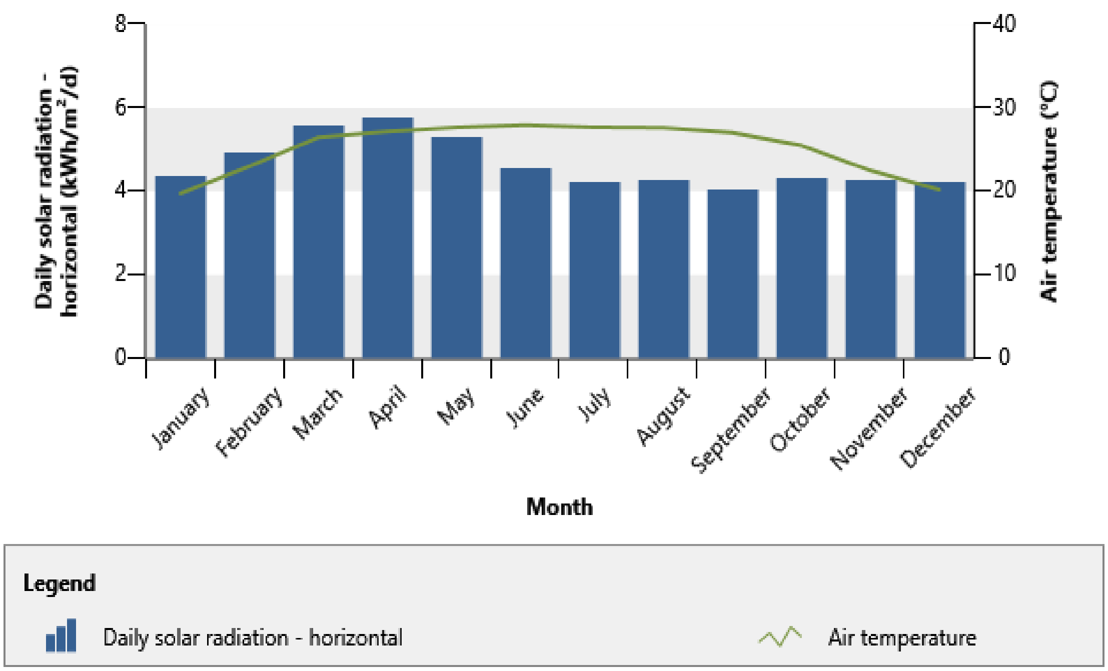

Fig.3. 8: Daily solar radiation and Temperature .

3.4 System Designing

The proposed design of an on-grid solar system for Egarosindur cold storage is shown in Fig,3.9.This system consists of solar PV, Inverter, Battery storage, charge controller, grid with an AC, and DC bus bar[33].The battery is used to supply electricity when no solar energy is available and the time of load shedding. To find the optimal design for the solar PV system different sizes and combinations of components are simulated. The system is designed to meet energy demand and supply the remaining power to the grid.

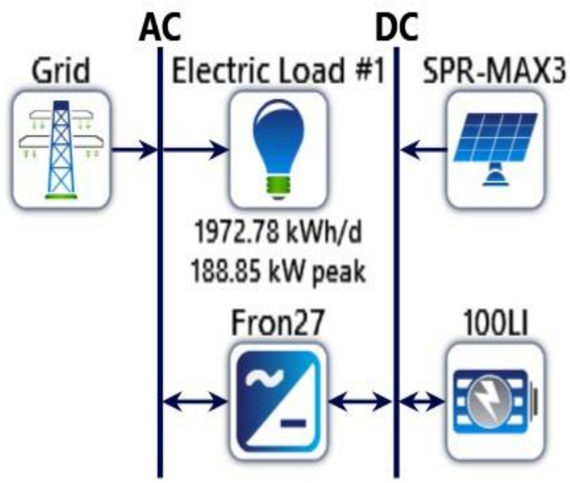

Fig.3. 9: Configuration of proposed on-grid solar system for Egarosindur cold storage.

3.4.1 Photovoltaic solar panels

A photovoltaic panel is an electrical power generator that directly converts solar energy into electrical energy. It converts solar energy into DC electricity with a lifetime range of 18 to 30 years. [33]. PV solar panel can be classified into different classes: CdTe, CIS/ CIGS, α-silicon, monocrystalline, polycrystalline etc [34, 35].In this study monocrystalline based SPR-MAX3-400 is selected because of reliability and higher efficiency . It's maximum rated power 400 watts/panel, and efficiency is 22.6%[36]. In this study PV array size consider as 480KW, 490KW, 500KW and 510 KW. The effect of temperature is also considered in this simulation with a derating factor of 94%. The capital cost of a solar PV panel is 850 USD/KW, and the operation and management cost is 12 USD/Year. Tracking system is not applied in this study, and the tilt angle is 23.81°.The techno-economical parameter of solar PV is shown in Table.3.2.

Table.3. 2: Cost and Technical parameter of solar PV .

Parameter	**Unit**	**Value**
Tilt angle	Degree	23.81
Azimuth angle	Degree	0
Capital cost	USD/KW	850
Replacement	USD/KW	850
Operation and Maintenance cost	USD/year	12
Tracking system	-	No Tracking
Efficiency	Percent (%)	22.6
Ground reflection	Percent (%)	20
Derating factor	Percent (%)	94
Lifetime	Year	25

3.4.2 Inverter

The inverter is an electronic device that converts the DC electricity into AC electricity. The inverter is a vital component in the PV power system which is essential for the safety, efficiency, and reliability of any system[33].The inverter used in the on-grid and the off-grid system that is different in types. In this study, FRONIUS ECO 27.0-3-S Inverter has used which capacity is 27KW/Inverter with an efficiency of 98%.

Table.3. 3: Cost and Technical parameter of Inverter

Parameter	Unit	Value
Inverter efficiency	Percent (%)	98
Capital cost	USD/KW	111
Replacement cost	USD/KW	111
Operation and maintenance cost	USD/Year	10
Lifetime	Year	10

The IP rating is 66, and the maximum input current is 47.7 A, and DC input voltage range from 580V to 1000V[37]. In this study PV Inverter size consider as 486KW, and 513 KW and the life time consider 10 years. Capital cost of the inverter is 111USD/KW.

3.4.3 Battery

An electrical battery is s component that converts electrical energy into chemical energy during charging and converts the chemical energy to electrical energy during discharging [38].For a grid-connected system, a battery is used when load shedding occurs and solar radiation is not available. For an on-grid system, a battery is not essential because energy is available to the grid but it can be useful. Use of battery increases the system cost significantly. The cost and specifications of Battery is shown in Table.3.4.

Table.3. 4: The cost and specifications of Battery

Parameter	Unit	Value
Nominal voltage	Volt	600
Nominal Capacity	(kWh)	100
Nominal Capacity	Ah	167
Maximum charge current	A	167
Round trip efficiency	Percent (%)	90
Minimum stage of charge	Percent (%)	20
Capital cost	USD/kWh	70,000
Replacement cost	USD/kWh	70,000.00
Operation and maintenance cost	USD/Year	1000
Lifetime	Year	15

Nominal voltage of battery is is 600V, Nominal capacity is 100KWh, Round trip efficiency is 90%, Maximum charge current is 167A, and discharge current is 500A. It's capital cost is higher it's about 70000USD/KWh. Life time of battery is also less which is about 15 years .

