

Impact of on-grid rooftop solar system with net metering for the industry in Bangladesh.

**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

Md. Anikul Islam

(ID #: 172-33-483)

Md.Fazle Rabbi

(ID #: 172-33-532)

Supervised by

Professor Dr. Md. Shahid Ullah

Professor & Head

Department of EEE

Daffodil International University

Co-Supervised by

Md. Mahbub –Ud-Jaman

Lecturer

Department of EEE

Daffodil International University



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 " **Impact of net metering rooftop solar system for the industry in Bangladesh** " 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: Md Anikul Islam

ID #: 172-33-483

Name Md. Fazle Rabbi

ID #: 172-33-532

Countersigned

Professor Dr. Md. Shahid Ulla

Professor and Head

Department of Electrical and Electronic
Engineering

Faculty of Science and Engineering

Daffodil International University

Md. Mahabub Ud-Jaman

Lecturer

Department of Electrical and Electronic
Engineering

Faculty of Science and Engineering

Daffodil International University.

The project and thesis entitled "**Impact of on-grid rooftop solar system with net metering for the industry in Bangladesh.**," submitted by **Md Fazle Rabbi**, ID No:- 172-33-532, Session: Summer 2017, 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

BOARD OF EXAMINERS

Dr. Engr. ...

Professor

Department of EEE, DIU

Chairman

Dr. Engr. ---

Professor

Department of EEE, DIU

Internal Member

Dr. Engr. ---

Professor

Department of EEE, DIU

Internal Member

Dr. Engr. ---

Professor

Department of EEE, DIU

Internal Member

Dedicated to

Our Parents

I want to dedicate my thesis to my parents and all my teacher.

CONTENTS

List of Tables	vii
List of Figures	viii
List of Abbreviations	ix
List of Symbols	x
Acknowledgment	xi
Abstract	xii
Chapter-1 Introduction	1
1.1 Background	1
1.2 Objective	2
1.3 Research Methodology	3
Chapter-2 Power Situation of Bangladesh	4
The present situation of the power sector of Bangladesh	4
2.1 Introduction	4
2.2 Electricity Capacity in Bangladesh	5
2.2.1 Fossil Fuels Power Plant in Bangladesh	6
2.2.2 Renewable power plant	10
2.2.3 Nuclear Power Plant	16
2.3 Annual power generation	17
Chapter-3 Study of Net Metering	22
3.1 Introduction	22
3.2 Basics of Net-Metering	22
3.3 Variations And Misconceptions About Net Metering	23
3.4 Modeling of PV solar cell.	24
3.5 Modeling of Inverter and MPPT controller	25

3.6	Flow chart of net metering	27
3.7	Grid-connected three phases of the solar PV system	29
Chapter-4 Net Metering Guidline for Bangladesh		31
4.1	Eligibility Law	31
4.2	Consumer classification	31
4.3	Appliance Standard and Anti Islanding	32
4.4	Net metering Statistics	
report.....		32
Chapter-5 On-grid Solar PV System for Indutry		33
5.1	Introduction	33
5.2	Design and simulation report	33
5.2.1	The summary of the project	34
5.2.2	The Parameters characteristic of the project	35
5.2.3	Cost of the system	36
5.2.4	Simulation output report	36
5.2.5	CO ₂ Emission Balance	40
5.3	Practical report	41
5.3.1	Solar power consumption	41
Chapter-6 Result and Discusion		45
6.1	Economical Calculation	45
6.1.1	Practical economic result	45
6.1.2	Simulation's economic result	45
6.2	Epact of the solar PV system on the industry	47
6.3	Discussion	47
Chapter-7 Conclusion and Recommendation		48
7.1	Conclusion	48
7.2	Recommendation	48
Reference		49
Reference.....		
.49		
Appendix.....		
...50		

LIST OF TABLES

Table 1.1-1 Renewable Energy Development part of Bangladesh	1
Table 2.2-1 Bangladesh Gas Turbine Power Plant list with Max. Capacity and turbine number	6
Table 2.2-2 Bangladesh Gas Engine Power Plant list with Max. Capacity and turbine number	7
Table 2.2-3 Steam Power Plant list with Max. Capacity of Bangladesh	7
Table 2.2-4 Steam Power Plant list Under Construction	8
Table 2.2-5: Bangladesh's Oil and Gas-fired Thermal power station	9
Table 2.2-6 Newly Approved Diesel Based Power Plants	9
Table 2.2-7 Wind Power List	12
Table 2.2-8 Biogas Large Project in Bangladesh	15
Table 2.3-1 Grade based production capacity (2019-20)	17
Table 2.3-2 Ability to set up year based power plants	17
Table 2.3-3 Installed Capacity, Maximum Demand, Maximum Peak Generation	19
Table 2.3-4 Present situation of the power sector of Bangladesh	21
4.2-1: Consumer classification	31
Table 5.2-1 Project summary	34
Table 5.2-2 Installation Cost of the system	36
Table 5.2-3 Operating costs of the system	36
Table 5.2-5 System Lifecycle Emission Details	40
Table 5.3-1 Daily stitching section solar power consumption log sheet	41
Table 5.3-2 Monthly stitching section solar power consumption log sheet	43
Table 5.3-3 Yearly Stitching Section solar power Consumption Log Sheet	44
Table 6.1-1 Comparative summary	46

LIST OF FIGURES

Figure 1.1-1 Renewable Energy Development part of Bangladesh	2
Figure 2.1-1 Energy and Power Master Plan 41 of Bangladesh	4
Figure 2.1-2 Renewable power production sector	5
Figure 2.2-1 Schematic arrangement of a gas turbine power plant	6
Figure 2.2-3 Oil-fired power plant	8
Figure 2.2-4 Solar power system	11
Figure 2.2-5 wind power	12
Figure 2.2-6 Hydro Power Plant	13
Figure 2.2-7 Biomass Power Plant	14
Figure 2.2-8 Biogas Power Plant	15
Figure 2.2-9 Nuclear Power Plant	16
Figure 2.3-1 Year base maximum power generation	18
Figure 2.3-2: Installed Capacity (Derated), Maximum Peak Generation & Demand Forecast	19
Figure 2.3-3 Forecast chart for Installed Capacity, Max Demand, Max Generation From 2009 to 2030	20
3.2-1 Typical net metering architecture [3]	23
Figure 3.4-1: Equivalent circuit of a solar cell	24
Figure 3.5-1 Three-phase inverter	26
Figure 3.5-2 Flowchart for MPPT Controller [9]	26
Figure 3.6-1 Net metering system flow chart	27
Figure 3.6-2: Net Meter Function in MATLAB Simulink.	28
Figure 3.7-1 Net Meter Function in MATLAB Simulink.	29
Figure 3.7-2 simulation output	30
Figure 4.4-1 Net meter install capacity.....	32
Figure 5.2-1 inverter	35
Figure 5.2-2 Solar panel	35
Figure 5.2-3: 2 core, 4sq mm flexible cable	35
Figure 5.2-4 Balance and main result	37
Figure 5.2-5 Loss diagram (source from the author)	38
Figure 5.2-6: Financial analysis of the project	39
Figure 5.2-7 Save CO ₂ Emission vs Time	40
Figure 5.3-1 Daily stitching section solar and REB/Generator power consumption chart	42
Figure 5.3-2 yearly solar power consumption (2019)	44
Figure 6.2-2 Industrial power consumption percentage	47
Figure 6.2-1 Power consumption value	47

List of Abbreviations

RE	Renewable Energy
MW	MegaWatt
KWh	Kilowatt-hour
Km	Kilometer
WEF	World Economic Forum

IDCOL	Infrastructure Development Company Limited
SREDA	Sustainable And Renewable Energy Development Authority
Max	Maximum
BREB	Bangladesh Rural Electrification Board
PV	Photo Voltaic
GDP	Gross Domestic Product
AC	Alternative Current
DC	Direct Current
USD	United States Dolar
GWh	Giga Watt-hour
LPG	Liquefied Petroleum Gas
LNG	Liquefied Naturel Gas

List of Symbols

λ	Wavelength
λ_B	Bragg wavelength
n_{eff}	Effective index
z	Position along the grating
n	Mode index
f	Fundamental Frequency
ω	Angular frequency
M	Modulation Index
T	Fundamental Period

ACKNOWLEDGEMENT

First of all, we give thanks to Allah or God. Then we would like to take this opportunity to express our appreciation and gratitude to our project and thesis supervisor, **Dr. Md. Shahid Ullah, Professor, and Head of Department of EEE** and **Md. Mahabub Ud-Jaman, Lecturer of the EEE department, is dedicated to** supporting, motivating, and guiding us through this project. This project can't be done without his useful advice and helps. Thank you very much for allowing us to choose this project.

We also want to convey our thankfulness to **Dr. Md. Alam Hossain Mondal, Associate Professor and Chairperson** of the **Department of EEE**, for his help, support, and constant encouragement.

Apart from that, we would like to thank our entire friends for sharing knowledge; information and helping us make this project a success. Also, thanks for lending us some tools and equipment.

To our beloved family, we want to give them our deepest love and gratitude for being very supportive and for their inspiration and encouragement during our studies at this University.

ABSTRACT

Bangladesh is one of the most populous developing countries in South Asia. Although dependent on agriculture, many industries have sprung up since this country's independence. To keep pace with the pace of development of any country, it is necessary to increase the power generation of that country. Bangladesh is still dependent on fossil fuels for power generation. But this fossil fuel is declining day by day. Gas is most commonly used in power generation. There is a gas crisis in cooking in the capital of Bangladesh. Bangladesh has recently started importing liquefied LP gas. In this case, we need to focus on renewable energy. From 2009 to 2020, the Government of Bangladesh planned to meet 10% of electricity demand from this renewable energy. These millions have now increased. The government's target is to get 55% of its electricity from renewable energy by 2041. And the most promising of these renewable fuels is power generation from sunlight. This thesis focuses on the on-grid solar system design. How an on-grid customer can benefit from being connected to the Grid with a net meter is discussed.

We know that no electricity is available when the on-grid PV system is not connected to the Grid. For this reason, it has been found that the number of off-grid PV systems installed in homes or commercial buildings is much higher than that of on-grid. Off-grid DC devices are commonly used. On the other hand, the extra electricity generated on-grid is being wasted. A nice solution to use this extra electricity is the net meter. With this net meter, the customer will be able to supply the surplus electricity to the Grid, resulting in a much lower electricity bill.

Here is how the net meter works.

Chapter-1

INTRODUCTION

1.1 Background

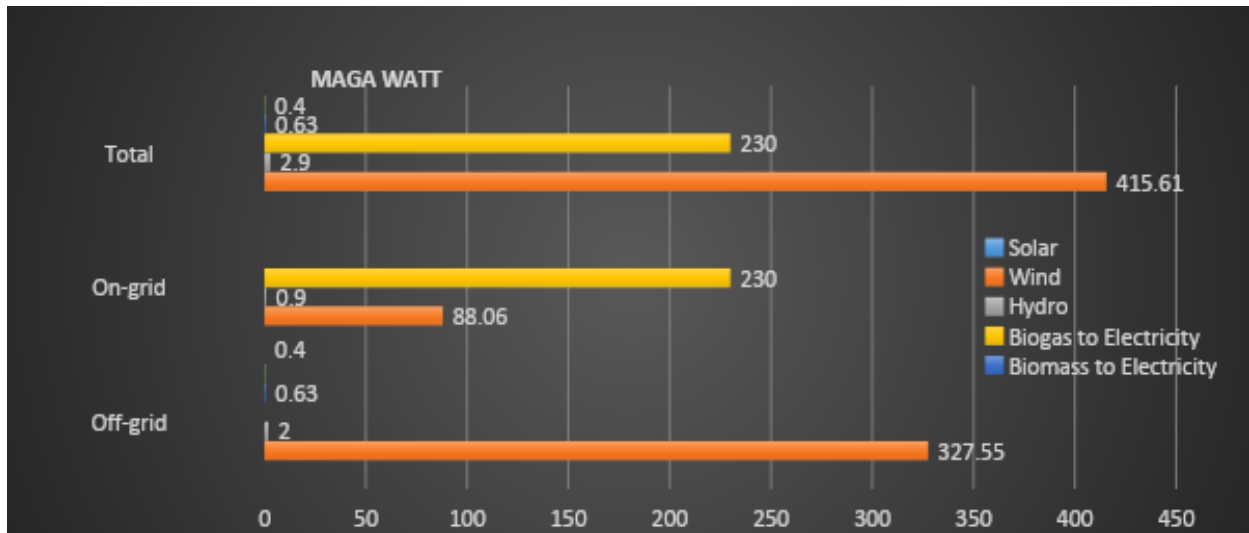
Bangladesh is a small country. The area of Bangladesh is 1,47,570 square km. The position of Bangladesh 95th in the world and area is 1,48,460 square according to the research of South Asia. In this small country, many people leave this. Bangladesh's total population is 162,951,560, and the density of population per square km is 1,106. In 2009-14, Bangladesh's target would be a medal-income country in 2021. Now Bangladesh has an aim to become a high-income country by 2041. The quantity and quality will be realized of long-tram economic development when energy and power infrastructure will be developed.[1]

At present power generation of Bangladesh is heavily dependent on fossil fuels. Bangladesh already faces a gas crisis. In especially the town area, it is very difficult to cook. Many people use LPG gas cylinders, giving up hope of gas in the pipeline. To protect the crisis of gas Bangladesh government has already started importing gas from abroad. In 2008 Bangladesh adopted the Renewable Energy Policy, which mandated 10% of total power generation should come from renewable energy sources by 2020. This means that by then, renewable electricity production capacity needs to increase to 2000MW from its current capacities of 500MW. [2]

Bangladesh already starts to install the renewable energy power plant. Renewable energy capacity is 649.54MW. Generally, we get renewable energy from Solar, Wind, Hydro, and Biomass to Electricity. In the bellow of the table shown the capacity of renewable.

Table 1.1-1Renewable Energy Development pant of Bangladesh

Technology	Off-grid (MW)	On-grid (MW)	Total (MW)
Solar	327.55	88.06	415.61
Wind	2	.9	2.9
Hydro	0	230	230
Biogas to Electricity	0.63	0	0.63
Biomass to Electricity	.4	0	.4
Total	330.58	318.96	649.54



Source: SREDA

Bangladesh enjoys a good amount of sunshine, and the use of solar energy continues to grow while the cost of solar technology continues to decline. Incentivizing grid-connected customers is of utmost importance to promote RE-based distributed generation. Net metering is one of the tools to popularize the RE based electricity generation in the country. Net metering is a policy approach designed to encourage distributed renewable energy development by allowing utility customers to generate their electricity from solar or any other renewable sources and use the electricity produced to offset the amount of energy they draw from the utility grid (sometimes called the distribution grid) and any access generation can feed into the Grid. Customers are only billed for their "net" energy use and receive credit, usually in the form of a kilowatt-hour (kWh) during a given period. A net balance in favor of the customer is carried forward to the next month, while a balance in favor of the utility is settled at the end of the month as usual. Net-metering can potentially drive widespread implementation of distributed generation by incentivizing end-users to adopt localized power generation through renewable energy technologies (RETs) such as solar, wind, and biomass. As of 2017, 46 countries have some form of active net-metering policy; local governments have adopted net metering policies in another nine countries in the absence of national-level actions.[3]

1.2 Objective

The main objective of this thesis is

1. To design an on-Grid rooftop solar system with net metering for the industry.
2. To investigate, an on-grid solar system with the net-metering is suitable for the industry?

Another object

1. To study the power generation of Bangladesh.
2. To study net metering guideline prepares.
3. The Aim of government for net metering.

4. Reduce the electricity bill and reduce dependence on the power grid.
5. Utilize the power and share the extra power with the power grid that we can get from the rooftop.
6. The unused-roof of industrial utilizes by on-grid solar.
7. Find out the limitation of net metering for consumers and try to overcome the limitation.

1.3 Research Methodology

Our thesis is called "Impact of on-grid rooftop solar system with net metering for the industry in Bangladesh." The methods we have used for this thesis are given below

1. The Internet is currently the easiest and largest way to search for information. We have taken the help of various government websites for our information w. We have also received data from various journals paper.
2. Invert design, and three-phase grid connection is shown with the help of MATLAB.
3. 200KWh On-grid solar system is simulated and cost analysis by PVsyst software.
4. We visit an industry for real-life data.
5. To write our thesis paper, we use the Microsoft office application and Mendeley software.

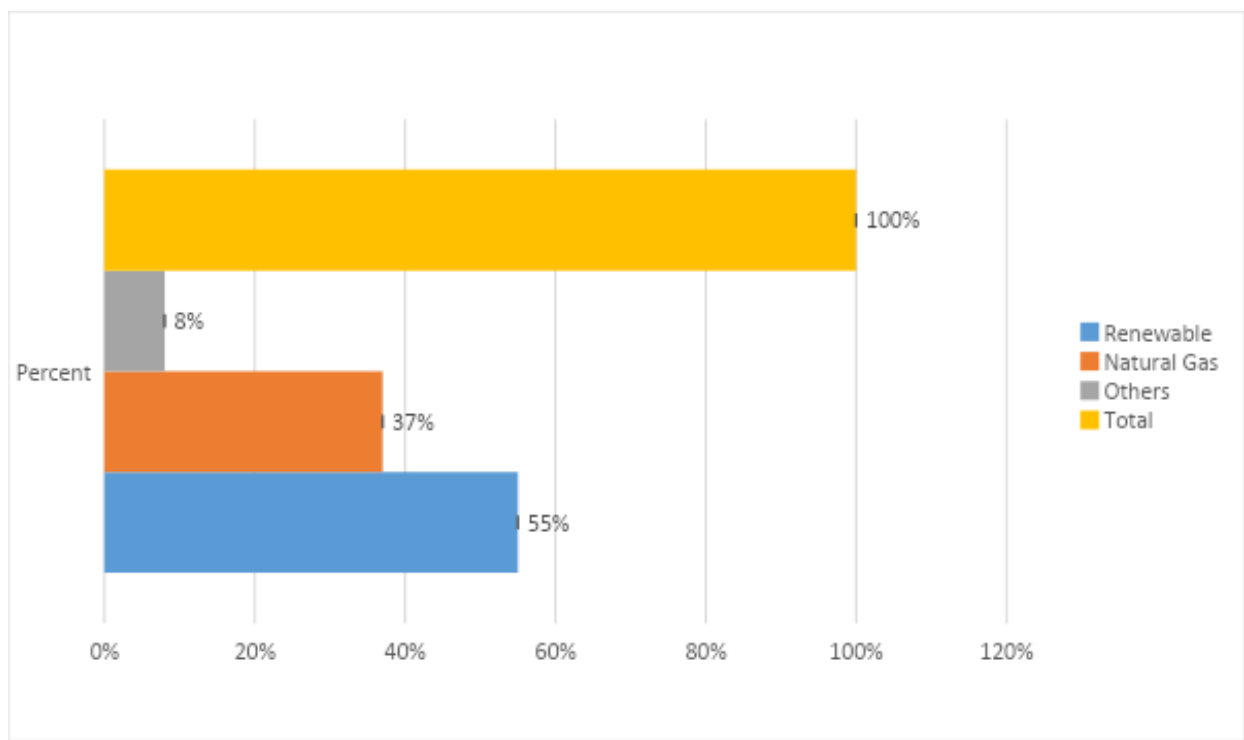
Chapter-2

Power situation of Bangladesh

2.1 Introduction

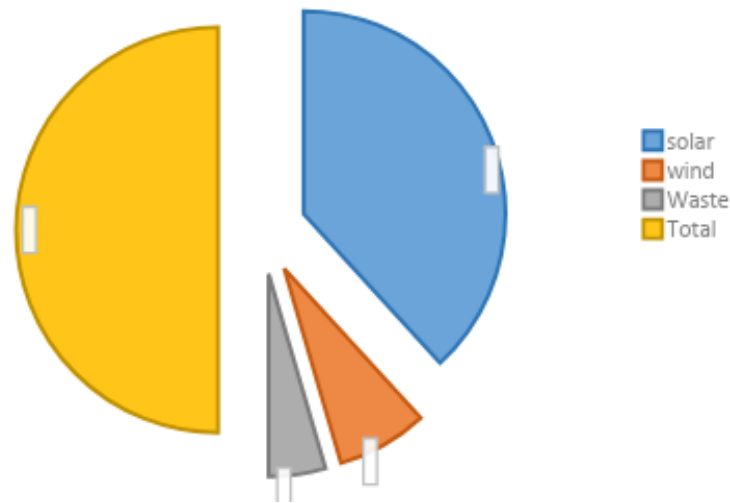
Electricity can be considered as a prerequisite for the development of any country. The economic development of a country depends on electricity as a driving force. Bangladesh's position is lag compare to other countries of the world in the production and management of electricity. World Economic Forum (WEF) published a report called "Energy Architecture Performance Index-2018," where Bangladesh ranks is 104th among 126 countries in the world in terms of power structure efficiency index. Since 2009, to overcome 72 new power plants have been set up in the power sector in this situation. About 1.5 core new connections were provided in 2012-2018.