3.4.4 Grid

This study is on-grid in type, so the cost of the grid is considered. This study is simulated by Homer software. Gird connected system is used to determine viability and reliability .Net grid purchase is calculated by subtracting total grid purchase from total grid sales. If the system purchases less than the total grid sell, then the net purchase is negative. Gird purchase price and sell price both are the same for this study, and a flat type simple rate is considered. This price is 0.100$/KWh.

3.4.5 Charge controller

The charge controller controls the current flow through the battery and load. It is used to protect the battery from over charging and discharging. In this study, the voltage rating of the charge controller is 600V, and the current rating is 250A. The charge controller protects against overly high voltage, excess amount of current, short circuit, polarity reverse, and lighting. The display of the charge controller indicates the voltage levels, current, and short circuit[5]. This study is considered a charge controller, which is priced at 5550 USD/Controller. The lifetime of a charge controller is greater that’s reduces the cost of the system.

3.4.6 Bidirectional meter

Meters that can measure the flow of electricity in two directions are called bi-directional meters. It can measure the amount of electricity being consumed from the grid as well as the amount of electricity being supplied to the grid from the solar generator. When the annual bill is calculated, the consumer pays only the amount of the net bill another if the net is sold on the grid, the utility pays to the customer.

3.5 Mathematical Model

Calculation of every software depends upon its mathematical model. Homer pro software uses some specific mathematical analysis to predict the power generation, radiation, battery charging, battery discharging, clearness index, Optimization, and sensitivity analysis.

3.5.1 Mathematical model of solar PV energy

The output of solar PV mainly depends upon solar radiation, the efficiency of the solar panel, Capacty of PV array , the effect of temperature, derating factor of the module[39].PV output of HOMER Pro is shown in eq.1 .

$P_{pv}=Y_{pv}\, f_{pv}\, (G_T/G_{T,STC})\, [1+\alpha p(T_C-T_{C,STC})]$ ………………..(3.1)

P_{pv} = PV output power.

Y_{pv}= Rated Capacity of PV array under standard condition .

f_{pv} = Derating factor of solar PV.

G_T = Incident solar radiation on the PV array in the current time step [KW/m^2].

$G_{T,STC}$ = Incident solar radiation at standard conditions .

αp = temperature coefficient of PV power [%/oc].

T_C = PV cell temperature in the current time step [oc].

$T_{C,STC}$ = the PV cell temperature under standard test conditions[25°C][40].

3.5.2 Clearness Index

Clearness Index and solar radiation is closely related to each other when one data is entered another data is automatically calculate by HOMER Pro . Clearness Index and solar radiation are closely related to each other. When one data is entered another data is automatically calculated by HOMER Pro. Clearness Index data is a dimensionless number that varies between 0 to 1. Eq.2 defines monthly average clearness index .

$K_T = H_{ave}/H_{o,ave}$…………………………(3.2)

H_{avc} = Monthly average radiation on the horizontal surface of the earth [kWh/m2/day]

$H_{0,ave}$=Extraterrestrial horizontal radiation.[40]

3.5.3 Financial & Economical analysis

The proposed system's financial viability is the most valuable criterion for industry owners to decide on the adoption of new technology. In the proposed area is on-grid which is design for the industry there have with battery and without battery system. The economic analysis includes cost and benefits, net present cost, cost of energy, annualized costs, simple payback, discount payback. The initial cost of the proposed system is the cost of the PV Panel, and auxiliary components are Inverter, charge controller, cable, and other accessories. The price of this component is taken according to the national and global market. That is why it will be gone for the diesel base generator for generating electricity for fulfilling electricity demand. For our proposed project, the initial cost is expenditures for an inverter PV module, NEM, and installation. The grid tide PV system needs maintenance because the prose project lifetime is 25 years. Our proposed system base on the industry in Bangladesh which could be very effective to reduce the electricity consumption cost for industry owners. The impact will be on the country's GDP as well as the environment. Despite large capital investment in the first startup. In the economic section, the calculation of cost and benefits of our proposed system as compare with our electricity rate in the local market as well as worldwide. Renewable energy like that solar rooftop PV is environmentally friendly due to there is no pollution effect that has no negative effect on the existing environment.

3.6 Cost model for optimization analysis

To calculate the cost for rooftop on-grid solar systems in the industry in Bangladesh are included different parameters like COE , NPC , Capital cost or fixed cost, Operational and management, or running cost .

3.6.1 Net Present cost

Net present cost is a vital issue to invest in any fanatical project . To calculate the NPC HOMER Pro software use following equation:

$NPC= C_{TAC}/CRF(I,R_{PLT})$…………………..(3.3)

Where ,

C_{TAC} = Total annualized cost.

I = Annual real interest rate .

CRF(.) =Capital recovery factor.

R_{PLT} = Project lifetime.

3.6.2 Cost of energy

To Find out the COE HOMER Pro software use following equation:

$COE= C_{TAC} /(E_{Prim}+E_{Def}+E_{GS})$.................(3.4)

Where

C_{TAC} = Total annualized cost.

E_{prim} =Total primary load /year.

E_{def} = Tortal deferrable load /year .

EGS = Amount of energy is sold to the grid /year [41]

3.6.3 Operating cost

Operation cost is important parameter for cost analysis to determine operating cost following equation is used by homer :

$C_{OC} = C_{TAC}-C_{TACC}$……………………………………(3.5)

Where ,

C_{TAC} = Total annualized cost.

C_{TACC} = Total annualized capital cost .

3.7 Scenario

In this propose PV installation for the industry, there are two scenarios carried out. The first scenario is grid-connected without a battery and another with a battery system. That system initially reduced a large amount of initial cost and there has 25 years life. Despite less capital cost but there is no load shedding backup in the industry. They have used diesel base generation for back up. On the other hand, the second scenario is a grid-connected PV System with a battery which is a perfect backup system for load shedding because in the present electricity tariff in the local market is 0.100$ when using diesel engine it cost become high than the present tariff rate.

Chapter 4

Result and Discussion

4.1 Introduction

In this study, Simulation is carried out by using the Homer model by the load profile. Using this, simulate to show the techno-economical viability of rooftop on-grid solar PV at the industry in Bangladesh. This is also analyzed the per unit electricity generation cost in net metering with battery and without battery. Moreover, Optimization and sensitivity analysis for the given system by using homer tools for simulation.

4.2 On grid system cost with battery and without battery

The cost summary is included components, capital cost, replacement and maintenance cost, resource cost, and salvage value. Capital cost is greater than all costs. From Fig.4.1, most of the capital cost is the reason for solar PV panel cost.

Fig.4. 1: On grid PV system cost without battery.

Others cost including the operation and management cost, replacement cost, etc. Inverter cost has a significant role in cost summary. Fig 4.2 is about an On-grid PV system with a battery system. For with battery system, most of the cost is the reason for battery and lifetime of a battery is less than a lifetime of solar PV. So it takes a large amount of capital cost and running cost. Without battery cost, other costs are as usual as without a battery system.