The present government has short, medium, and long-term plans to solve the power sector problem. Besides, it has finalized a master plan to generate 60,000MW of electricity by 2041. But The National Committee for Protection of Oil, Gas, Mineral Resources, Power and Ports has given priority to renewable power generation in their draft outline.



The National Committee has set a target of generating 91,600MW of electricity by 2041, of which 55% will be renewable (solar 42%, wind 8%, waste 5%). Besides, 4% present will be oil-base, and 4 percent of electricity will be through regional cooperation, and 37 percent of production capacity will be gas-base.

Percentage



The 55% renewable energy we get from three sectors. There are Solar power plants, Wind power Plant, and Waste power plants. Capacity will be 42% solar, 8% wind, and 5% Waste.

Source: BBC News [t.ly/Vla4]

In this chapter, try to do a short review of Bangladesh power generation.

2.2 Electricity Capacity in Bangladesh

In 1901 Bangladesh's capital city Dhaka started fast electrification by Nawab Khwaja Ahsanullah. Then in 1948, East Pakistan established an electricity Directorate. There were few Steam Turbines in Siddhirganj (maximum size 10MW), Chittagong, and Khulna at that time. In 1962, Kaptai hydro-electric project with 40MW capacity was installed and a 132KV transmission line between Dhaka and Chittagong. Only 3% of the population had access to electricity in 1971, after the independence of Bangladesh. However, 79% present of the connected consumer suffer from load-shedding, and 60% of the consumers face low voltage supply[4]. In 1978-75, the installed electricity generation capacity was 667 MW, whereas, in 2019, it is 12,893MW, including 1160MW power import from India[5]

2.2.1 Fossil Fuels Power Plant in Bangladesh

We usually use fossil fuels to generate electricity, such as gas, coal, oil, etc. In this chapter, we will shortly discuss Fossil Fuels Power Plant.

2.2.1.1 Gas Power Plant:

In this present situation, maximum power generates gas. In 2018-19, about 57.37% of percent power plant used gas as fuel, and in the year, 10,877 MW electricity generation from this sector.

Gas-based power station's total capacity is 2,356MW, and 13 turbines and 84 gas engines produce electricity. In the below, we give the list of Gas turbine power station in the table.

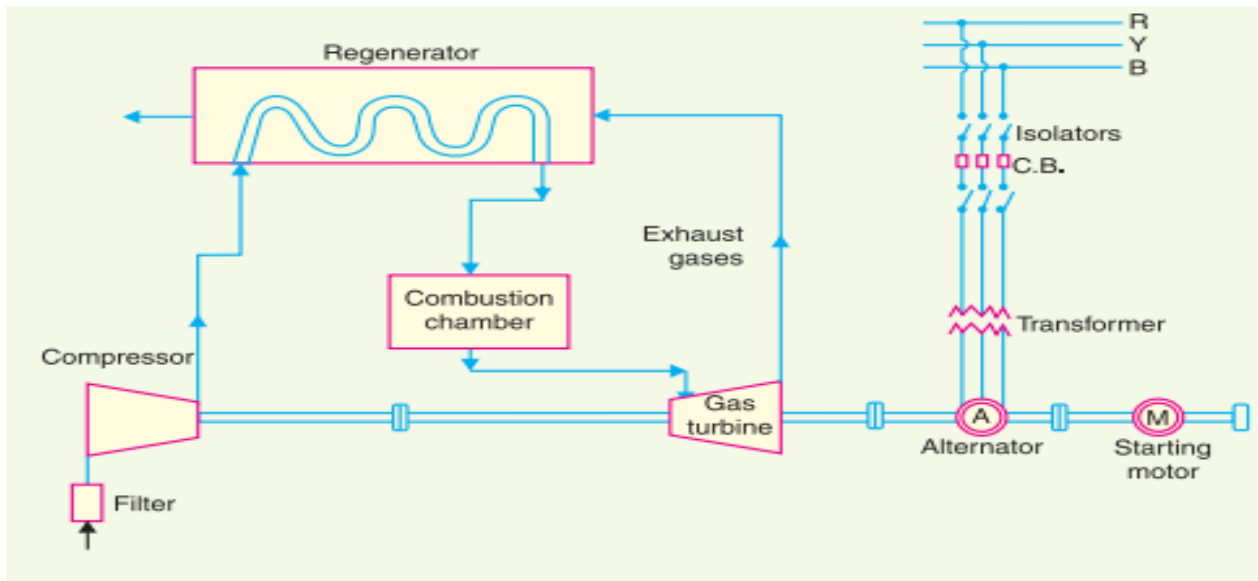


Figure 2.2-1 Schematic arrangement of a gas turbine power plant

Source: t.ly/9nQZ

Table 2.2-1 Bangladesh Gas Turbine Power Plant list with Max. Capacity and turbine number

Power Station	Max. Capacity (MW)	Turbine	Fuel type
Ashuganj	146	2+1	Natural gas
Goalpara, Khulna	265		Heavy fuel oil
Haripur	360	1+1	Natural gas
Magnaghat	450	2+1	Natural gas
Mymensingh	210	4+1	Natural gas
Siddirganj	240		Natural gas

Source: https://en.wikipedia.org/wiki/List_of_power_stations_in_Bangladesh

Table 2.2-2 Bangladesh Gas Engine Power Plant list with Max. Capacity and turbine number

Power station	Max. Capacity (MW)	Engines	Fuel type
Baraka Power Ltd.	51	16	<u>natural gas</u>
Dhaka	7	2	<u>natural gas</u>
Gazipur	53	6	<u>natural gas</u>
Gopalganj	100	16	<u>natural gas</u>

Maona	35	4	<u>natural gas</u>
Raozan	240	6	<u>natural gas</u>
Ghorashal Regent	108	34	<u>natural gas</u>
Baghabari, Sirajgonj	50		<u>natural gas</u>
APSCL, Ashuganj	50		<u>natural gas</u>

Source: https://en.wikipedia.org/wiki/List_of_power_stations_in_Bangladesh

2.2.1.2 Coal Power Plant/ Steam Power Station (Thermal Station)

The price of coal is relatively more stable in the international market and has lower volatility with oil and natural gas. The availability of coal also wider throughout the world and can provide a more diversified and stable supply. Bangladesh government has a plan to set up coal base large base-load power plants. The plan is to produce about 7500MW from coal base power plant by 2021. Barapukuria Power station is the only coal-based power plant in Bangladesh, and its capacity is 225 MW.

There are three power plants under construction, and they are Matarbari Power station, Payra Thermal Power station, and Rampal power plant.

Table 2.2-3 Steam Power Plant list with Max. Capacity of Bangladesh

Power Station	Location	Capacity (MW)	Coal Type
Barapukuria Power Station	Durgapur, Dinajpur	525	Anthracite

Table 2.2-4 Steam Power Plant list Under construction

Power station	Location	Capacity (MW)	Coal Type	Plant Type	Expected in Operation
Matarbari Power Station	Maheshkhali Upazila, Cox's Bazar District	1200	Sub-Bituminous	Ultra Super Critical	2024
Payra Thermal Power Plant	Kalapara Upazila, Patuakhali District	1320	Sub-Bituminous	Ultra Super Critical	1 st unit in August 2019
Rampal Power Plant	Rampal Upazila Bagerhat District	1320	Sub-Bituminous	Ultra Super Critical	

Source: https://en.wikipedia.org/wiki/List_of_power_stations_in_Bangladesh

2.2.1.3 Oil-fire Power Plant

Oil-fired power station. Diagram showing the main parts of an oil-fired power station. Oil from a storage tank (left) enters the burner-boiler section where it is burnt, with waste gases and the smoke exiting through the chimney. The heat from the burning oil boils water in a steam drum (cylindrical).



Figure 2.2-2 Oil-fired power plant

The resulting steam is piped to the turbines (lower center), where electricity is generated. The steam is condensed (bottom) and piped back to the steam drum. Excess heat and steam are vented through a cooling tower (lower right). The electricity is transformed and distributed through a grid of pylons and cables (bottom right).

Source: <https://www.sciencephoto.com/media/723613/view/oil-fired-power-station-diagram>

Bangladesh has seven power stations that use oil and gas-fired to produce electricity. The capacity of power stations are 2654.2 MW

Table 2.2-5: Bangladesh's Oil and Gas-fired Thermal power station

Power Station	Location	Capacity (MW)
Ashuganj Power Station	Brahmanbaria	1627
Ghorasal	Shikalbaha, Chatagram	150
Shiddirganj	Siddirganj	260
Orion Group(4 plants)	Narayanganj & Khulna	400

Lakdhanavi Banla Power Limited	Comilla	52.2
Desh Energy Chandpur Power Company Ltd.	Chandpur	200
Doreen Power Generation and Systems Limited	Nababganj,manikganj & Munshigonj	165

Source: https://en.wikipedia.org/wiki/List_of_power_stations_in_Bangladesh

Recently The government has approved ten power plant bases of diesel and fern oil on privet initiative that's capacity is 1086 MW.

Table 2.2-6 Newly Approved Diesel Based Power Plants

Power Station	Fuel type	Capacity (MW)
Keraniganj	Diesel	300
Keraniganj	Diesel	200
Jassor	Diesel	100
Comilla	Diesel	200
Chittagong	Diesel	100
Bogra	Diesel	113
Chadpur	Diesel	200
Brahmanbaria	Diesel	150
Khulna	Diesel	105
Gazipur	Diesel	300

Source: Somoynews.tv link: t.ly/OgxY

2.2.2 Renewable power plant

Energy is immortal; it cannot be created or destroyed. Only one form can be converted from another. Sunlight, wind pressure, river waves, underground heat are all one type of energy. Renewable energy is a method by which natural energy is converted into electrical energy. Bangladesh's mineral resources are declining day by day, so the Bangladesh government has already taken many steps on how to increase renewable energy. According to government estimates, only 3% of the total power generated in Bangladesh comes from renewable energy. At present, we get 649 MW of power from renewable sources like solar home systems, irrigation systems, hydropower systems, biomass, etc. The government's goal is to bring in 10% of total electricity generation from renewable energy by 2021. In this piece, we will discuss different types of renewable energy and highlight the position of Bangladesh.

2.2.2.1 Solar power system

There are a number of industrial-scale photovoltaic solar parks proposed in Bangladesh: 200 MW Teknaf Solar Park, 50 MW Sutiakhali, Mymensingh Solar Park, and 32 MW Sunamganj Solar Park. US company SunEdison sponsored the 200 MW Teknaf project, while Singapore-based entities Sinenergy Holdings, Ditrollic, and local company IFDC Solar are sponsors of the 50 MW Sutiakhali solar park. Edisun PowerPoint & Haor Bangla - Korea Green Energy Ltd is the 32 MW Sunamganj solar park project.

The government has undertaken a total of 19 solar energy projects with a total capacity of 1070 MW, which has obtained the Prime Minister's approval in principle as part of its plan to generate 10% of electricity from a renewable energy source for 2020.

Of these, power purchase agreements (PPAs) have been signed for only six 532 MW projects, while nine 483 MW projects are awaiting the signature of the PPA, and four are being processed by the project selection committee. [14] Sun Solar Power Plant Ltd. installed a 5 MW solar power plant in Sylhet

The country's largest solar power plant in Mymensingh has been connected to the National Grid. The plant can generate 73 MW of electricity, which will help meet the government's goal of generating 10% of the country's total electricity through the use of renewable energy by 2021.

How to Design & Install a Solar PV System

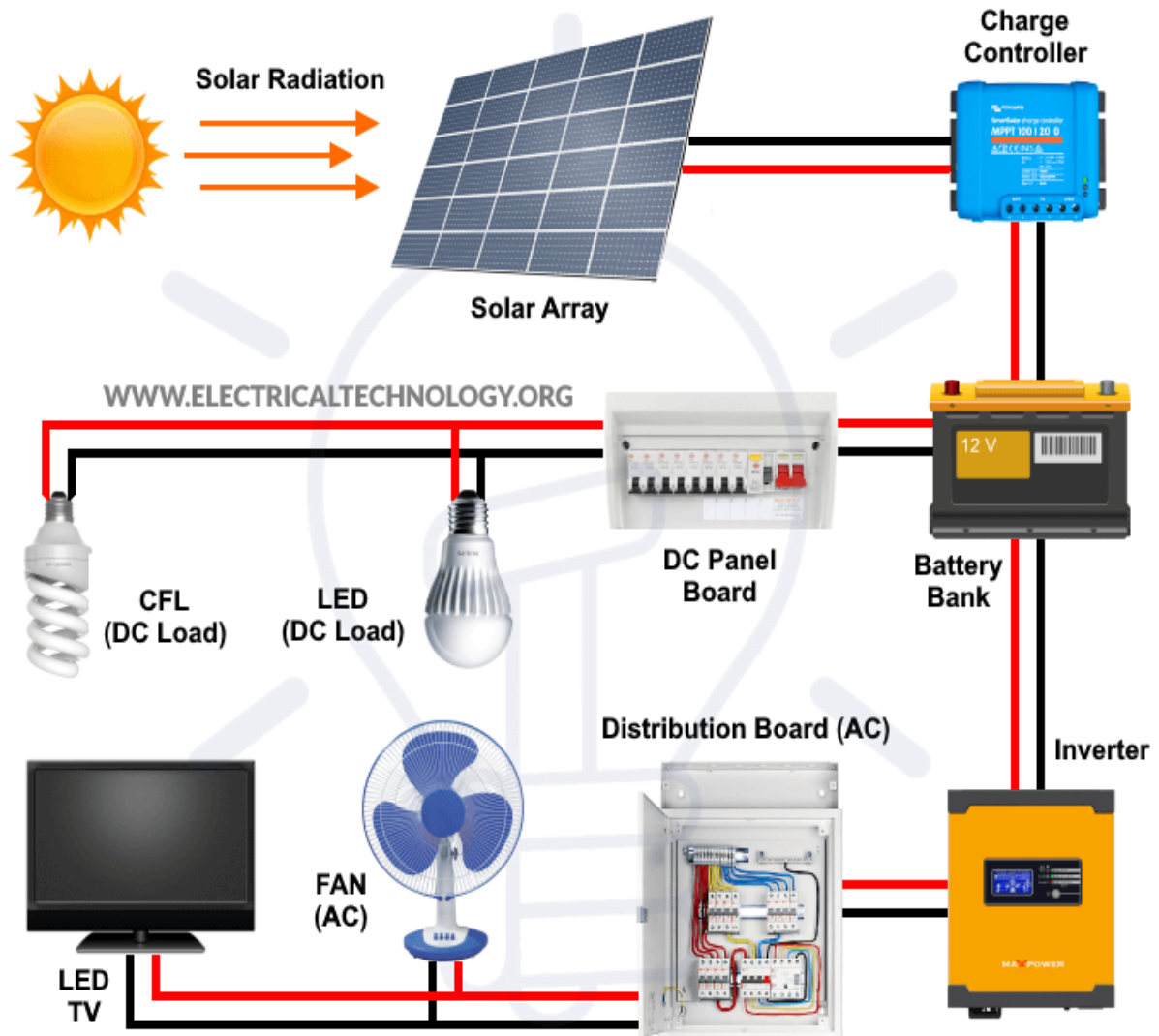


Figure 2.2-3 Solar power system

Source: <https://www.electricaltechnology.org/2020/07/design-and-installation-of-solar-pv-system.html>

To generate electricity, sunlight is first applied to the solar panel. This solar panel is made up of silicon semiconductor diodes, which consists of a p-n junction. This solar panel receives photons from sunlight and converts them into electrical energy. This electrical energy is direct Current. The DC is converted to the AC by a converter. This power can be stored with the help of batteries. Power is supplied from these batteries at night or in cloud cover. There are two types of solar power plants on-grid and off-grid. Solar will be discussed in detail in the next chapter.

2.2.2.2 Wind Power

Wind turbines operate on a general principle. The force of the wind rotates two or three propeller-type blades around a rotor. The rotor is joined to the main shaft, which rotates a generator to generate electricity.

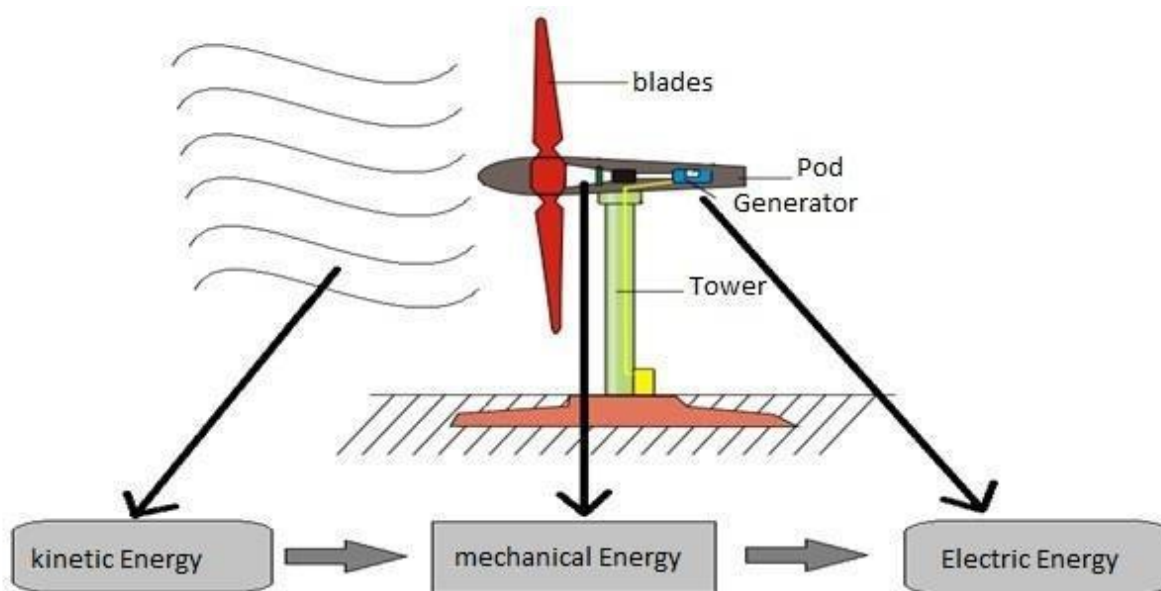


Figure 2.2-4 wind power

In keeping with the developed world, wind power plants have been set up in some districts of Bangladesh by analyzing climate and air pressure. At present, 2.9 MW of electricity comes from this field, of which 2MW comes from off-grid, and the remaining 0.9MW comes from on-grid. A list of wind power plants is given in the table below.

Table 2.2-7 Wind Power List

SL	SID	Location of the power station	Capacity MW	RE Technology
1	172	Kutubdia , Cox's Bazar	1	Off-Grid
2	171	Kutubdia, Cox's Bazar	1	Off-Grid
3	173	Sonagazi,Feni	0.9	On-Grid
4	370	Sirajganj Sadar, Sirajgonj	2	On-Grid
5	155	Kalapara, Patuakhali	10	On-Grid
6	280	Maheshkhali, Cox's Bazar	0	On-Grid
7	158	Chakaria, Cox's Bazar	60	On-Grid

Source: SREDA

2.2.2.3 Hydro Power Plant

Hydropower plants are usually set up along the river. In rivers that flow all year round, high dams are used to retain water. In hydropower plants, water flows through a pipe or penstock. Since the water is blocked, the water level rises. Water gains much kinetic energy due to its height. Water is very dynamic when it passes through pipes or penstocks. This moving water is sent through the turbine. The turbine is a wheel with a blade. The turbine is directly joined to an electric generator. This generator generates electricity. The electricity generated is then sent to different places by wire.

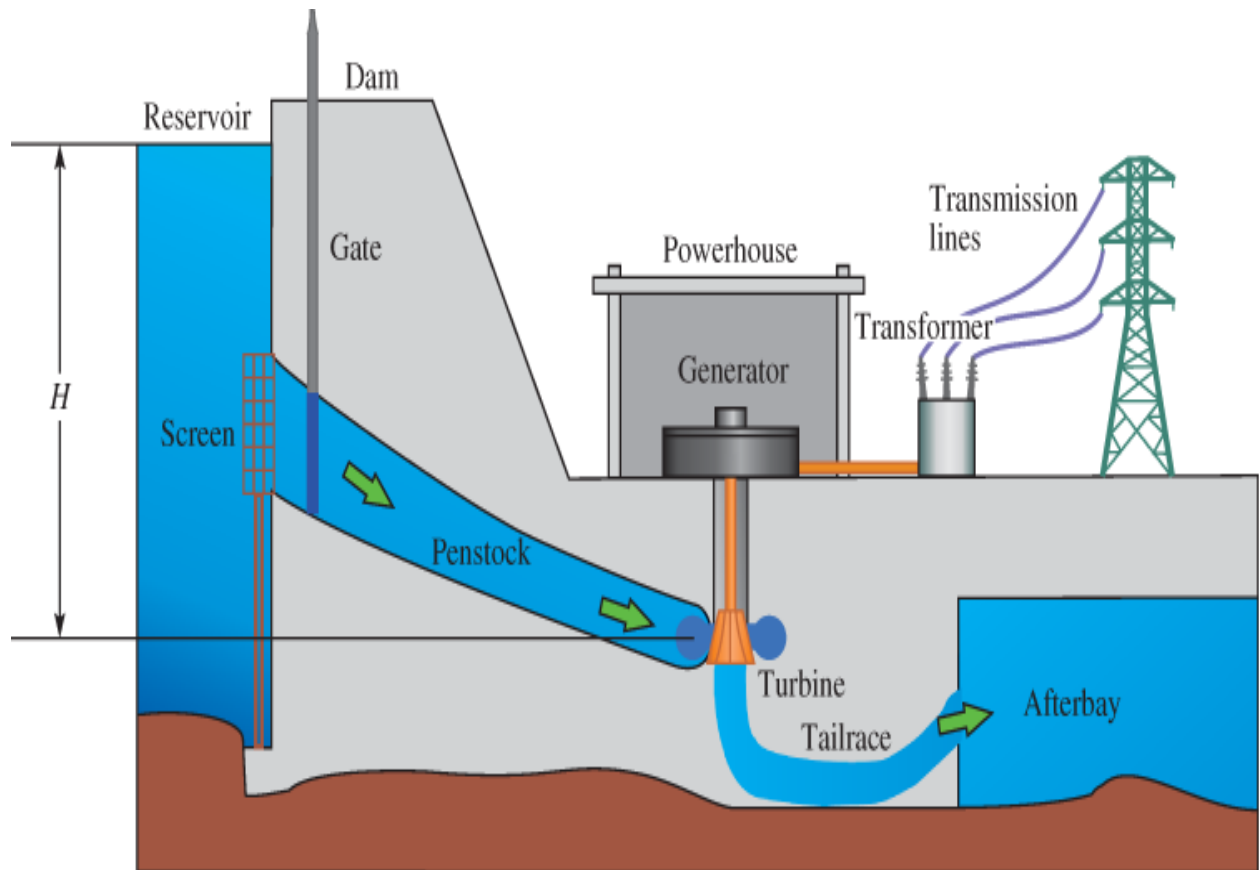


Figure 2.2-5 Hydro Power Plant

Source: <https://electricalacademia.com/wp-content/uploads/2018/08/Figure-1-3.png>

There is only one hydropower plant in Bangladesh. And this is the Kaptai of Karnafuli river in the Rangamati district. Its water holding capacity is 6.48 million cubic meters. It has two turbines of 40 MW and three turbines of 50 MW capacity, a total of 5 turbines. The total capacity of the Kaptai Hydropower Plant is 230 MW.

2.2.2.4 Biomass Power Plant

This system uses biomass resources from biological sources as fuel for power generation. A biomass burner is a type of heat supply device that prepares fuel by storing heat at high temperatures. Organic matter is used as a raw material to make biomass fuel, which is divided into four parts:

Crop Waste: Mainly straw, peanut shell, husk, etc.

Wood waste: waste wood powder, kheuri, etc.

Forest waste: bark, branches, thorns, leaves, bamboo, etc.

Household waste: paper, plastic, etc.

It can be used as a new energy source as fossil fuels like oil and coal. This biomass power plant works like all other thermal power plants. Its main difference from all other plants is that it uses biomass fuel instead of gas or coal. This biomass fuel is used to generate heat by burning. This heat is used to generate steam. This steam is then sent through the turbine. The turbine rotates at high pressure of steam. The turbine is connected to the rotor of the generator so that the rotor of the generator also rotates along with the turbine, and electricity is generated.

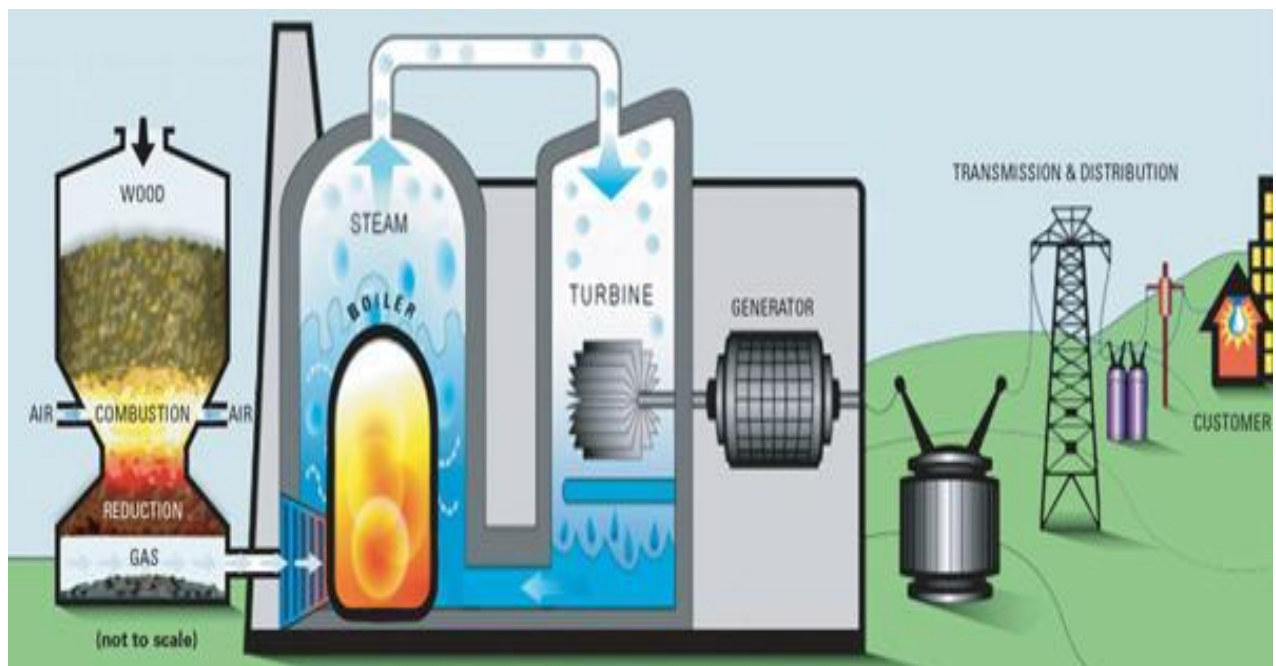


Figure 2.2-6 Biomass Power Plant

It can be said that the biomass power plant has just started in Bangladesh. So far, there is only one biomass project that was set up in 2015. It is located in the Thakurganj district in the Rangpur division. This project is called SEAL Biomass-based Electricity Project. Its capacity is 400 KW.

Source: SREDA

2.2.2.5 Biogas Power Plant

Biogas is a mixed form of the several gases that are taken as a result of the breakdown of organic matter and is generally produced from raw elements such as agricultural waste, organic compost, municipal waste, plant materials, sewage waste, green waste, or food waste. In this method, biogas is used as fuel for the engine. This generator engine is used to convert from mechanical energy to electrical energy. We get AC from most of the generators. This electric generator is like all other generators.

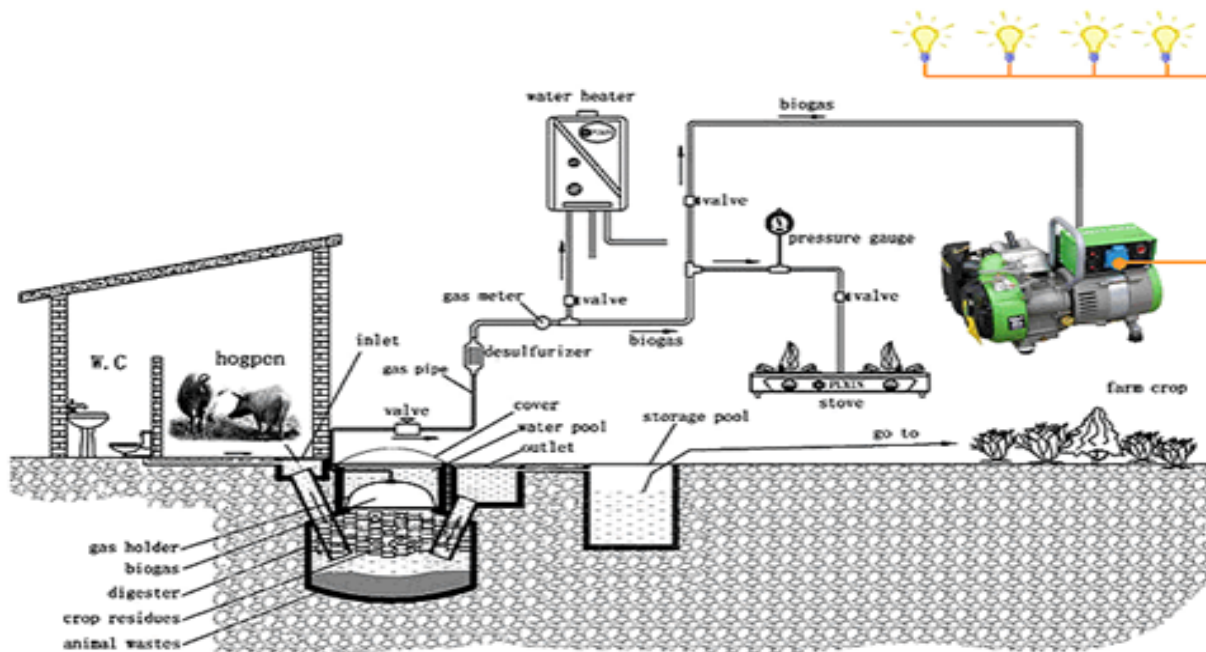


Figure 2.2-7 Biogas Power Plant

Source: https://energypedia.info/wiki/Electricity_Generation_from_Biogas

Table 2.2-8 Biogas Large Project in Bangladesh

Project Name	Capacity KW	Location	RE Technology
Phenix Agro Ltd. At Member bari, Gazipur	400	Gazipur	Off-grid
KKT Bio-Electricity Project	100	Panchagarh	Off-grid
ZPL Bio-Electricity Project	30	Chuadanga	Off-grid
UKAL Bio-Electricity Project	30	Tangail	Off-grid
Seed Bangla Foundation Bio-Electricity Project	20	Gazipur	Off-grid
RKKL Bio-Electricity Project	50	Mymensingh	Off-grid
UAL Bio-Electricity Project	60	Gazipur	Off-grid
1MW Grid Connected Power Plant Based on Municipal Solid Waste under Pilot Project at Keraniganj on Turnkey Basis	1000	Keraniganj , Dhaka	On-grid

The first biogas plant was installed in Bangladesh in 1972. Many organizations have worked on this biogas plant, but IDCOL is notable among them. Out of the eight works of power generation from biogas given in the table above, eight have been done by IDCOL, and BPDB has done the remaining one. The number of large biogas plants in Bangladesh is 8, and the capacity is 1.79 MW.

2.2.3 Nuclear Power Plant

Nuclear power plants do not burn any gas or coal to generate electricity. Here a lot of heat is generated through chemical reactions. This heat is used to convert water into steam. This

steam is used to rotate the turbine and convert the mechanical energy into electrical energy with a generator's help. In the nuclear reactor, heavy materials such as uranium (U^{235}) or thorium (Th^{232}) are used for nuclear fission processes. A huge amount of heat energy is produced due to fission. Which is transferred to the furnace coolant. The coolant can be water, gas, or liquid metal. The heated coolant flows through a heat exchanger where water is converted to high-temperature vapor. The steam generated is then allowed to run the steam turbine. The steam, after its work, is converted into the water again and recycled in the heat exchanger. The steam turbine is combined with a generator that produces electricity. The generated electrical Voltage is then measured using a transformer for long-distance transmission.

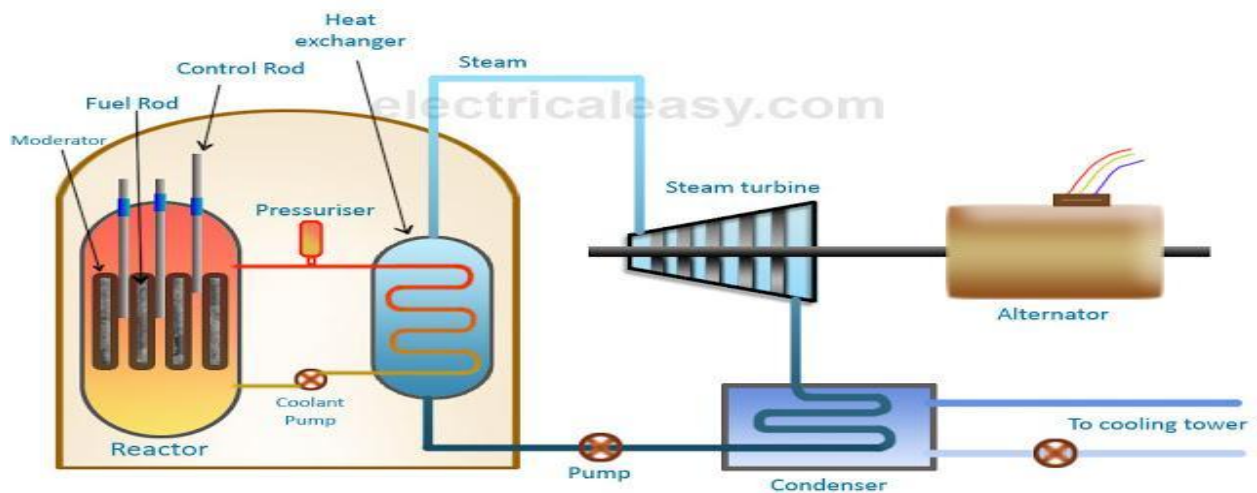


Figure 2.2-8 Nuclear Power Plant

Source: <https://www.electricalcaeasy.com/2015/09/nuclear-power-plant.html>

Power generation with nuclear technology started about 50 years ago. About 30 countries are using nuclear technology to generate electricity. In line with the developed world, work has been undertaken to set up a nuclear power plant in Bangladesh. Work is underway to set up Bangladesh's first nuclear power plant at Rooppur with a capacity of 2.4 GWh, which is expected to be completed by 2023.

2.3 Annual power generation

Electricity is the main driving force in achieving national growth, poverty alleviation, and socio-economic development. Electricity demand is continuously increasing in the country. The government is committed to ensuring electricity facilities for all. With the highest priority of the power sector, a periodical power generation plan has been adopted for the overall and balanced development of the sector, including an increased Power generation plan. In addition to setting up gas-fired power plants, steps have been taken to set up coal, liquid fuel, dual-fuel, renewable energy, and nuclear power plants. A favorable environment has been created to attract domestic and foreign entrepreneurs to invest in the power sector. Considering the immense importance of electricity in social and economic development, the plan has been implemented through intensive supervision of power generation. In the fiscal year 2019–20, the installed capacity for electricity has been increased to 23 thousand 546

MW. Of these, grid-based generation capacity is 20,373 MW, captive 2600 MW, and renewable energy (off-grid) 365 MW.[5]

Table 2.3-1 Grade based production capacity (2019-20)

SL	Sector	Installed production capacity MW	Percentage
1	Government	9,717	48%
2	Privet	8,884	43%
3	Joint venture	622	3%
4	Import of electricity	1,160	6%
	Total	20,383	100%

Source: Power Division

Grid-based generation capacity 20,363 MW; Of this, 9,616 MW was in the public sector, 8,64 MW in the private sector, 662 MW in joint ventures, and 1,160 MW in power imports.

At present, 43 more power plants with a capacity of 15,294 MW are under construction. Of these, 16 power plants with a capacity of 9065 MW are being constructed in the public sector, and 27 power plants with a capacity of 6229 MW are being built in the private sector. Besides, contracts are being signed for twelve power generation projects of 2785 MW, and tenders for six power generation projects of 650 MW are under process. Sixteen more power plants with a capacity of 19,100 MW have been planned. From January 2009 to June 2020, 128 new power plants with a total capacity of 15,901 MW have been commissioned.[5] The following is the capacity of the year based power plants :

Table 2.3-2 Ability to set up year based power plants

Year	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020 (Jun)	Total
Capacity MW	356	775	1763	951	663	635	1357	1132	1187	3763	2404	915	15901
Import of electricity	0	0	0	0	500	0	0	100	60	500	0	0	1160
Total	356	775	1763	951	1163	635	1357	1232	1247	4263	2404	915	17061

The comparative figure for power generation growth (Grid):

In the financial year 2018-19, 9560 MW in the public sector, 8284 MW in the private sector, and 1160 MW of electricity imports were 18 thousand 961 MW. In the fiscal year 2019-20, the increase in generation capacity stood at 973 MW in the public sector, 8884 MW in the private sector, 622 MW in joint ventures, and 20383 MW with 1160 MW of power imports. This means that the production capacity has increased by about 7.5 percent in the fiscal year 2019 to 2020 compared to the fiscal year 2018 to 2019.