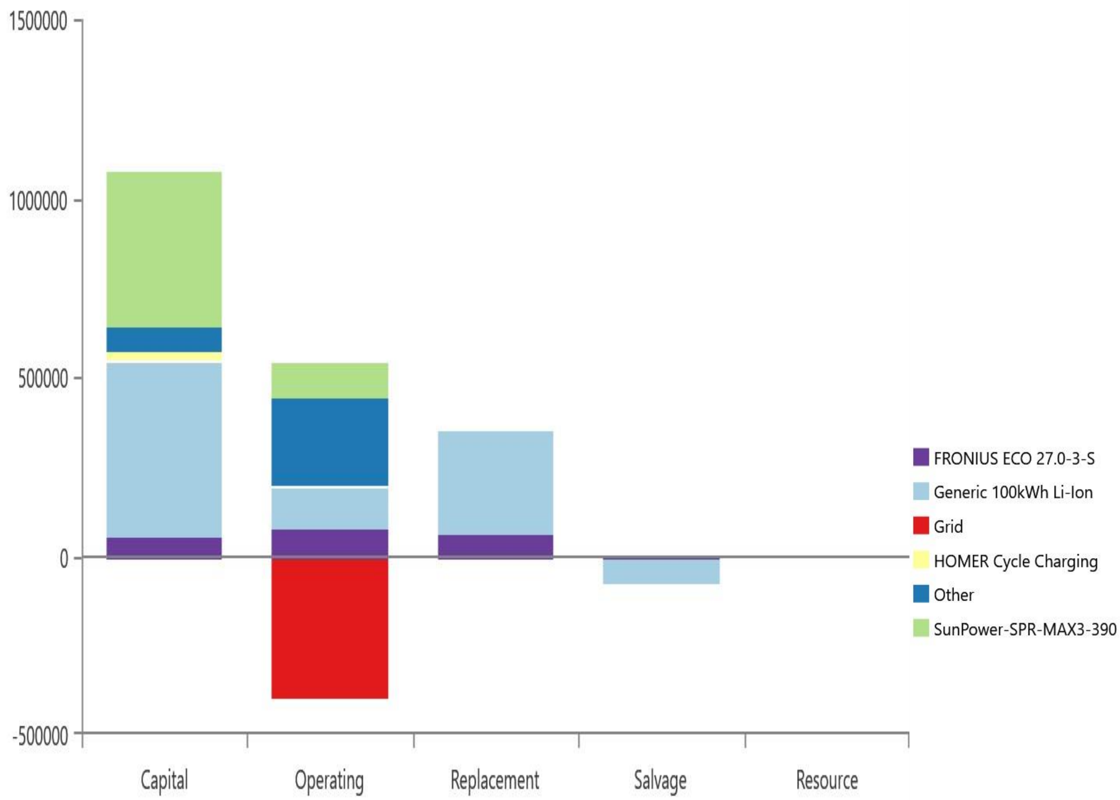

Fig.4. 2: On grid PV system cost with battery.

From fig 4.1 which represents the without battery grid-connected system that capital consumption on PV panel setup almost 40% of capital cost. Without battery system is comparatively chipper but it is less reliable because of there is no power supply system when electricity is not available for load shading or other reasons. So with battery system is more costly but reliable .

4.3 Cash flow

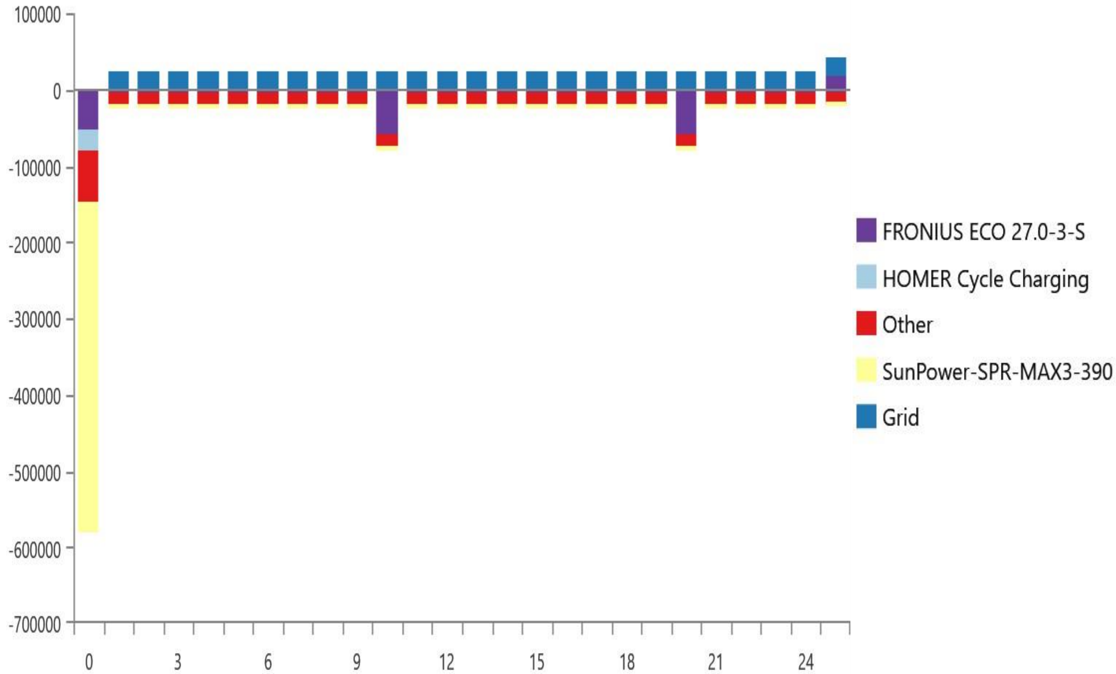

Fig.4. 3: Cash flow(component) of proposed model for given Life time without battery

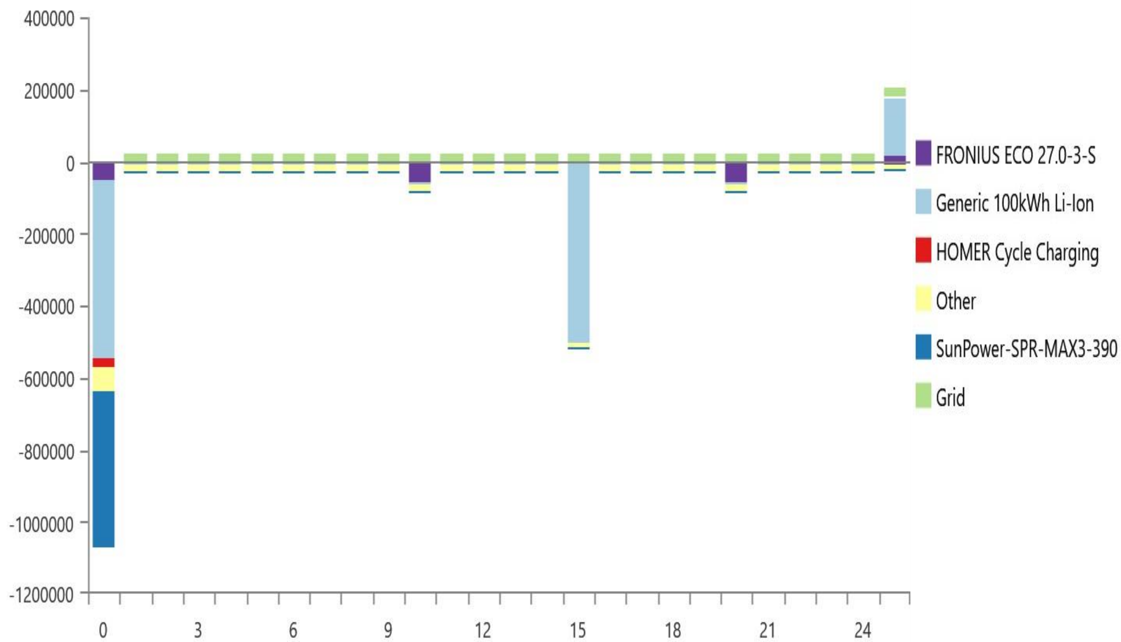

Fig.4. 4:Cash flow(component) of proposed model for given Life time with battery.