The maximum power generation from 2009 to 2010 was 4606 MW, which stands at the highest amount of 12738 MW (5 August) 2019 for the fiscal year 2019 to 2020. Due to intense heat and irrigation in summer, power supply increases every year, and production plans are adopted in that light. Electricity demand was lower than projected due to the closure of schools, colleges, and factories in the wake of the Corona (COVID-19) epidemic in 2020. The highest annual power generation from 2009-10 to 2019-20 is given below:

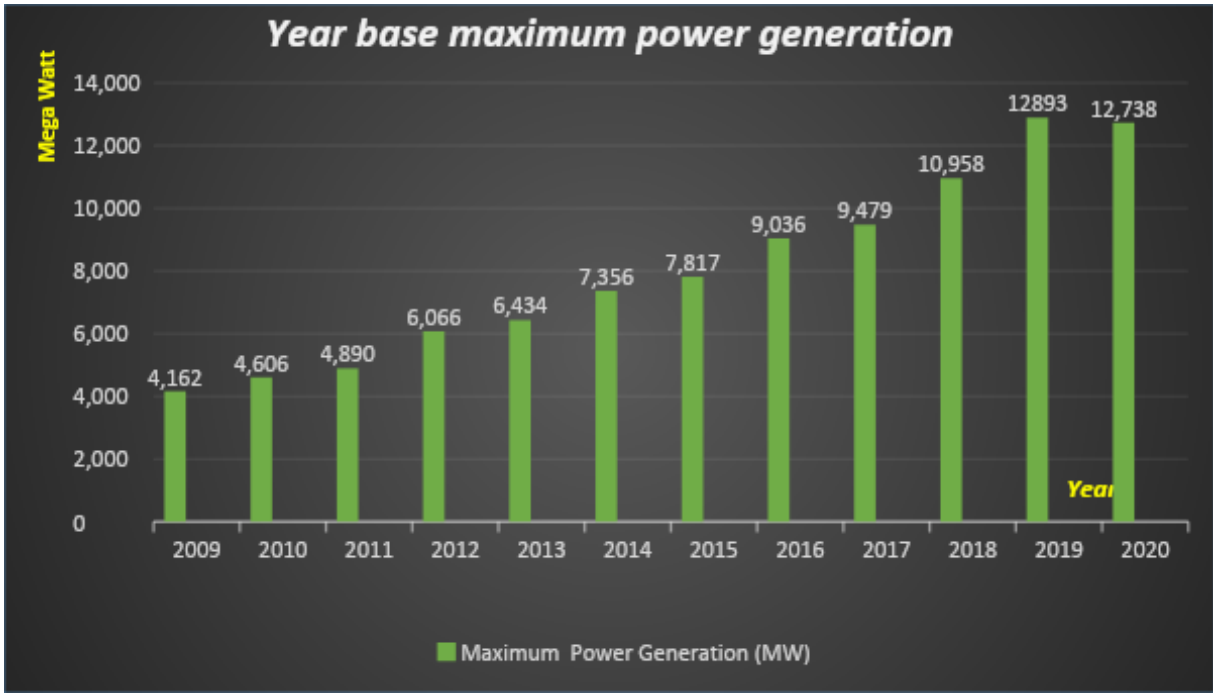


Figure 2.3-1 Year base maximum power generation

Source: Power Division

The figure above shows the maximum power generation of Bangladesh from 2009 to June 2020.

Table 2.3-3 Installed Capacity, Maximum Demand, Maximum Peak Generation

Year	Installed Capacity(MW)	Maximum Demand(MW)	Maximum Peak Generation (MW)
2009	5719	6,066	4,162
2010	5823	6,454	4,606
2011	7264	6765	4890
2012	8716	7518	6066
2013	9151	8349	6434
2014	10416	9268	7356
2015	11534	10283	7817
2016	12365	11405	9036
2017	13555	10500	9479
2018	15953	11500	10958
2019	18961	13044	12893

Source: Bangladesh Power Development Board.

The table above shows the list of maximum power generation, maximum demand, and installed capacity of Bangladesh from 2009 to 2019.

Below is a forecast for the relationship between these three variables, published by the Bangladesh Power Development Board.

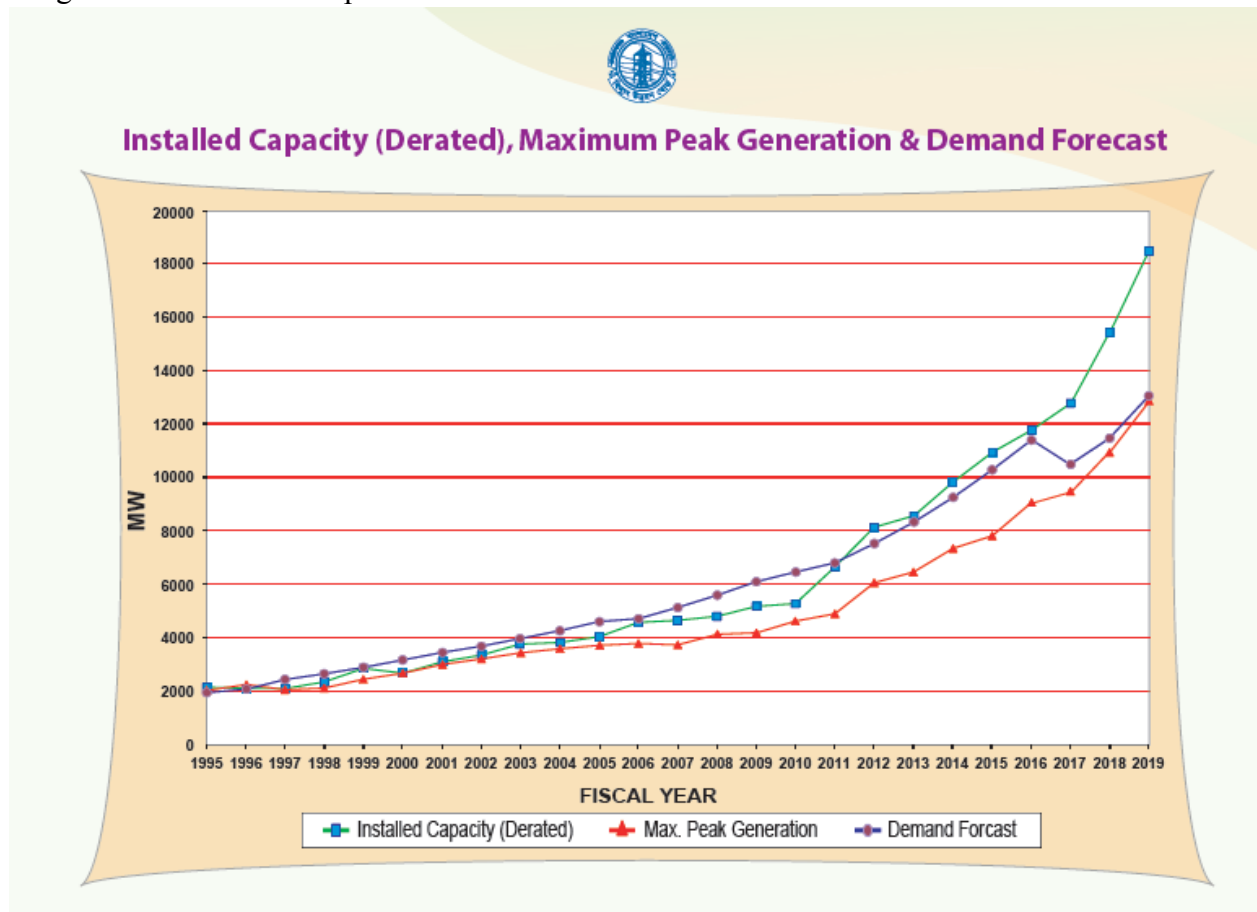


Figure 2.3-2: Installed Capacity (Derated), Maximum Peak Generation & Demand Forecast

Source: Bangladesh Power Development Board.

As we can see in the figure above, the green color line is the installed capacity, the red color line is the maximum generation, and the blue color line is the maximum demand. In the picture, we can see that the forecast chart started in 1995 and ended in 2019. The maximum generation line in the whole figure is always flowing below the demand line. In particular,

from 2010 to 2015-16, the maximum generation of Bangladesh was much less than the demand. But we also see that from 2016 to 2019, power generation has increased at a great rate. Not only that, by 2019, the generation and demand line is very close.

An analysis of the data in the table above (2-11) provides a forecasting figure from 2009 to 2030.

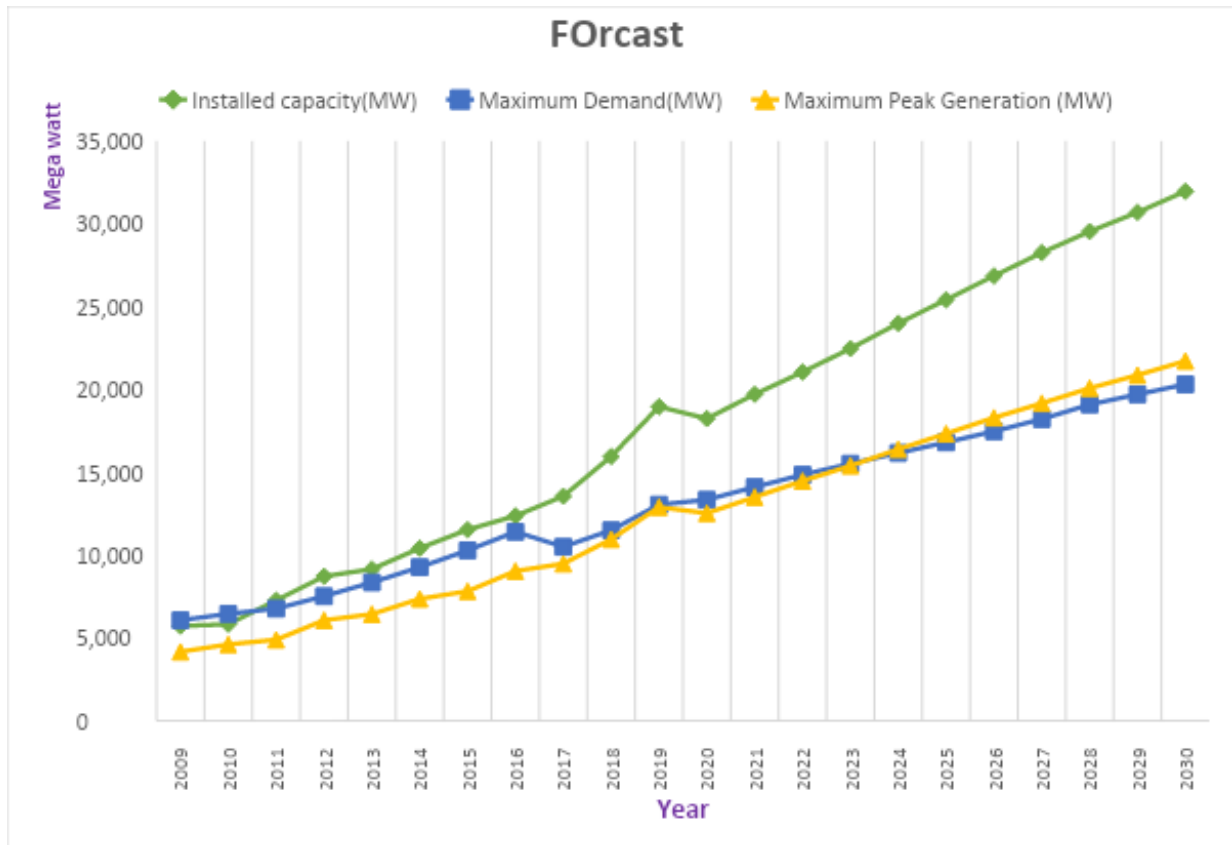


Figure 2.3-3 Forecast chart for Installed Capacity, Max Demand, Max Generation From 2009 to 2030

In this figure, the maximum peak generation line's color is yellow, and the maximum demand line's color is blue. We can see that in 2019 the generation line point and demand line point are meeting that we did see in figure 2.3-2. Looking at 2019, we see that the generation line and the demand line of the two images meet at the same time. This means that this plot is working in line with the previous figure 2.3-2. Based on this figure 2.3-3, we can say that if Bangladesh can maintain its current product as it is now, then the day is not far away when Bangladesh will be able to generate more electricity than it needs. In this picture, we can see that since 2025, the maximum generation line has been flowing over the maximum demand line, which means that Bangladesh's production capacity will exceed its demand.

Table 2.3-4 Present situation of the power sector of Bangladesh

Topic	2019	2020	Achievements of the last 12 years (2020-2009)
Number of power stations	27	141	(+)114
Number of retired power plants	-	05 (Fiscal Year 2019-2020)	-
Power generation capacity (MW)	4,942	24,421 (Including captive and renewable fuels)	(+)19,479
Maximum power generation (MW)	3,268 (6 th January 2009)	12,892 (5 th September 2020)	(+)9,624
Total transmission lines (km)	8,000	12,494	(+)4494
Grid substation capacity (MVA)	15,870	48,015	(+)32145
Import of electricity (MW)	--	1,160	(+)1,160
Electrified Distribution Line (km)	2 lakh 80 thousand	5 lakh 94 thousand	(+) 3 lakh 34 thousand
Power Beneficiary Population (%)	47	99	(+)52
Per capita power generation (KWh)	220	512 (Including captive and renewable fuels) (Fiscal Year 2019-2020)	(+)292
Number of electricity consumers	1 crore 8 lakhs	3 crore 91 lakhs	(+)2 crore 83 lakhs
Irrigation connection number	2 lakh 34 thousand	3 lakh 62 thousand	(+) 1 lakh 28 thousand
Annual Development Program Allocation (in crores)	2,677	26,546 (Fiscal Year 2020-2021)	(+) 23,869
Distribution system loss (%)	14.33 (Fiscal Year 2008-2009)	8.73 (Fiscal Year 2019-2020)	(-) 5.60

Chapter-3

Study of Net Metering

3.1 Introduction

Conventional mineral resources such as oil, coal, and natural gas have been used to generate electricity to increase greenhouse gas emissions. However, the Department of Energy Safety has recently shown interest in taking alternative measures to reduce fossil fuel dependence. We can produce sustainable and environmentally friendly alternative energy from renewable energy sources such as the sun, wind, and fuel cells. Along with the growing environmental problem, the problem of growing demand is also becoming a major concern.

Nowadays the electricity demand is increasing day by day, but power generation is not able to meet that demand. Renewable fuels such as solar PV and wind melt net metering systems it is possible to meet this demand. We get solar energy effortlessly and cleanly. Solar photovoltaic is a type of current source made up of semiconductor components. It behaves like a diode when exposed to sunlight and then produces DC at its output.

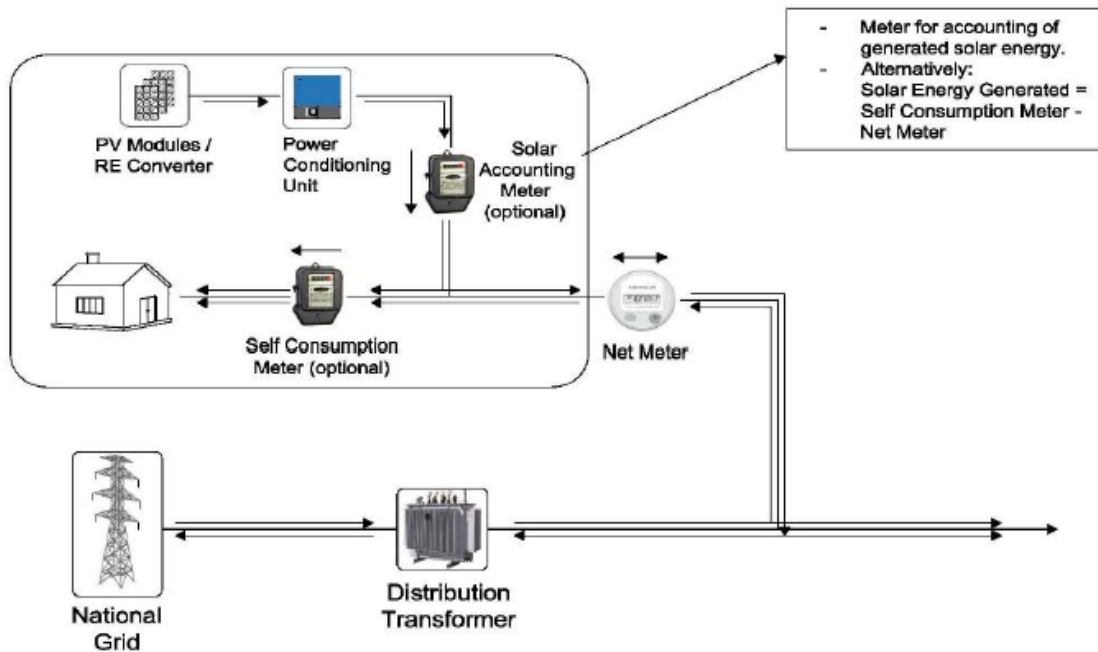
As a result of this method, residential customers will be able to generate electricity. Solar PV can be installed considering the customer's load demand and roof space. The big advantage of this is that if the solar PV system is connected to the Grid, then the customer will be able to meet the demand with his generated electricity and send additional electricity to the Grid, and this will reduce the electricity bill of the customer.

The calculation of how much electricity the customer generates and sends to the Grid and how much electricity he receives from the Grid is kept with the help of a bidirectional meter, and this meter is known as the net meter[6].

3.2 Basics of Net-Metering

Net metering is an electricity policy that allows utility customers to offset some or all of their electricity consumption with electricity self-generated from renewable energy systems.[7] Net metering facilitates the self-consumption of the electricity produced by the roofing project and allows excess energy to be channeled to the network or the distribution network. Depending on whether the customer consumed more electricity than what was produced or exported more to the Grid, if the net consumption is positive, the customer pays the electricity bill. If the net consumption is negative, the customer receives a credit on the electricity bill. Net metering policies can vary widely by country and state/province: whether net metering is available if you can keep your bank credits and for how long, and how much credit is worth (retail/wholesale). Most net metering laws involve a monthly renewal of kWh credits, a modest monthly connection fee, a monthly shortfall payment (i.e., a normal electricity bill), and an annual settlement of any credit. Residual. Unlike a feed rate (FIT), which requires two meters, net metering uses a single bidirectional meter and can measure the current flowing in two directions. Net measurement can only be implemented as an accounting procedure and does not require any special measurement or even prior approval or notification. Net metering is a policy designed to encourage private investment in renewable energies. Net metering works by using a meter that can spin and record the flow of energy in either direction. The meter spins forward when a customer draws electricity from the distribution grid (i.e., it uses more energy than it produces) and spins backward when the energy is returned to the service (that is, it uses less energy from the product). Net metering only works for grid-connected systems and what makes it so beneficial, besides offsetting a

home's energy consumption with a RES-E system, is that the excess energy sent to the utility company may resell at retail.[6]



3.2-1 Typical net metering architecture[3]

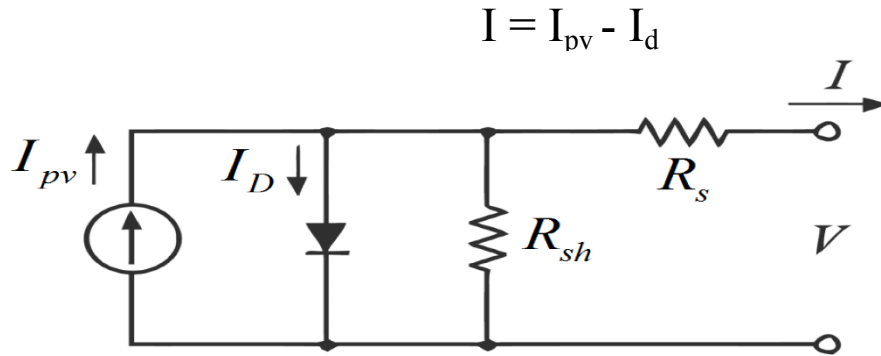
3.3 Variations And Misconceptions About Net Metering

Market net meter and time of use (TOU) meter are a few variations of net metering mechanisms. TOU uses a specialized reversible smart meter that determines electricity consumption at any time of the day. Utility rates are evaluated based on when the electricity is used, i.e., day or night or seasonal rates. In general, the cost of generating electricity is higher during the peak period of use during the day compared to the night, so that the rates for the electricity consumed are charged more during the day, while the rates they are comparatively low, but the TOU regime is a problem for renewable energy sources, for example. Solar systems produce energy only during the day and produce almost no energy at night when electricity rates are low [8]. Market-rate net metering systems are priced according to some of the wholesale electricity prices for the user's fuel consumption. The user's meters are programmed remotely to calculate the value and are read remotely. Net metering applies such variable values for the extra power produced by qualification systems. Misconceptions about net-metering schemes, such as utility, hit the bottom line by reducing net-metering earnings. This argument reduces utility income by reducing the purchase of electricity by consumers as requested as opposed to energy efficiency. This would be true if all families installed PV systems on their roofs. This is a fraction of the current market small and does not affect the other misconception that is the burden of net metering for the small users. The opposite is true because larger organizations are better equipped to handle more complex arrangements. Net metering is as simple as it is managed because it does not require any special equipment, no new rates for the installation, and no new method. All that is required is that the utility adds a line to the account to allow each net metering customer to

carry credit in advance by the end of the year. A study found that the cost of reading additional meters for a residential PV system alone exceeded the cost of net metering[6].

3.4 Modeling of PV solar cell.

The model does not take into account internal flow losses. A diode is connected in antiparallel with the light. That current source generated. The output current I is obtained by Kirchhoff's law of figure 3.4.1:



The photovoltaic Current is I_{pv} and I_d is the diode current, which is proportional to the saturation current. This is given by equation (1)

$$I_d = I_o \left[\exp \exp \left(\frac{V}{A.N_s.V_T} \right) - 1 \right] \dots \dots \dots (1)$$

Where,

$$V_T = k \times T_c / q$$

- V = voltage imposed on the diode
- I_o = reverse saturation or leakage current of the diode,
- $V_{Tc} = 26 \text{ mV}$ at 300 k for silisium cell,
- T_c = actual cell temperature (K)
- $K = 1.381 \times 10^{23} \text{ J/K}$ (Boltzman Constant)
- $q = 1.602 \times 10^{19} \text{ C}$ electron charge.

The determination of I_{pv} is done using equation (2), which shows that the photocurrent I_{pv} is directly proportional to the ratio of the Irradiance G and the reference irradiance G_{ref} at standard test condition i.e, the ideal value of irradiance.

$$I_{pv} = \frac{G}{G_{ref}} (I_{pv,ref} + \mu_{sc} \Delta T) \dots \dots \dots (2)$$

Where,

- G = Irradiance (W/m^2)
- G_{ref} = Irradiance at STC ($\text{STC} = 1000 \text{ W/m}^2$)
- $\Delta T = T_c - T_{c,ref}$ (Kelven)
- $T_{c,ref}$ = temperature at STC = $25 + 273 = 298\text{k}$,
- ISC = Coefficient temperature of short circuit current (A/K) ,provided by the manufacturer,
- $I_{pv,ref}$ = Photo current (A) at STC.

I_0 is a reverse saturation current that is identified by equation (3). Here, the actual reverse saturation current is the reverse saturation ratio at T_c = actual cell temperature K and $T_{c,ref}$ = standard cell temperature (25 + 273) K.

$$I_0 = I_{0,ref} \left(\frac{T_c}{T_{c,ref}}\right)^3 \exp \exp \left[\left(\frac{q \epsilon_G}{A K}\right) \left(\frac{1}{T_{c,ref}} - \frac{1}{T_c}\right) \right] \dots\dots\dots (3)$$

ϵ_G = Material band gap energy (eV) (1.12eV for Si) ,

A = The ideality factor related to the technology of the PV cell used.

In the present case, the material of PV is Si-poly; thus, it has an ideality factor of 1.3, and K is the Boltzmann constant.

The total Current I_{total} can be determined by subtracting the diode current I_d from the photocurrent I_{pv} as given in the equation (4).

$$I_{total} = I_{pv} - I_0 \left[\exp \exp \left(\frac{V_d q}{N_s K T_c} \right) - 1 \right] \dots\dots\dots (4)$$

3.5 Modeling of Inverter and MPPT controller

The inverter's modeling is done based on the basic circuit of a three-phase inverter with six IGBT.

Insulate Gate Bipolar Transistor (IGBT) is a switching element that is given gate signal by using Sinusoidal Pulse Width Modulation technique which compares the AC sin wave from the Grid to the reference signal and triggers the IGBT in synchronization with the AC signal from Grid. In detailed MATLAB/SIMULINK model of the three-phase inverter is shown in figure 3.5-1.

The output voltage from the solar panel is supplied to the three-phase inverter, where the DC voltage is converted to AC. Here the MPPT driver is used to keep up with PowerPoint as much as possible. For this simple and effective disturbance and observation, the algorithm is used. Figure 3.5-2 shows the flowchart of the MPPT controller using the P&O algorithm. Here voltage V (k) and Current I (K) are read from the solar panel, then power P (k) is calculated. These V (k), I (k), and P (k) are delayed by (k-1), and the change in power P is calculated and checked whether it is greater than zero or not. If ΔP is greater than zero, then a change in Voltage ΔV is calculated, and if it is less than zero, the duty cycle D is reduced by ΔD . If it is greater than zero, D is increased by ΔD . If ΔP is less than zero, then ΔV is calculated, and the reverse operation to the previous one is performed. Here, to operate the solar panel on a particular voltage, the duty cycle is varied depending on the changes that occur in the Irradiation.

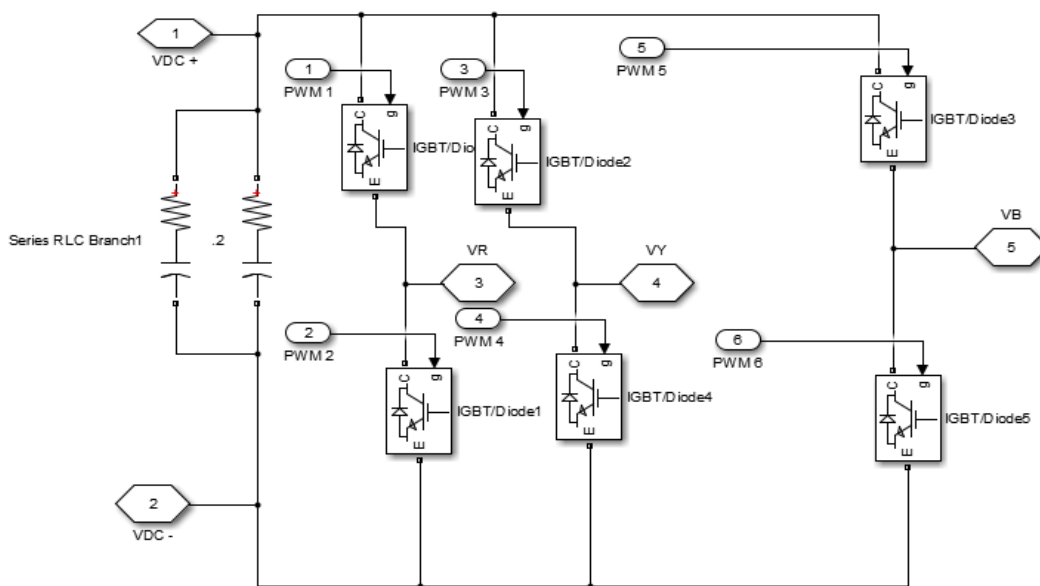


Figure 3.5-1 Three-phase inverter

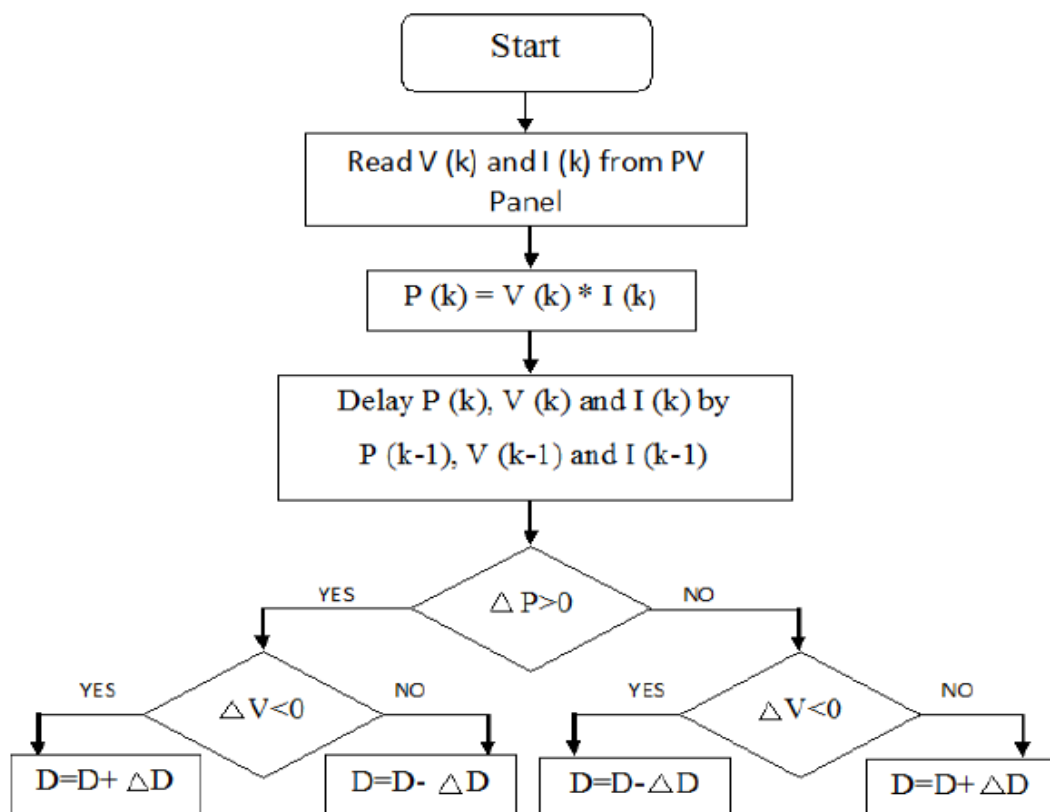
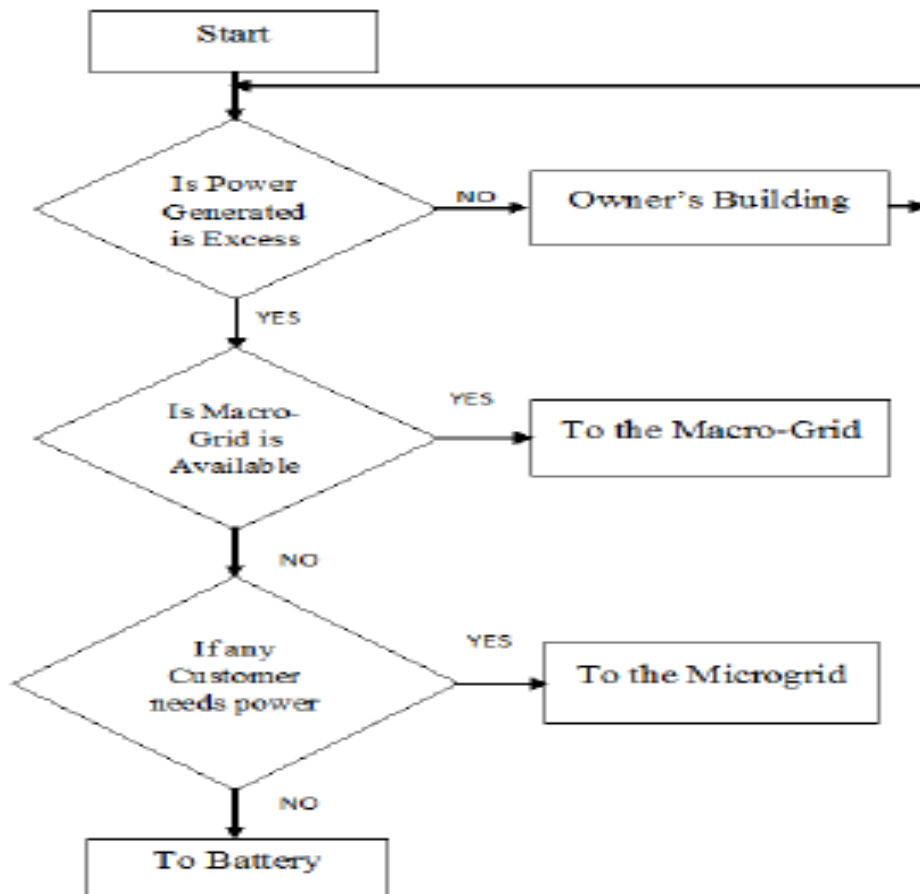


Figure 3.5-2 Flowchart for MPPT Controller [9]

3.6 Flow chart of net metering

The principle of operation is explained using the flowchart shown in figure 3.6-1. When the system starts up, it checks if the solar panel's energy is in excess; if it is in excess, it proceeds to supply this energy to the Macro Grid. If it is not an excess, it means that the owner has used all the solar panel energy. Then it checks if the Macro Grid is available to supply power; if so, power will be supplied to the Macro Grid by matching many parameters such as frequency, phase grid, and several. If the Macro Grid is not available, check if the Microgrid clients need power. If they need Current, power is sent through the micro-grid, and its usage is monitored by the grid meter. Finally, if neither the Micro Grid nor the Macro Grid is available at that time, the extra energy that is generated is stored in an efficient type of battery like the flux battery and many others [9].



In Net Meter, the following calculation will be carried out.

t = Simulation Time.

time = Simulation Time In an hour.

C1 = Control Signal 1. When C1 = 1, the Net meter will calculate the power from the Grid to the owner. Then, $Power = V1 * I1$.

Total Power = $Power * (1000 / Power) * time$.

Power in Units = $Total Power / 1000$.

Amount1 = $Power in Units * 2.5$.

Amount = $Amount1 - Amount2$.

The MATLAB Simulink function is shown in figure 3.6-2.

Where $V1$ = Voltage in the Grid when the owner is using the power from the Macro Grid.

$I1$ = Current in the Grid when the owner is using the power from the Macro Grid.

$V2$ = Voltage in the Grid when extra energy is fed to the Macro Grid.

$I2$ = Current in the Grid when the extra energy is fed to the Macro Grid.

$V3$ = Voltage in the Microgrid.

$I3$ = Current in the Microgrid.

Amount1= The amount that is to be paid by the owner to the electricity board.

Amount 2 = The incentives that are to be paid by the electricity board to the owner.

Amount 3 = The incentive that is to be paid by the customer connected to the Microgrid.

Amount = Total amount.

If it is negative, then the electricity board has to pay the owner or else vice versa. $C1$, $C2$, $C3$ are the control signals used to control the energy flow from and to the Grid. To measure the simulation time, a digital clock is used that takes the value of the total simulation time[9].

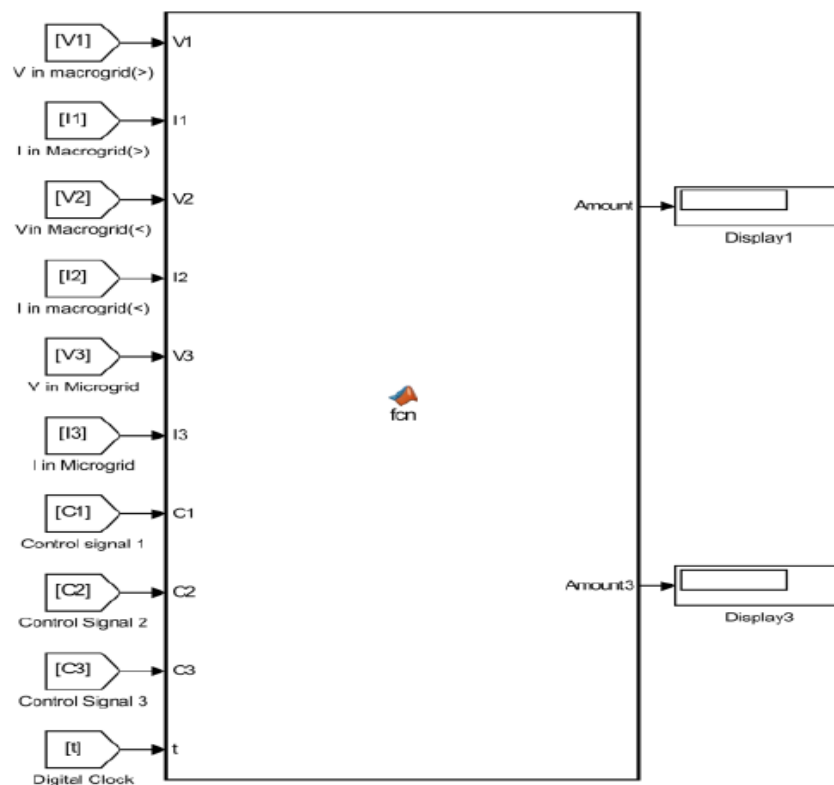


Figure 3.6-2: Net Meter Function in MATLAB Simulink.