Figure 4.3 presents the yearly cash flow of each component of grid-connected solar PV for the lifespan. It represents a clear idea of cash flow for the proposed system. Initially need a big amount of capital cost for setup the on-grid solar system in the industry and then a small amount of replacement cost will be needed frequently after 10 years of its life span. The inverter and charge controller cost will add to the cost of the project.

Figure 4.4 present same type of cash flow, battery cost is added to it. As a result initial cost increases and a periodic cost is added with the system because lifetime of battery is 15 years.

4.4 PV Power Output

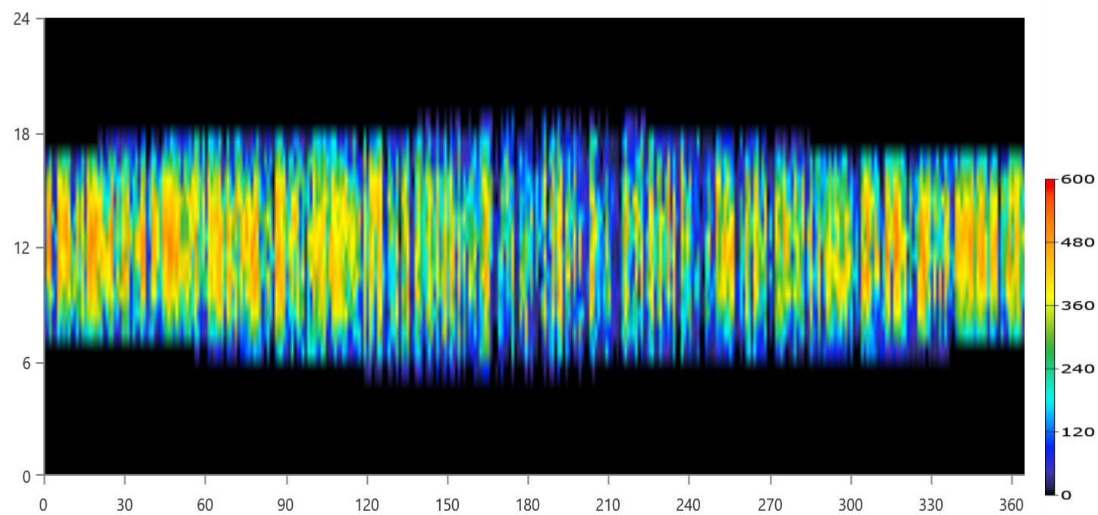

Fig.4. 5:PV Power Output

Fig 4.5 shows that PV output is maximum from February to April because the temperature is low and radiation is high. April to October PV power absorption time increase because the duration of sunlight increases but for low radiation, rain, and excess temperature solar radiation decreases. After October PV output increase but not enough because of the low sunlight period and foggy climate. Fig 4.6 shows that the solar PV cell temperature is minimum from December to January after January it increases. From May to September, the solar PV cell temperature is maximum.

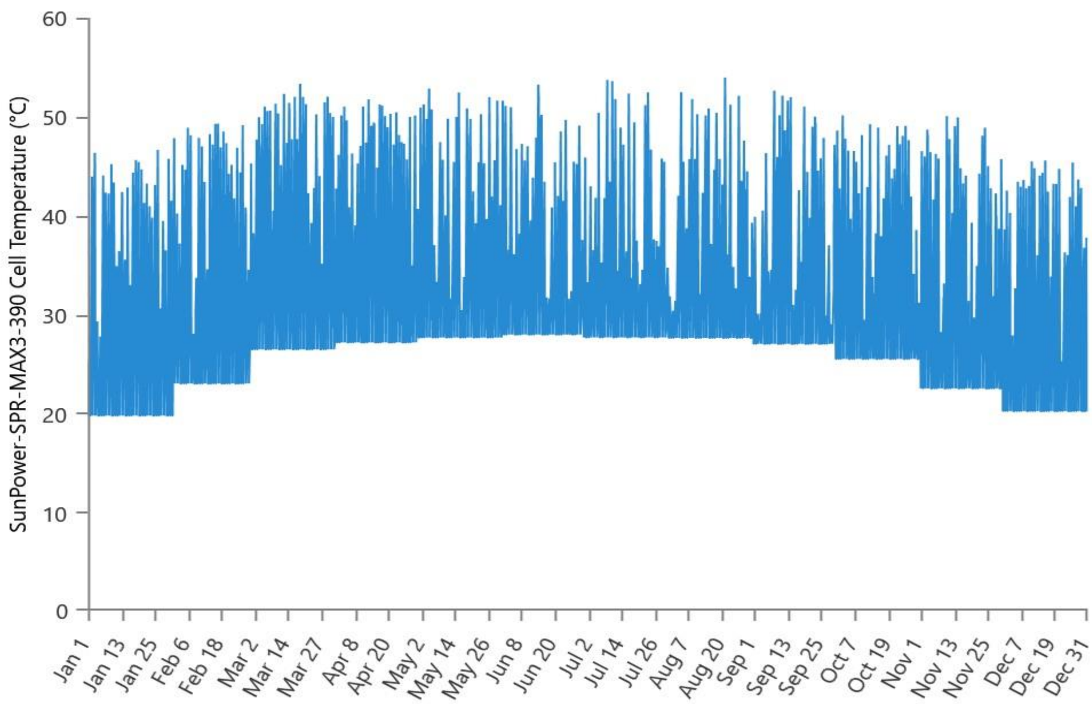

Fig.4. 6:Yearly cell temperature

Table 4.1 shows the PV output summary. It shows that the rated capacity is 510 KW and means output is 112 KW that's clear that capacity factor is 22%. Daily average PV energy production is 2687 kWh/d, per year production is 980721 kWh and the total hour of operation is 4374 hours in a year.

Table.4. 1: PV Power Output

PVs	SunPower-SPR-MAX3-390	Unit
Rated capacity	510	kW
Mean output	112	kW
Mean output	2,687	kWh/d
Capacity factor	22	%
Total production	980,721	kWh/yr
Minimum output	0	kW
Maximum output	554	kW
PV penetration	136	%
Hours of operation	4,374	hrs/yr
Levelized cost	0.0333	$/kWh

4.5 Energy Purchase and sold to grid

Monthly Grid purchase and sales are shown in table 4.2 . from January to May net energy is sold but from June to September net energy is purchased from the grid and from October to December net energy is sold to the grid. Peak demand is in April. Annual energy purchase 408,829 kWh and Sales is 648,366 kWh. So after a year net energy is sold to the grid.