3.7 Grid-connected three phases of the solar PV system

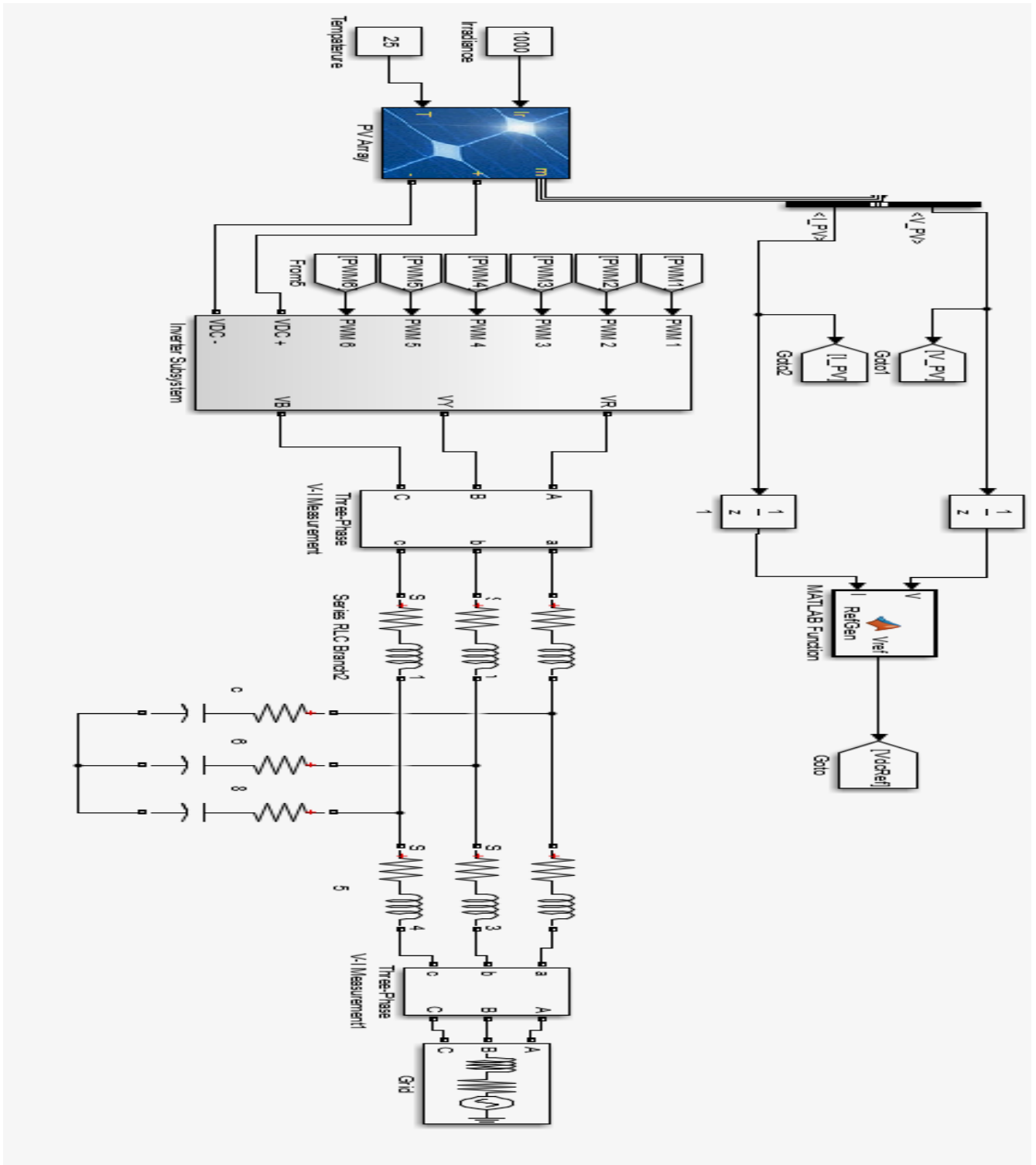


Figure 3.7-1Net Meter Function in MATLAB Simulink.

The figure above shows a single state three-phase grid connect solar PV system. MATLAB has been used to design the system. Solar arrays are used to generate solar Current here. IGBT has been used to design Invert. We get DC from Solar Array. This DC is converted to AC with the help of an inverter. We do not get pure AC from this inverter, so RLC filters have been used to reduce harmonics.

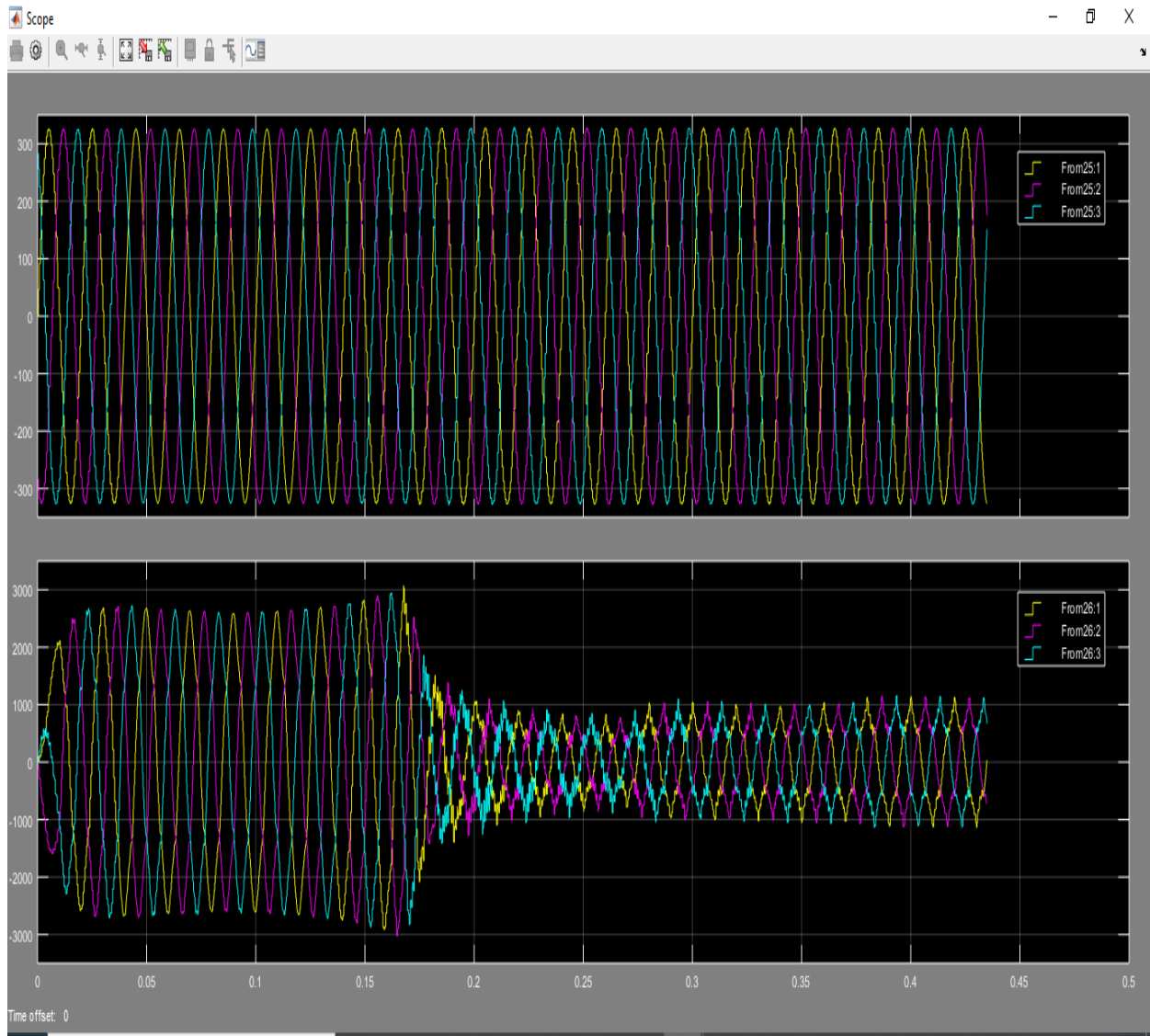


Figure 3.7-2 simulation output

In figure 3.7-2, we can see two plots first plot for output Voltage and the second plot for Current. In the second plot, see that the first-time signal amplitude is big. Because at this time, the solar irradiance is 1000. After a few times, when we decrease the value of irradiance at a time, the current amplitude also decreases. Again we increase irradiance, and then we can see that the current amplitude also increases. But all the time, Voltage is not changing because when we connected solar PV with Grid, then the Grid voltage and PV voltage must be equal; otherwise, we can't join with others.

Chapter-4

Net metering guideline for Bangladesh

4.1 Eligibility Law

- **Current utility customer:** current utility customer who is responsible for supplying electricity in the region;
- **No overdue arrears:** Applicant must not have overdue arrears before applying;
- **Type of renewable energy source:** electricity produced ONLY from renewable energy sources is eligible;
- **Legal Rights for Installation:** Applicant must be the legal owner or have legal permission from the owner or their legal representative to install the proposed renewable energy system on the premises.
- **Type of premises:** roofs of buildings, parking lots, garages or similar buildings or on land located in the premises of the consumer where there are utility meters or any other suitable area accepted by public services;
- **Self-consumption:** it will consume electricity at the point of renewable energy production and will only export the surplus to the Grid;
- **Interconnection standards:** they must comply with the interconnection rules and standards established by the utility company or any other competent authority[3];

4.2 Consumer classification

Eligible consumers (as described in section 4.1) under this net metering rule can be classified into three broad categories.

4.2-1: Consumer classification

Consumer category	Capacity limited
Residential / domestic	5KW to 100 KW
Commercial	10KW to 500KW
Industrial	100KW to 3MW

Capacity and energy export limit

- ❖ Any three-phase customer will be considered eligible for net metering.
- ❖ The output (AC) of the renewable energy converter shall not exceed 70% of the customer's allowable load.
- ❖ The highest output (AC) of the renewable energy system installed in the case of net metering cannot exceed 10 MW.
- ❖ In the case of medium Voltage, the capacity of the renewable power generation system installed under metering cannot exceed 70% of the capacity of the transformers or the cumulative total of the transformers [10].

4.3 Appliance Standard and Anti Islanding

- ❖ The key components of other renewable energy systems, including rooftop solar PV systems, must comply with national standards in terms of design, operation, maintenance, and environmental standards.
- ❖ The grid-tie inverter or renewable energy converter will have the latest version of IEC 71827 (now IEC 61727:2004) or the latest version of IEEE 1547 (now IEEE 1547:2018) or equivalent standard SREDA recognized utility interface standard.
- ❖ Within 2 seconds of the grid current going out, the power system generated from the projector's PV system should be automatically disconnected, which is possible with an anti-islanding inverter. The grid-tied inverter used in the net metering system must be a scaffold in anti-islanding, according to IEC 62116 (Utility-interconnected photovoltaic inverters – Test procedure of islanding prevention) [10].

4.4 Net metering Statistics report

Utility Name	Installed Capacity	Quantity
BPDB	1.399 MW	265
BREB	10.094 MW	204
DPDC	2.158 MW	235
DESCO	1.991 MW	282
WZPDCL	0.886 MW	174
NESCO	0.808 MW	39
TOTAL	17.336 MW	1199

Figure 4.4-1 Net meter install capacity

At present Bangladesh's statistics of installed net metering system quantity is 1199 and capacity is 17.336 MW. In this figure is the list of progress of net metering system. The BREB is leading position according to capacity. BREB installed 204 system and there installed capacity is 10.094 MW. On the other hand DESCO installed maximum quantity of system but their capacity is only 1.991MW.

Chapter-5

On-Grid Solar PV System for Industry

5.1 Introduction

Bangladesh is a developing agricultural country. The development of a country depends on the industrialization of that country. The lion's share of Bangladesh's foreign income comes from the ready-made garment sector. 35.14% of the national income comes from the industrial sector. There are more than 35,000 ready-made garment factories in Bangladesh. About 29.55% of the electricity generated in Bangladesh is used in small and large scale industries. The roofs of all these industries are mostly unused. The big industries supply most of their electricity themselves. They use diesel or gas-powered generators to generate electricity. Because by doing so, they get an uninterrupted power supply and get electricity at a low cost. Industries also depend on fossil fuels for power generation. The Government of Bangladesh is working to ensure the use of renewable energy. If a solar PV grid is officially installed, then it is seen that a lot of huge land is required. It will waste a lot of cultivable lands. And the most beautiful solution to this problem may be the huge roof of the industry. Since industries have an uninterrupted power supply, it is most advisable to install an on-grid solar PV system on the roofs of these industries[5].

5.2 Design and simulation report

The project name is Noman Terry Towel Mills Limited. That project simulates by PVsyst simulation software. In the bellow, we represent the full design step by step.

Project: Noman Terry Towel Mills limited

Variant: New simulation variant

System power: 200 KWp

Mirzapur-Bangladesh

5.2.1 The summary of the project

Table 5.2-1 Project summary

Geographical site	Mirzapur Bangladesh
Situation	
Latitude	24.08°N
Longitude	90.36°E
Altitude	11 m
Time zone	UTC+6
Project Settings	
Albedo	0.20
PV Field Orientation	
Fixed Plane	
Tilt/Azimuth	30/0°
System Information	
PV Array	260 W
Nb. Of modules	770 units
Modules	35 Strings ×22 in series
Pnom Total	200 KWp
Inverters	25.00 kWh
Nb. Of units	8 units
Pnom Total	200 KWac
Project lifetime	20 years
Cost of the system	
Installation cost	1,94,459 USD or 1,64,31,785 TK
Operating cost	1183.47 USD or 1,00,000 TK / year
Income Tax rate	5.00% / year
Energy sold to the Grid	319900 kWh/year
Cost of produced energy	0.034 USD/kWh or 2.87 TK/kWh
Feed-in tariff	0.09 USD/kWh or 7.7 TK/kWh
Return on investment	
Payback period	7.2 years
Net present value	3,45,956.63 USD or 2,92,33,335 TK
Return on investment	177.9%

In this section, we present our simulation summary. The simulated project capacity is 200kWh. We design this project with PVsyst software. The solar panel's power is 260w, and the inverter rating is 25.00 kWh. Totally 770 solar panel modules use for eight inverters. The investment cost is 1,64,31,785 Tk and operation cost is 1,00,000 Tk per year. Energy sold per year 319941 kWh, and the per-unit rate is 7.7 TK. On the other hand, the cost of producing energy is 2.87 T per kWh—the investment payback within 7.2 years.

5.2.2 The Parameters characteristic of the project

Characteristic of Inverter		
Model	25000LT-30	
Serial	1901305809	
DC	V _{DC} max	1000V
	V _{DC} MPP	390-800 V
	I _{DC} max	33A/33A
	I _{SC} PV	43A/43A
AC	V _{AC,r}	380/400/415V
	P _{AC,r}	25000W
	S max	25000VA
	f _{AC,r}	50/60Hz
	I _{AC} max	36.2 A
	Cos(φ)	0....1....0



Characteristic of Solar Panel	
Model Number	SLP260-20
Max Power (Pmax)	260W
Operating Voltage(Vmp)	32.04V
Operating Current(Imp)	8.11A
Open-circuit Volt (Voc)	37.92V
Short-circuit current(Isc)	8.64A
Output Tolerance	23%
Max series Fuse Rating	15A
Weight	18.20kg
Size	1640×992×40mm
Cell	Poly-crystalline silicon
Cell Temp	45°C±2°C
Operating Temperature	-40°C-80°C



Characteristic of Cable	
Brand	Finolex
Size	4 sq mm
Core	2 core
Length	100 mtr
Conductor Material	Copper
Material	PVC Insulated
Current Rating AC	27 Amp
Nom. Dia of Wires	65/0.30 mm
Thickness of Insulation	0.8mm
Nominal Thickness of Sheath	1.0 mm
Certification	IS 694



5.2.3 Cost of the system

Table 5.2-2 Installation Cost of the system

Item	Quantity Units	Cost BDT	Total BDT
PV modules SLP260-20	770	18,200	1,40,14,000
Inverter Sunny Tripower 25000TL-30	8	2,20,000	17,60,000
Studies and analysis Engineering	1	84500	84500
Installation			
Transport	1	120000	120000
Accessories, fasteners	1	120000	120000
Wiring	1	200000	200000
Settings	1	50000	50000
Grid Connection	1	10000	10000
Total			1,64,31,785 TK

Table 5.2-3 Operating costs of the system

Items	Total TK/Year
Maintenance Cleaning	1,00,000Tk
Total (OPEX)	1,00,000TK

The costs of the system deviate into two-part. The first part is the installment costs second part is operating costs. We use 770 pieces of solar panel, and every panel's power is 260 W. A good grad solar panel price is 70 TK per watt in the Bangladesh market. Total solar panel price is 1,40,14,000 TK. We use eight-piece inverter, and every inverter price is 2,20,000TK. The total inverter price is 17,6,0000 TK. Other installation costs like as (Engineering, transport, accessories, wiring, setting, grid connection) is 5,84,500TK. The installation costs are fixed, but there has another cost is operation costs is 1,00,000 per year.

5.2.4 Simulation output report

System Production

Produce Energy	319.9 MWh/year
Specific production	1598 KWh/KWp/year
Performance Ratio PR	82.44%
Solar Fraction SF	100%

Economic Summary

Total Installation cost	1,64,31,785 TK
Operating Cost	1,00,000 TK/year

Cost of production energy 2.873 TK / KWh
Return on investment
 Payback period 7.2 year
 Net present value 2,92,33,335 TK
 Return on investment 177.9%

	GlobHor kWh/m ²	DiffHor kWh/m ²	T_Amb °C	GlobInc kWh/m ²	GlobEff kWh/m ²	EArray MWh	E_User MWh	E_Solar MWh	E_Grid MWh	EFrGrid MWh
January	125.5	52.7	17.09	170.2	166.9	29.71	0.000	0.000	29.13	0.000
February	137.2	56.1	20.66	169.3	166.3	28.75	0.000	0.000	28.16	0.000
March	172.7	79.0	25.25	189.7	185.5	31.56	0.000	0.000	30.90	0.000
April	177.6	90.2	27.36	175.0	170.4	29.00	0.000	0.000	28.40	0.000
May	179.8	102.4	28.05	162.9	157.8	27.17	0.000	0.000	26.61	0.000
June	144.5	90.9	27.71	127.0	122.6	21.39	0.000	0.000	20.94	0.000
July	147.0	88.7	28.18	130.1	125.6	21.86	0.000	0.000	21.39	0.000
August	144.3	89.9	28.42	134.5	130.2	22.62	0.000	0.000	22.15	0.000
September	143.2	75.3	27.63	148.0	144.0	24.68	0.000	0.000	24.16	0.000
October	142.4	72.4	26.76	165.0	161.4	27.63	0.000	0.000	27.06	0.000
November	139.2	42.1	22.82	189.0	185.6	31.67	0.000	0.000	31.01	0.000
December	126.2	47.0	18.92	177.9	174.7	30.65	0.000	0.000	30.04	0.000
Year	1779.7	886.7	24.92	1938.6	1891.1	326.67	0.000	0.000	319.94	0.000

Legends

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

Figure 5.2-4 Balance and main result

This figure shows that monthly irradiation and total irradiation annually 886.7 KWh/m², annual ambient temperature is 24.94°C, and annually effective energy at the output of the array is 326.67 MWh. Irradiation is very impotent to produce electricity from the solar PV system, as more Irradiation as more electricity. If any day is cloudy, that day's Irradiation is low. Therefore that day's electricity production will also be pure. The Effect of Irradiation on solar energy's production we see in practical data from the Monthly stitching section solar power consumption log sheet.