Fig 4.7 and Fig 4.8 show the energy purchase and sold from the grid. according to this figure Fig 4.7 first three months of the year system purchase energy only night time or when sunlight is not available. From April to September energy purchase both day and night time because demand is maximum during this period. After that mainly energy purchase from the grid when sunlight is not available but sometimes it also purchases energy from the utility in the daytime when enough energy is not produced from the grid.

Table.4. 2: Monthly energy purchased , sold and energy charge table .

Month	Energy Purchased (kWh)	Energy Sold (kWh)	Net Energy Purchased (kWh)	Peak Demand (kW)	Energy Charge
January	15,998	77,044	-61,047	64.4	-$6,105
February	14,708	71,409	-56,701	70.3	-$5,670
March	15,768	84,012	-68,243	75.1	-$6,824
April	43,459	54,766	-11,307	188	-$1,131
May	39,443	49,338	-9,895	160	-$989.45
June	46,736	33,843	12,893	178	$1,289
July	42,563	33,863	8,700	161	$869.98
August	42,364	37,283	5,081	148	$508.14
September	43,765	35,324	8,440	148	$844.04
October	34,941	50,299	-15,359	139	-$1,536
November	34,304	56,744	-22,440	141	-$2,244
December	34,780	64,439	-29,660	129	-$2,966
Annual	**408,829**	**648,366**	**-239,537**	**188**	**-$23,954**

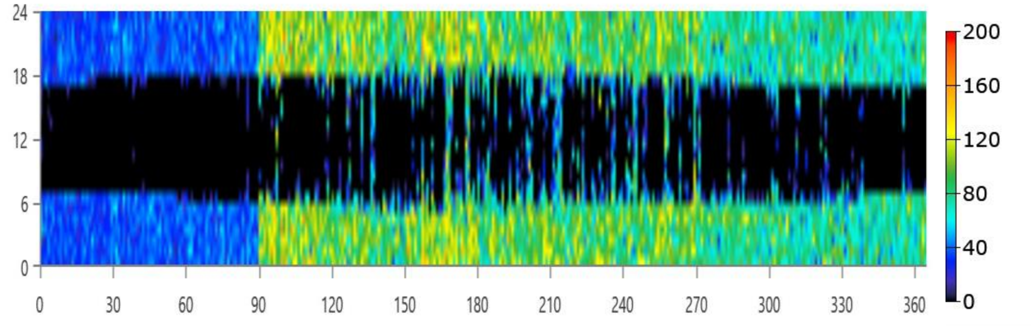

Fig.4. 7: Energy Purchased From Grid (kW)

Fig 4.8 shows energy sold to the grid. Solar PV cell produces energy when radiation is available it’s a general range for Bangladesh is 6 AM to 6 PM energy sold depends upon generation and load. Though maximum generation is in April through maximum energy sold to the grid in March because the load is relatively small.

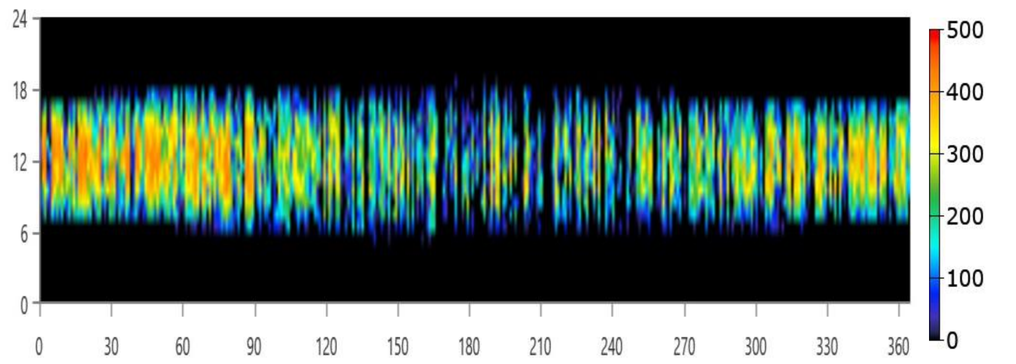

Fig.4. 8: **Energy Sold To Grid (kW)**

4.5.1 Monthly energy production from PV and Grid

Fig 4.9 illustrates that the yellow color represents the Power production from the PV system and another color represents the grid electricity import for company use. Electricity production varies due to temperature. Also depend on a seasonal cause like the winter season, rainy reason and summer season. In the winter and rainy seasons, the sky becomes cloudy and gloomy. At that time electricity production fluctuate.

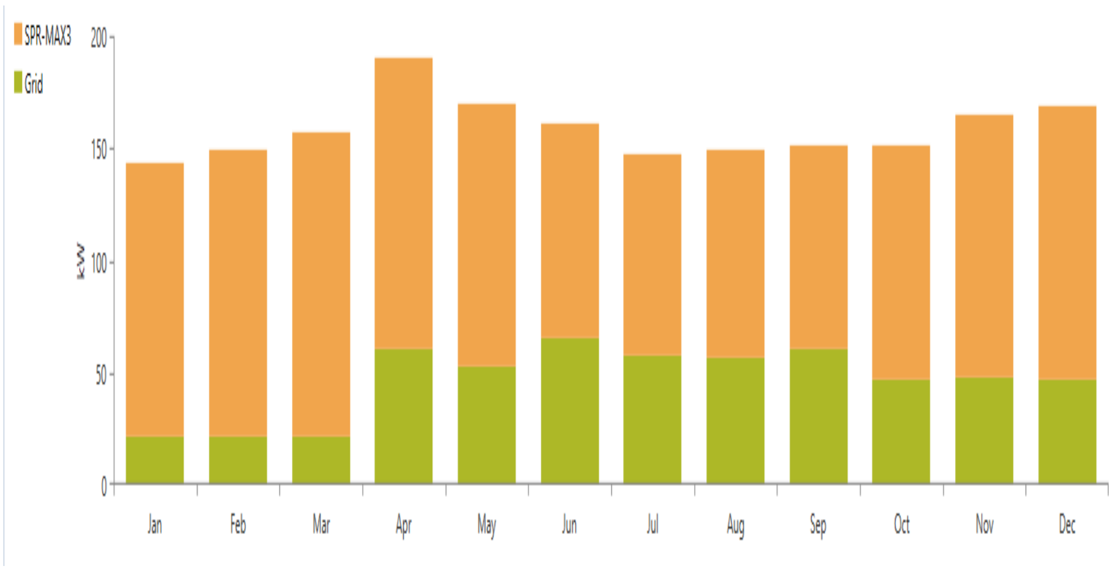

Fig.4. 9:Monthly average electric production (PV and grid)

4.5.2 Load and PV Producrion variarion for different time period

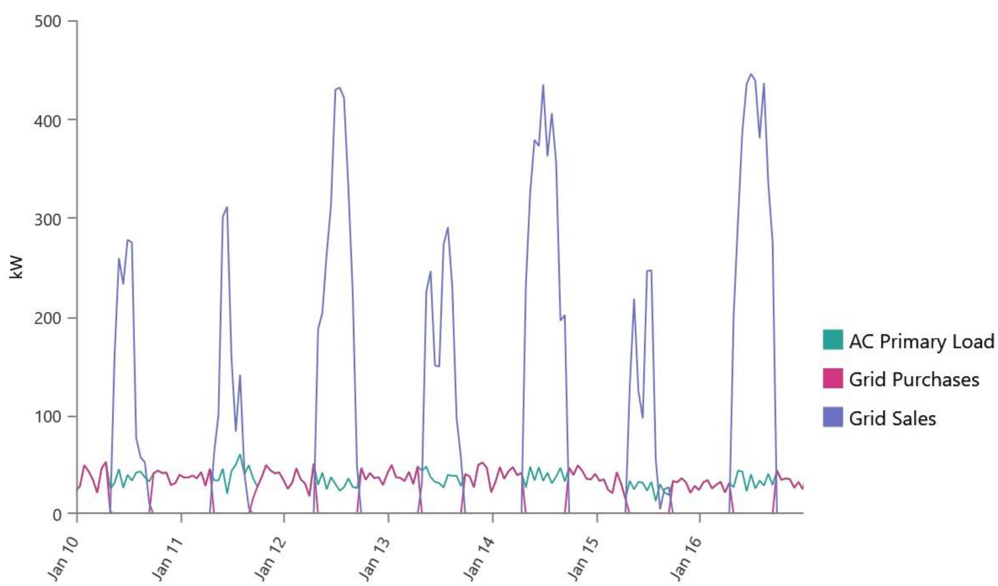

Fig.4. 10: Load ,Grid Purchases and Grid sales (January 10^{th} to January 16^{th}) .

To analyze the relation among load, grid purchases and gird sales this study selected three different time periods depends on temperature, radiation, and load variation. For January operation of cold storage is off. So the load requirement is low and solar

PV production is less. Fig.4.10 shows that PV generation is higher than load, in the night there is no PV production so the system purchase electricity from the grid at night. Fig.4.11 indicates that total PV production is lesser than total demand. From April load for cold storage is maximum so the net purchase is greater. The grid purchase is rate is relatively constant because the electricity demand for cold storage is not varied

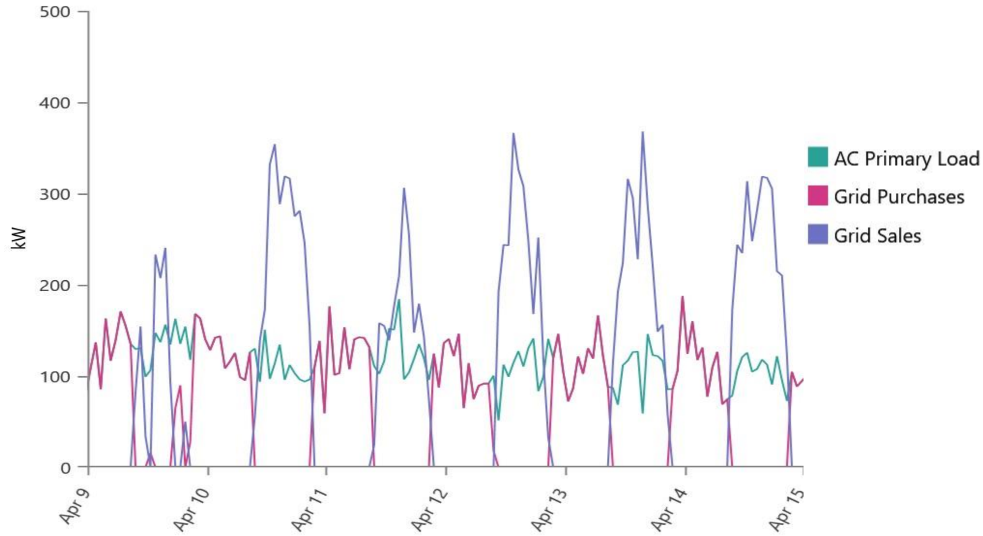

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Fig.4. 11:Load ,Grid Purchases and Grid sales (April 9th to April 15th).

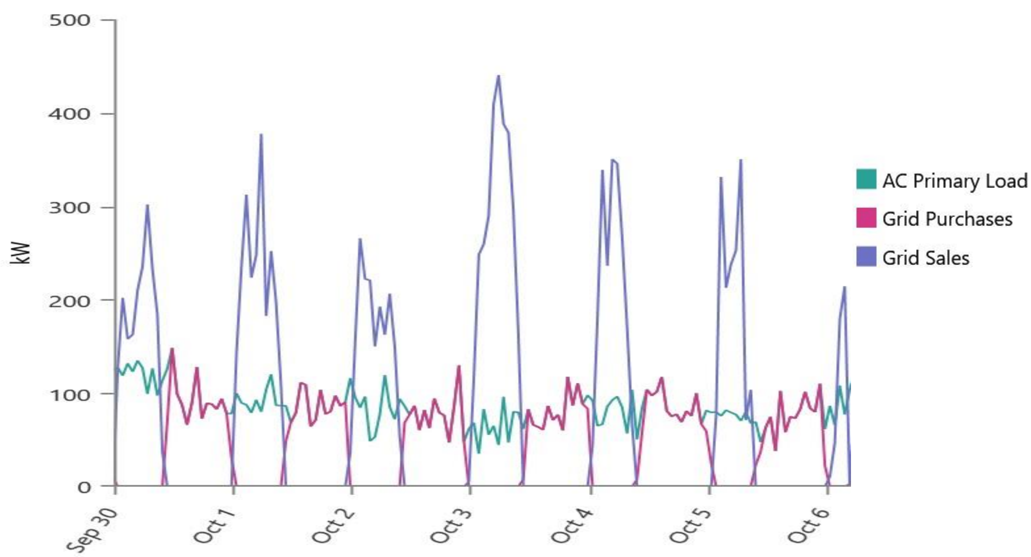

Fig.4. 12: Load ,Grid Purchases and Grid sales(September 30th to October 6th).

4.6 Optimization

Using the Homer model to identify the proposed project is feasible or not. That performs to analyze the simulation, optimization, and sensitivity analysis. In this study analysis, we considered an industry load profile. Assuming propose life span 25 years. In optimization, there are two categories that are overall optimization and category optimization there result based on initial capital, NPC, COE, production, energy purchases, and energy sold to the grid.

Fig 4.13 shows the categorized optimization result and fig 4.14 shows the overall optimization result. In this study two category is considered with battery and without battery system. COE for without battery system is $0.0300 and for with battery system is $0.0669. That means the COE is more than double for with battery system.