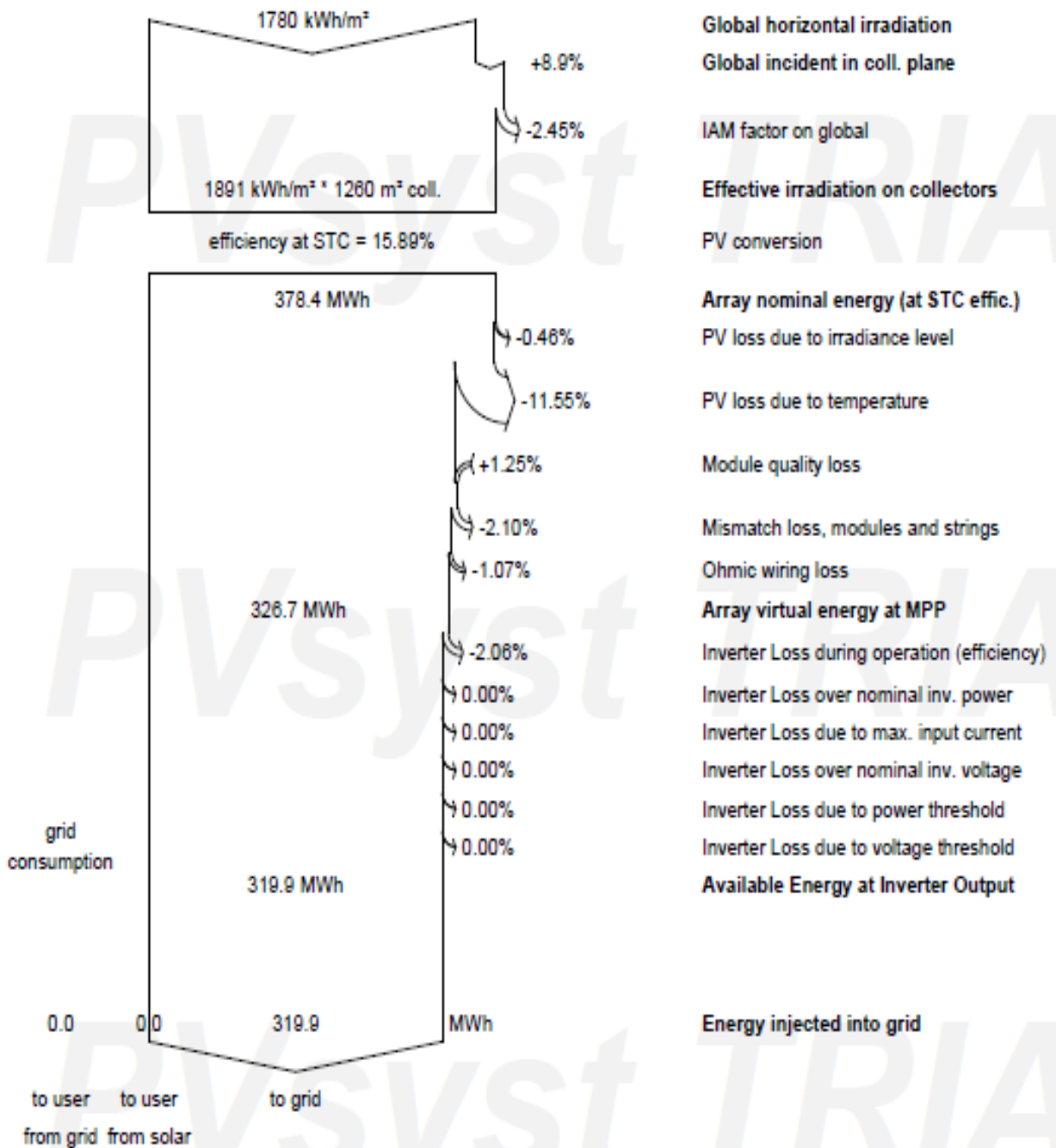


Figure 5.2-5 Loss diagram (source from the author)

In this figure 5.4-3, we see different types of loss in the system. In this project, firstly, we get array nominal energy 378.4 MWh. But we see that different type of loss effect occurs in the project like PV loss -0.46% due to irradiance level and -11.55% due to temperature. Inverter loss during operation is -2.06%; finally, available energy at Inverter output is 319.9 MWh.

Detailed economic results (USD)

	Gross income	Run. costs	Deprec. allow.	Taxable income	Taxes	After-tax profit	Self-cons. saving	Cumul. profit	% amorti.
2021	29'115	1'183	9'723	18'208	910	27'021	0	-167'438	13.9%
2022	29'115	1'183	9'723	18'208	910	27'021	0	-140'417	27.8%
2023	29'115	1'183	9'723	18'208	910	27'021	0	-113'397	41.7%
2024	29'115	1'183	9'723	18'208	910	27'021	0	-86'376	55.6%
2025	29'115	1'183	9'723	18'208	910	27'021	0	-59'355	69.5%
2026	29'115	1'183	9'723	18'208	910	27'021	0	-32'334	83.4%
2027	29'115	1'183	9'723	18'208	910	27'021	0	-5'314	97.3%
2028	29'115	1'183	9'723	18'208	910	27'021	0	21'707	111.2%
2029	29'115	1'183	9'723	18'208	910	27'021	0	48'728	125.1%
2030	29'115	1'183	9'723	18'208	910	27'021	0	75'749	139.0%
2031	29'115	1'183	9'723	18'208	910	27'021	0	102'770	152.8%
2032	29'115	1'183	9'723	18'208	910	27'021	0	129'790	166.7%
2033	29'115	1'183	9'723	18'208	910	27'021	0	156'811	180.6%
2034	29'115	1'183	9'723	18'208	910	27'021	0	183'832	194.5%
2035	29'115	1'183	9'723	18'208	910	27'021	0	210'853	208.4%
2036	29'115	1'183	9'723	18'208	910	27'021	0	237'874	222.3%
2037	29'115	1'183	9'723	18'208	910	27'021	0	264'894	236.2%
2038	29'115	1'183	9'723	18'208	910	27'021	0	291'915	250.1%
2039	29'115	1'183	9'723	18'208	910	27'021	0	318'936	264.0%
2040	29'115	1'183	9'723	18'208	910	27'021	0	345'957	277.9%
Total	582'292	23'669	194'459	364'165	18'208	540'416	0	345'957	277.9%

Figure 5.2-6: Financial analysis of the project

In this figure, the profit of the project is shown. Project lifetime is 20 years. The start time is 2021, and the end time is 2040. For this calculation, every value is fixed for every year. The annual gross income of 29,115 USD is fixed for every year. As with gross income, the run costs, depreciation value, and taxes are fixed for every. It has been done for easy calculation. The annual running costs are 1183 USD, and the depreciation value of the asset is 9723 USD. The income tax is 5%. The income taxes allow in gross income without depreciation value. Therefore the taxes are considered in taxable income $(29115-9723)= 18208$ USD. The annual taxes will be 5% of 18208, equal to 910 USD. The annual profit is annual income with running cost and taxes. The profit is $(29115-1183-910)=27021$ USD. First-time investment costs were 1,94,459 USD . after one year, the investment cost will be decreased by profit. 1st year the annual profit will be -167438 USD. 2nd year's profit will be -140417 USD, and after 20 years, they will be 3456957 USD. In this section, we present all cost in USD for easy because the simulation softer has not any option to calculate in TK.

In this figure, we also see that from 2021 to 2028, the profit Cullum color is brown, which means in this time, the project could not get investment cost. After 7.2 years, the project gets full investment cost, and from 2029 to 2040, they earn 345957 USD.

5.2.5 CO₂ Emission Balance

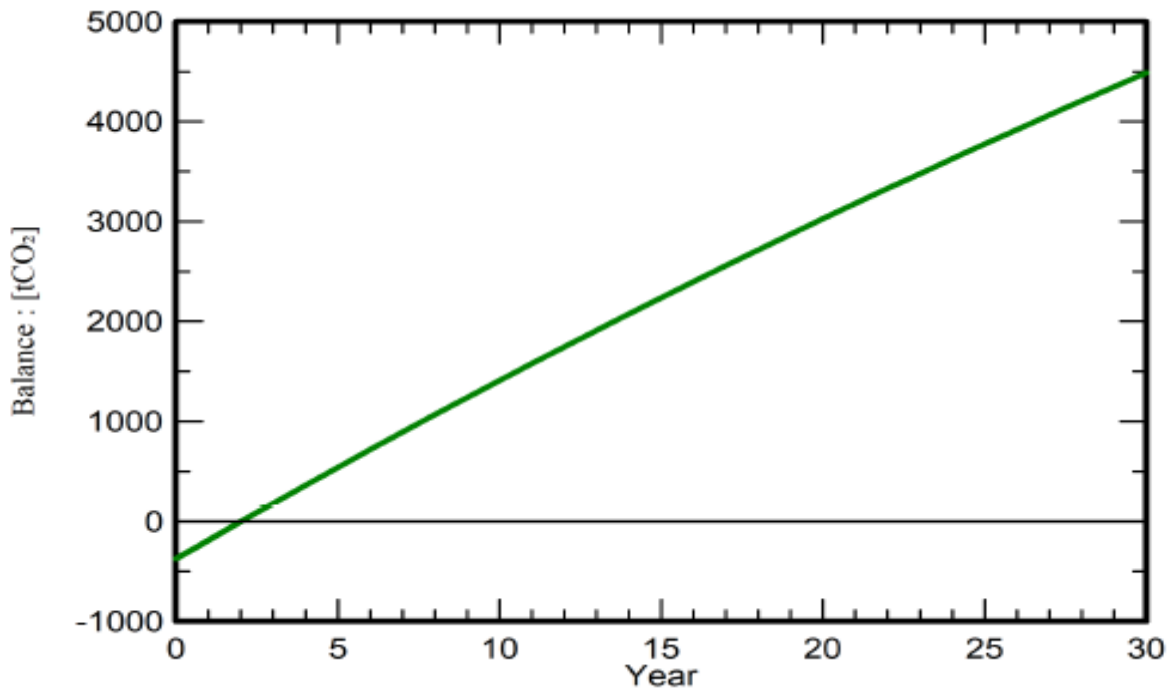


Figure 5.2-7 Save CO₂ Emission vs Time

Total: 4487.6 tCO₂

Generated emission

Total: 375.97 tCO₂

Replaced Emissions

Total: 5605.4 tCO₂
 System production 319.94MWh/year
 Grid Lifecycle Emissions 584 gCO₂/KWh
 Source: IEA list
 Country: Bangladesh
 Lifetime: 20 years
 Annual degradation 1.0%

Table 5.2-5 System Lifecycle Emission Details

Item	LCE	Quantity	Subtotal
			[kgCO ₂]
Modules	1713 kgCO ₂ /KWp	200KWp	342887
Supports	3.90 kgCO ₂ /KWp	7700Kg	29994
Inverter	386 kgCO ₂ /	8.00	3087

5.3 Practical report

The amount of this industrial land is 102 acres. A total of 7,000 workers work in this industry. We went to Noman Terry Towel ltd to visit On-Grid rooftop solar system. The area of the roof 56,000 square feet. March 2017 solar panel on-grid system has been installed by solar land. Solar panel installation cost is around BDT 1.8 core. Which capacity is 200 KWh, and 770 solar panels have been used in this project. Each solar panel maximum power of 260 watts. Totally eight inverters used & Each inverter is 25 kW. Each inverter is connected to 96 solar panels, but one inverter is connected to 98 solar panels. Total= (7*96) = 672 + 98 = 770 solar panel Each solar panel maximum power 260 watts Total capacity (770*260) = 2,00200 watts = 200.2 KW



5.3.1 Solar power consumption

Table 5.3-1 Daily stitching section solar power consumption log sheet

Time Date;06-12-20	Solar reading (KWh)	Solar Reading Percentage	REB/Generator Reading (KWH)
6 AM TO 7 AM	1	0.50	621
7 AM TO 8 AM	15	7.50	139.5
8 AM TO 9 AM	43	21.50	295.5
9 AM TO 10 AM	53	26.50	279.5
10 AM TO 11 AM	64	32.00	260
11 AM TO 12 AM	61	30.50	236
12 PM TO 1 PM	78	39.00	236
1 PM TO 2 PM	52	26.50	80.5
2 PM TO 3 PM	53	26.00	194.5
3 PM TO 4 PM	12	6.00	353
4 PM TO 5 PM	4	2.00	375
5 PM TO 6 PM	1	0.5	412
Total	437	18.21%	3482.5

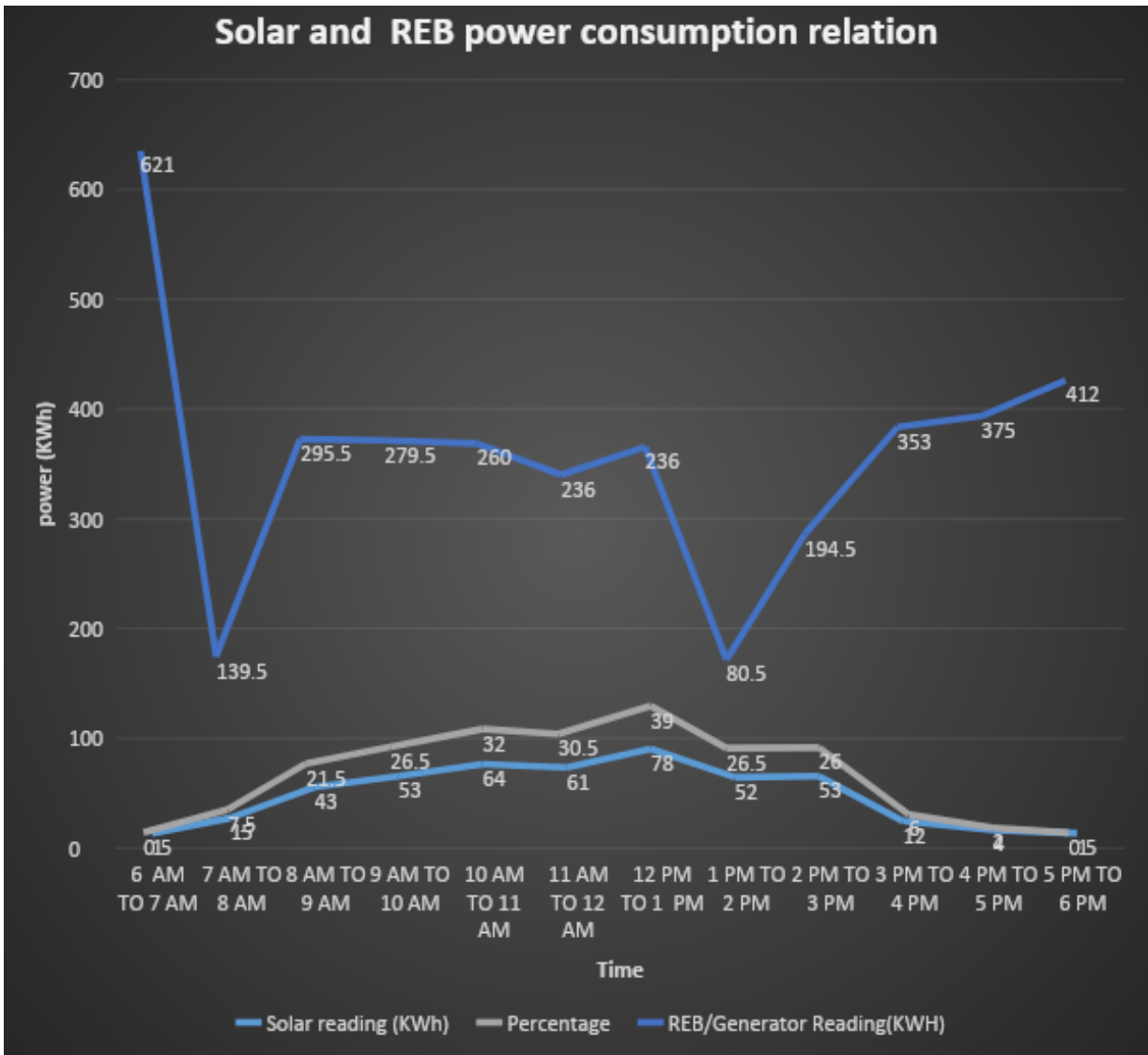


Figure 5.3-1 Daily stitching section solar and REB/Generator power consumption chart

The figure above shows the schedule of electricity generated from the solar PV system on 6 December 2020. In the day, total solar power 437 KWh, that day temperature was 24°C, and Irradiation was 281(W/m²).

In this figure, we can easily understand the amount of electricity being generated from 6 AM to 6 PM. We can see that the chart is getting closer to the ground in the morning and the afternoon, and gradually, this line is getting higher. Here in the morning and the afternoon, we get less radiation from the sun. Due to which the rate of power generation is also low. In the picture, we can see that the maximum amount of 78 KW of electricity is being generated from 12 noon to 1 PM, which is 39% of the original capacity.

Table 5.3-2 Monthly stitching section solar power consumption log sheet

March 2020 Date	Solar Reading	Solar power Efficiency Percentage(%)	Irradiation (W/m²)
1	857	35.71	671
2	701	29.21	522
3	812	33.83	547
4	804	33.50	525
5	817	34.04	654
6	630	26.25	441
7	372	15.50	177
8	692	28.50	394
9	964	40.17	674
10	1026	42.75	846
11	884	36.83	624
12	646	26.92	454
13	861	35.88	554
14	736	30.37	504
15	938	39.08	754
16	955	39.79	783
17	834	34.35	674
18	880	36.37	622
19	904	37.67	745
20	521	21.71	443
21	817	34.04	614
22	741	30.88	571
23	852	35.50	547
24	778	32.421	490
25	879	36.63	620
26	729	30.38	502
27	917	38.08	740
28	940	39.17	745
29	1040	43.33	850
30	852	35.5	554
31	906	37.60	745
Total power consumption	25,282		
Average power consumption	813	38.69%	599.54

The table above shows the amount of electricity generated in March 2020. Here we see that on 29 March the highest amount of 1040 kWh of electricity was generated. Solar Irradiation on this day was 850 (W / m²). The total power generation in March was 25,285 kWh, and the average generation was 813 kWh. The average efficiency was 38.69%, and Irradiation was 599.54 (W / m²).

Table 5.3-3 Yearly Stitching Section solar power Consumption Log Sheet

Date(2019)	Solar power reading	REB/Generator reading
January	23114	65420
February	22720	62757.6
March	26156	97024.9
April	19501	120597.4
May	20286	140509.7
June	18303	110519.7
July	18036	152853.3
August	23142	119363.9
September	19488	133984.7
October	21020	138761.4
November	21211	144770.3
December	16329	112146.7
Total power consumption	249306	1398709.6
Average power consumption	20775.5	116559.1333

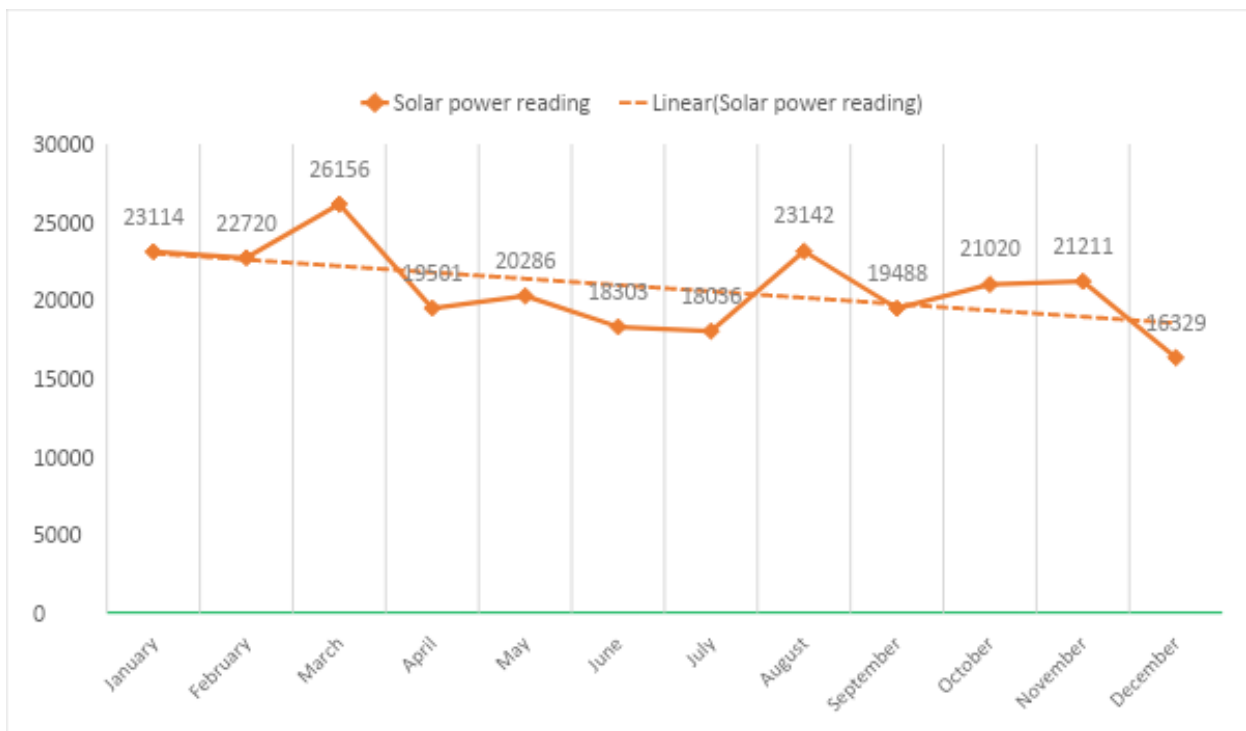


Figure 5.3-2 yearly solar power consumption (2019)

Table 5.3-3 shows the one-year power generation of 2019. This year a total of 249308 kWh of electricity has been generated. The average power output is 2075.5 kWh. From Chart 5.3-2, we see that the highest amount of 26156 kWh of electricity was generated in March while the lowest amount of 16329 kWh was generated in December.