Architecture			Cost				SPR-MAX3		Fron27	Grid	
SPR-MAX3 (kW)	Grid (kW)	Fron27 (kW)	COE ($)	NPC ($)	Operating cost ($/yr)	Initial capital ($)	Capital Cost ($)	Production (kWh/yr)	Inverter Mean Output (kW)	Energy Purchased (kWh)	Energy Sold (kWh)
510	999,999	486	$0.0300	$669,956	$5,398	$581,746	433,500	980,721	110	408,829	648,366
510	999,999	486	$0.0669	$1.50M	$25,943	$1.07M	433,500	980,721	110	408,829	648,366

Fig.4. 13: Categorized Optimized results from HOMER

The optimization result shows in figure 4.14 that the result for grid-connected solar PV with and without battery. The optimization process conducts through every possible solution of the variable propose system without considering sensitivity analysis. From figure 4.14 we see that grid-connected PV system without battery is less cost, that means the NPC, COE and operating cost respectively $669956, $0.0300 and $5395.on the other hand if considered in with the battery in propose system the following cost is slightly more than that. Different value of inverter is considered for this study. Overall optimization result shows that 446 KW Inverter size is enough for this operation because mean output of inverter is 100kW. The minimum cost of energy is $0.300 and the electricity purchase cost from grid is $0.100 . So without battery system is feasible for this study .

Architecture			Cost				SPR-MAX3		Fron27	Grid	
SPR-MAX3 (kW)	Grid (kW)	Fron27 (kW)	COE ($)	NPC ($)	Operating cost ($/yr)	Initial capital ($)	Capital Cost ($)	Production (kWh/yr)	Inverter Mean Output (kW)	Energy Purchased (kWh)	Energy Sold (kWh)
510	999,999	486	$0.0300	$669,956	$5,398	$581,746	433,500	980,721	110	408,829	648,366
510	999,999	513	$0.0303	$678,273	$5,723	$584,743	433,500	980,721	110	408,829	649,628
500	999,999	486	$0.0312	$689,221	$7,096	$573,246	425,000	961,491	107	409,871	631,219
500	999,999	513	$0.0316	$698,363	$7,472	$576,243	425,000	961,491	108	409,871	631,976
490	999,999	486	$0.0325	$708,859	$8,818	$564,746	416,500	942,261	105	410,944	613,874
490	999,999	513	$0.0330	$718,593	$9,231	$567,743	416,500	942,261	105	410,944	614,269
480	999,999	486	$0.0339	$728,780	$10,557	$556,246	408,000	923,032	103	412,037	596,376
480	999,999	513	$0.0343	$738,887	$10,992	$559,243	408,000	923,032	103	412,037	596,543
510	999,999	486	$0.0669	$1.50M	$25,943	$1.07M	433,500	980,721	110	408,829	648,366
510	999,999	486	$0.0669	$1.50M	$25,943	$1.07M	433,500	980,721	110	408,829	648,366
510	999,999	486	$0.0669	$1.50M	$25,943	$1.07M	433,500	980,721	110	408,829	648,366
510	999,999	486	$0.0669	$1.50M	$25,943	$1.07M	433,500	980,721	110	408,829	648,366
510	999,999	486	$0.0669	$1.50M	$25,943	$1.07M	433,500	980,721	110	408,829	648,366
510	999,999	486	$0.0669	$1.50M	$25,943	$1.07M	433,500	980,721	110	408,829	648,366
510	999,999	486	$0.0669	$1.50M	$25,943	$1.07M	433,500	980,721	110	408,829	648,366
510	999,999	486	$0.0669	$1.50M	$25,943	$1.07M	433,500	980,721	110	408,829	648,366
510	999,999	486	$0.0669	$1.50M	$25,943	$1.07M	433,500	980,721	110	408,829	648,366
510	999,999	486	$0.0669	$1.50M	$25,943	$1.07M	433,500	980,721	110	408,829	648,366
510	999,999	486	$0.0669	$1.50M	$25,943	$1.07M	433,500	980,721	110	408,829	648,366
510	999,999	486	$0.0669	$1.50M	$25,943	$1.07M	433,500	980,721	110	408,829	648,366
510	999,999	486	$0.0669	$1.50M	$25,943	$1.07M	433,500	980,721	110	408,829	648,366
510	999,999	486	$0.0669	$1.50M	$25,943	$1.07M	433,500	980,721	110	408,829	648,366

Fig.4. 14: Overall HOMER optimization results according to the total net present cost

4.7 Financial Viability

Metric	Value
Present worth ($)	$58,825
Annual worth ($/yr)	$3,599
Return on investment (%)	16.2
Internal rate of return (%)	20.0
Simple payback (yr)	4.94
Discounted payback (yr)	5.54

Fig.4. 15: Financial Viability.

4.8 Sensitivity

Sensitivity Analysis: the sensitivity analysis is one short of analysis where discuss power price and sell back rate as include that COE and NPC that system is feasible is defined as a possible solution.

Sensitivity		Architecture								Cost			
Power Price ($/kWh)	Sellback Rate ($/kWh)						SPR-MAX3 (kW)	Grid (kW)	Fron27 (kW)	COE ($)	NPC ($)	Operating cost ($/yr)	Initial capital ($)
0.100	0.100						510	999,999	486	$0.0300	$669,956	$5,398	$581,746
0.100	0.125						510	999,999	486	$0.0249	$557,743	-$1,469	$581,746
0.125	0.100						510	999,999	486	$0.0306	$684,302	$6,275	$581,746
0.125	0.125						510	999,999	486	$0.0256	$572,089	-$590.91	$581,746

Fig.4. 16: Sensitivity results for the grid tide photovoltaic

In fig 4.16 the power price and sell back price is varied from $0.100 to $0.125 for both. As a result of different conditions, the cost of energy is varied from $0.0249 to $0.0306. This result is represented in fig 4.17.

When power price is $0.100/kWh and sell back rate is 0.125 that time COE and NPC are much more than other times that are respectively $0.0306/kWh and $684302/kWh. On the other hand, power price is $0.100/kWh and sell back is $0.125/kWh that time Minimum COE and NPC.

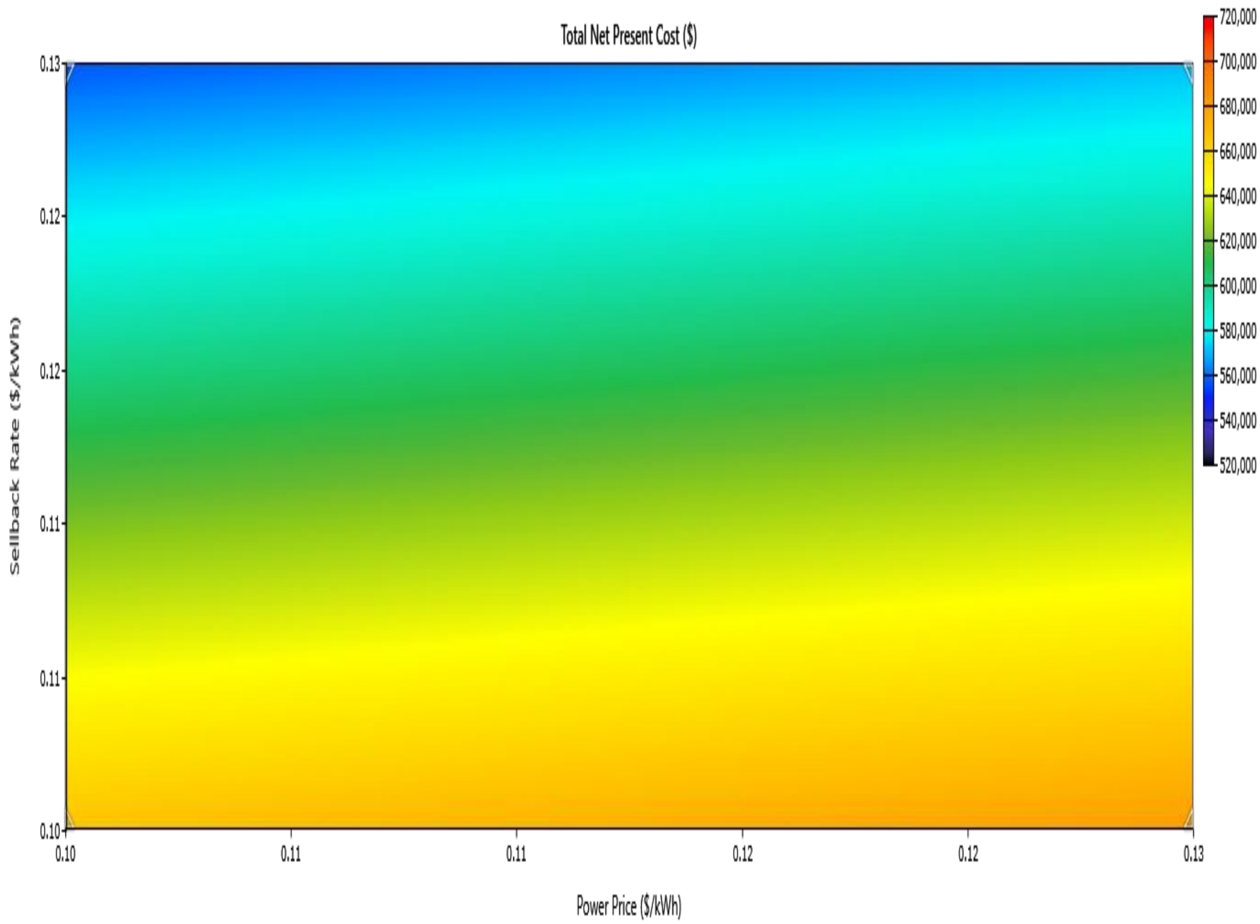

Fig.4. 17: Variation Of NPC for different sellback rate and power price .

From fig 4.17 it's clear that when power price is minimum and sell back price is maximum then NPC is minimum. NPC is varied with different power price and sells back price. From sensitivity analysis, it's clear that all the sensitivity NPC is viable for investment because all of the results are suitable for investment and risk level in minimum.

4.9 Per unit generation cost different point of Bangladesh

To determine per unit generation cost for different locations of Bangladesh only solar radiation and data of temperature is varied and other data and cost considered as constant. This study determines COE for without battery system only. By changing this data minimum COE is found for Dinajpur, it's about $0.0213 and COE for Rangpur is close to it, it's about $0.0237. The maximum cost of energy is found for Barisal it's about $0.0315. For Dinajpur daily solar radiation is maximum and for Barisal Daily solar radiation is minimum Besides that temperature of Barisal is greater than Dinajpur. Temperature is inversely proportional to the solar PV power generation. This result clearly indicates that COE is not varied a large for different locations of Bangladesh.

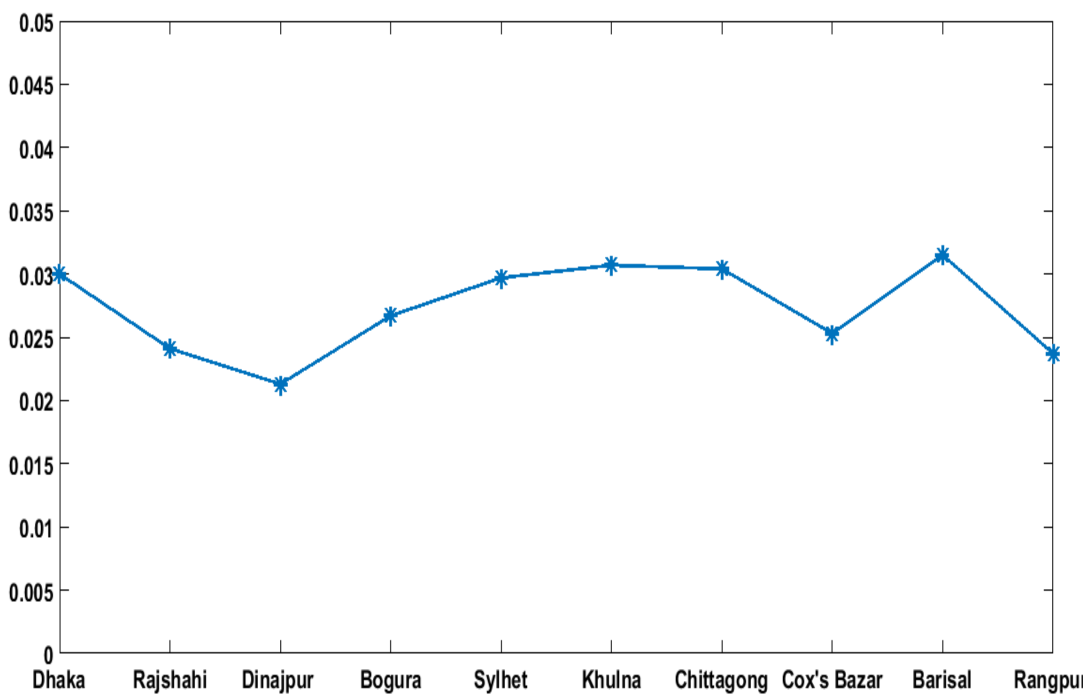

Fig.4. 18: COE for solar PV system for 10 locations, Bangladesh.

4.10 Summary

This study focused on the financial viability of with and without battery grid-connected solar PV systems under net metering. The result of the HOMER analysis shows that without a battery solar home system is more feasible. COE for different locations of Bangladesh is also determined.

Chapter 5

Conclusion

5.1 Conclusion

The research has tried to confirmed Rooftop PV solar system with on-grid in the industry. Using homer feasibility analysis has been conducted to show the system is viable for the industry. According to the load on the proposed system, the analysis basically carried two ways, one is with battery grid-connected system PV and without battery grid-connected PV system. Techno-economical analysis with proposed PV components based on price, quality, and availability. Energy Security was the most valuable priority for carried research because in the industry occurred on load shedding on the grid-connected system then they alternatively used diesel generator that is more costly than any other energy generation system. Our research tried to keep it up to energy security as well as reduction of energy production cost also sold to grid extra electricity that system produced.

Determination of the reduction of per-unit cost of energy consumption by comparing electricity production cost, energy purchase cost from the grid, and energy sold revenue to the grid The study has carried the Levelized cost of energy is ($0.0300/Kwh), total net present cost shows ($669955) and its sell back rate is ($0.10/Kwh)

This result contributes not only security of energy but also to perform economic support for the investor, to protect against environmental damage

5.2 Future Scopes of the Work

In this study, we focused on only the gird solar PV system. This analysis can be extended with wind energy. Also, it could be possible to design a model by taking other renewable energy sources like hydro and biomass. Besides that this study is about the feasibility for the industry it can be applied for an office building, university, on gird solar home system.

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