Chapter-6

Result and Discussion

6.1 Economical Calculation

6.1.1 Practical economic result

Yearly stitching section solar power consumption log sheet 2019 of Noman Tarry terry towel ltd we collected data.

For solar PV system

Total power consumption	2,49,306 KWH	
Average Power consumption per month:	20775.5 KWh	
Total month is:	20×12 = 240 month	[lifetime 20years]
20 year's total power consumption:	49,86,120 KWH	[20775.5×240]
The REB off-pic rate is	7.70 BDT per unit	
20 year's total income is:	3,83,93,124 BDT	[49,86,120×7.70]
Installment cost: 18,00,000 BDT	18,00,000 BDT	

$$\text{Per unit cost} = \frac{\text{Installment cost}}{20 \text{ year's total average power consumption (KWH)}} = \frac{1,80,00,000}{49,86,120} = 3.61 \text{ TK per unit}$$

Total profit: (3,83,93,124 – 1,80,00,000) = 2,03,93,124 TK

Profit per unit: 7.70 - 3.61= 4.08 TK

6.1.2 Simulation's economic result

In chapter 5, we already simulate a 200KWh solar system. From this simulation report, we make the result that we show below.

Annual energy production	319900 KWh
Investment cost	1,64,31,785 TK
Annual gross income	24,60,217 TK
Annual running cost	99,963 TK
Annual depreciation value	8,21,593
Income taxes rate	5%
Sell unit rate	7.7

Taxable income =(gross income – depreciation value)

$$\begin{aligned}
&= (24,60217 - 8,21,593) \\
&= 1638623 \text{ TK} \\
\text{Annual taxes} &= 1638623 \times 0.05 = 81931 \text{ TK} \\
\text{Annual profit} &= (\text{gross income} - \text{running cost} - \text{taxes}) \\
&= (24,60,217 - 99,963 - 81931) \\
&= 22,78,323 \text{ TK} \\
\text{Total income in 20 years is} &= (22,78,323 \times 20) = 4,55,66,460 \text{ TK} \\
\text{Unit rate} &= \{164,31,785 \div (319900 \times 20)\} = 2.56 \text{ TK} \\
\text{Total profit} &= (4,55,66,460 - 1,64,31,785) = 2,91,34,675 \text{ TK} \\
\text{Payback period} &= (1,64,31,785 \div 22,78,323) = 7.2 \text{ years}
\end{aligned}$$

Table 6.1-1 Comparative summary

List	Simulation result	Practical result
Invest	1,64,31,785 TK	18,00,000TK
Annual production	319900 KWh	2,49,306 KWH
Unit per rate	2.5 TK	3.61 TK
Payback period	7.2 year	5.6 year

In this comparative summary, we see that the investment cost of the practical result is greater than the simulation result. The annual energy production of the simulation result is greater than the then practical result. The unit rate practical result also lagging from the simulation result. But we see that the payback period of practical value is leading from simulation results because we don't include income taxes and running costs for the practical section so that the Noman Terry Towel Limited doesn't sell any energy to the outside. Full energy consumption in this industry. On the other hand, there were no extra person to take care of the project. The industrial engineer and worker are work there. So there is no running cost.

6.2 Impact of the solar PV system on the industry

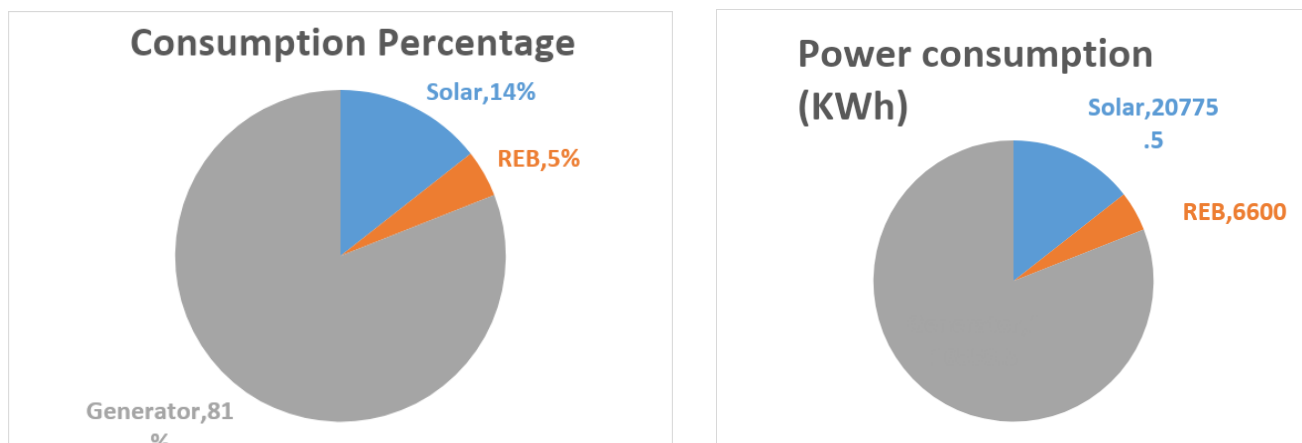


Figure 6.2-2 Industrial power consumption percentage

The Noman tarry Towel Lmt: company's average monthly power consumption is the show in figure 6.2-1 and 6.2-2. The industry is very large in size. The average monthly power demand of this industry is 1,43,935 KWh. In this demand, the industry's own generator produces 81% (1,16,559.5KWh), and the On-grid solar system produces 14%(20775.5 kWh) energy. A little amount of 5% energy takes from REB. On the other hand that, generator per unit cost is 6 TK, REB's per unit cost is 7.7 TK in off-peck rate and solar system per unite cost is 3.61TK. So we see that if we utilize 20775.5 KWh per month without solar PV system in the industry therefore our extra cost will be 84,971 TK or 49,653 TK by using REB/generator.

6.3 Discussion

In our observations, we see that the demand for electricity in Noman Terry Towel Limited is much higher.

With the amount of electricity generated from their 200 kWh solar system, only 14% of the demand can be met. And 81% of their electricity comes from their generators. They are taking only 5% of the electricity from the Grid. Since so much demand is not being met with the solar system, no electricity is being supplied to the Grid from this project. The good news is that 14% of electricity generated from solar has significantly reduced the pressure on the grids and reduced the carbon footprint.

Chapter-7

Conclusion and Recommendation

7.1 Conclusion

Bangladesh is a developing country. The per capita income and GDP of this country are increasing day by day. To sustain this trend of development, we must increase power generation. And on-grid solar systems can be a beautiful, environmentally friendly field for this power generation. With the on-grid solar system, we can run all types of electric devices in the home because we get AC from the on-grid solar system. On the other hand, in the case of off-grid, our chances are much less.

In our thesis, we have discussed the state of power generation in Bangladesh. What we mean here is that we need to reduce our dependence on fossil fuels. And to that end, we've worked with on-grid solar systems. This will reduce the pressure on fossil fuels and ensure the use of renewable fuels. Involved in this work, we became acquainted with the net meter. On-grid solar systems are connected to the Grid with the help of net meters.

The advantage of a net meter is that it allows the customer to keep track of how much electricity he has taken or given from the Grid. In this thesis paper, we have designed an MPPT three-phase invert. We have connected the solar system to the Grid through MATLAB apps. We can also see the effect on the output power due to the low and high frequency of Irradiation.

In this thesis, I have learned 200 KWH on-grid solar system design. In designing, we have become acquainted with different types of devices and software.

Our bibliography has made it even easier when we see on-grid solar projects in our industrial observations.

7.2 Recommendation

If we work on all the recommendations we got while researching the net meter, then it is possible to meet the electricity demand of Bangladesh with the on-grid solar system.

1. Net meter usage has not yet gained popularity in Bangladesh. To increase popularity, you have to increase publicity.
2. The process of applying for a net meter connection needs to be made easier.
3. So far, only three-face subscribers are getting this service, and the government has to work in the light that Seagull Face subscribers can also avail of the net meter service.
4. The use of on-grid solar systems in industries should be encouraged, and simple government policies should be put in place to install solar systems on the roofs of industries.
5. Large on-grid solar systems need to be facilitated by government back loans.
6. Training facilities need to be provided to build skilled manpower for the installation of on-grid solar systems.
7. Necessary equipment will be readily available and affordable.

Reference

- [1] G. of the P. R. of B. Power Division, Ministry of Power, Energy and Mineral Resources, "Bangladesh Power system master plan 2016," no. December, p. 1128, 2016.
- [2] "Bangladesh's Net -Metering Policy : Jump-Starting the Solar Rooftop Market ?," pp. 1–32.
- [3] S. A. Chowdhury, "Guidelines for Net Energy Metering in Bangladesh Integrating Distributed Renewable Energy," 2017.
- [4] V.K.Mehta, "Text Book of Principal of Power System," pp. 461–462, 2005.
- [5] "Annual Report -2019-2020.pdf." [Online]. Available: <https://powerdivision.gov.bd/>.
- [6] K. B. Bhatt, N. A. Sheikh, and M. V Gohil, "Mathematical Modelling and Implementation of Net Metering on MATLAB / SIMULINK Platform," vol. 4, no. 03, pp. 725–729, 2016.
- [7] H. Yin and N. Powers, "Do state renewable portfolio standards promote in-state renewable generation{glottal stop})," *Energy Policy*, vol. 38, no. 2, pp. 1140–1149, 2010, doi: 10.1016/j.enpol.2009.10.067
- [8] M. Sahanaa Sree, S. Arunkumar, and K. K. Murugavel, "Feasibility study for the net metering implementation in residential solar PV installations across Tamil Nadu," *2014 Int. Conf. Comput. Power, Energy, Inf. Commun. ICCPEIC 2014*, pp. 359–362, 2014, doi: 10.1109/ICCPEIC.2014.6915390.
- [9] V. R. Deskar and P. P. Kumar, "Simulation of Net Meter Connected to Microgrid," *Ijireeice*, vol. 4, no. 2, pp. 70–76, 2016, doi: 10.17148/ijireeice/ncaee.2016.14.
- [10] R. Energy and D. Authority, "- A way forward to Achieve '10 % RE by 2020' 'Net Metering Rooftop solar on all Govt . Office building' - Directive of the Cabinet Division," 2020.

Appendix A

In the bellow we give the MATLAB programing code that we use to design the MPPT solar Inverter:

```
function Vref = RefGen(V,I)
Vrefmax = 907.5;
Vrefmin = 0;
Vrefinit = 750;
deltaVref = 1;
persistent Vold Pold Vrefold;

dataType = 'double';

if isempty(Vold)
    Vold =0;
    Pold =0;
    Vrefold = Vrefinit;
end

P = V*I;
dV = V - Vold;
dP = P - Pold;

if dP ~= 0
    if dP<0
        if dV < 0
            Vref = Vrefold + deltaVref;
        else
            Vref = Vrefold - deltaVref;
        end
    else
        if dV < 0
            Vref = Vrefold - deltaVref;
        else
            Vref= Vrefold + deltaVref;
        end
    end
else Vref = Vrefold;
end

if Vref >=Vrefmax | Vref <= Vrefmin
    Vref = Vref;
end

Vrefold = Vref;
Vold =V;
Pold = P;
```

Appendix B

Noman Terry Towel Mills LTD companies data sheet that we get by visiting the industry.

NOMAN TERRY TOWEL MILLS LTD
VAWAL, MIRZAPUR, GAZIPUR.

DAILY STITCHING SECTION SOLAR AND GENERATOR POWER CONSUMPTION LOG SHEET

Date:-06-12-20

Time	Solar Present Meter Reading (KWH)	Solar Previous Meter Reading (KWH)	Solar Reading Difference (KWH)	Solar Reading Percentage	REB/Generator Present Meter Reading(KWH)	REB/Generator Previous Meter Reading(KWH)	REB/Generator Reading Difference (KWH).	Remarks
6 AM To 7AM	707,813	707,812	1	0.50%	6113165.5	6112544.5	621	
7 AM To 8 AM	707,828	707,813	15	7.50%	6113305	6113165.5	139.5	
8 AM To 9 AM	707,871	707,828	43	21.50%	6113600.5	6113305	295.5	
9 AM To 10 AM	707,924	707,871	53	26.50%	6113880	6113600.5	279.5	
10 AM To 11 AM	707,988	707,924	64	32.00%	6114140	6113880	260	
11 AM To 12 PM	708,049	707,988	61	30.50%	6114376	6114140	236	
12 PM To 1 PM	708,127	708,049	78	39.00%	6114612	6114376	236	
1 PM To 2 PM	708,179	708,127	52	26.00%	6114692.5	6114612	80.5	
2 PM To 3 PM	708,232	708,179	53	26.50%	6114887	6114692.5	194.5	
3 PM To 4 PM	708,244	708,232	12	6.00%	6115240	6114887	353	
4 PM To 5 PM	708,248	708,244	4	2.00%	6115615	6115240	375	
5 PM To 6 PM	708,249	708,248	1	0.50%	6116027	6115615	412	
Total Solar =			437	18.21%			3482.5	

Total solar Day's Consumption.....**437**.....(KW:H), Total Generator Power Day's Consumption**3482.5**.....(KWH).

Total solar Consumption.....**3235**.....(KWH), Total Generator Power Consumption**19916.5**.....(KWH).

708,244

N.B: Today's Temperature...**24°C**..... Today's Irradiation (Lax)...**281(w/m2)**.....

Daily Solar and REB/generator power consumption log sheet

MONTHLY STITCHING SECTION SOLAR AND GENERATOR POWER CONSUMPTION LOG SHEET

Time	Solar Present Meter Reading (KWH)	Solar Previous Meter Reading (KWH)	Solar Reading Difference (KWH)	Solar Power Efficiency Percentage (%)	REB/Generator Present Meter Reading(KWH)	REB/Generator Previous Meter Reading(KWH)	REB/Generator Reading Difference (KWH)	Remarks
3/1/2020	529,453	528,596	857	35.71%	4991995.1	4988624.3	3370.8	(871w/m2)
3/2/2020	530,154	529,453	701	29.21%	4995755.3	4991995.1	3760.2	(522w/m2)
3/3/2020	530,966	530,154	812	33.83%	5000090.7	4995755.3	4335.4	(547w/m2)
3/4/2020	531,770	530,966	804	33.50%	5004525.6	5000090.7	4434.9	(525w/m2)
3/5/2020	532,587	531,770	817	34.04%	5009050.5	5004525.6	4524.9	(656w/m2)
3/6/2020	533,217	532,587	630	26.25%	5013638.4	5009050.5	4587.9	(441w/m2)
3/7/2020	533,589	533,217	372	15.50%	5018455.3	5013638.4	4816.9	(177w/m2)
3/8/2020	534,281	533,589	692	28.83%	5021850.2	5018455.3	3394.9	(394w/m2)
3/9/2020	535,245	534,281	964	40.17%	5025310.6	5021850.2	3460.4	(846w/m2)
3/10/2020	536,271	535,245	1,026	42.75%	5029270.5	5025310.6	3959.9	(624w/m2)
3/11/2020	537,155	536,271	884	36.83%	5033465.7	5029270.5	4195.2	(454w/m2)
3/12/2020	537,801	537,155	646	26.92%	5037780.4	5033465.7	4314.7	(554w/m2)
3/13/2020	538,662	537,801	861	35.88%	5042270.1	5037780.4	4489.7	(504w/m2)
3/14/2020	539,398	538,662	736	30.67%	5046669.8	5042270.1	4399.7	(754w/m2)
3/15/2020	540,336	539,398	938	39.08%	5050815.5	5046669.8	4145.7	(783w/m2)
3/16/2020	541,291	540,336	955	39.79%	5055015.8	5050815.5	4200.3	(674w/m2)
3/17/2020	542,125	541,291	834	34.75%	5059175.2	5055015.8	4159.4	(622w/m2)
3/18/2020	543,005	542,125	880	36.67%	5063571.3	5059175.2	4396.1	(745w/m2)
3/19/2020	543,909	543,005	904	37.67%	5066987.4	5063571.3	3416.1	(443w/m2)
3/20/2020	544,430	543,909	521	21.71%	5070298.7	5066987.4	3311.3	(614w/m2)
3/21/2020	545,247	544,430	817	34.04%	5073844.1	5070298.7	3545.4	(571w/m2)
3/22/2020	545,988	545,247	741	30.88%	5077379.2	5073844.1	3535.1	(547w/m2)
3/23/2020	546,840	545,988	852	35.50%	5080297.9	5077379.2	2918.7	
3/24/2020	547,618	546,840	778	32.42%	5083494.7	5080297.9	3196.8	
3/25/2020	548,497	547,618	879	36.63%	5086307.8	5083494.7	2813.1	
3/26/2020	549,226	548,497	729	30.38%	5086384.1	5086307.8	76.3	
3/27/2020	550,140	549,226	914	38.08%	5089203.4	5086384.1	2819.3	
3/28/2020	551,080	550,140	940	39.17%	5090955.8	5089203.4	1752.4	
3/29/2020	552,120	551,080	1,040	43.33%				
3/30/2020	552,038	552,120	852					
3/31/2020	552,944	552,038	906					
Total Power Consumption			25,282				102331.5	
Average Power Consumption			813	38.69%			3654.70	

43.33% - 15.50%

Engineer (Electrical) GM (Operation & Planning)

Prepared by

Monthly power consumption log sheet

YEARLY STITCHING SECTION SOLAR AND GENERATOR POWER CONSUMPTION LOG SHEET

Date	Solar Present Meter Reading (KWH)	Solar Previous Meter Reading (KWH)	Solar Reading Difference (KWH)	REB/Generator Present Meter Reading(KWH)	REB/Generator Previous Meter Reading(KWH)	REB/Generator Reading Difference (KWH)	Remarks
January	315,185	292,071	23114	3461667.7	3396247.7	65420	
February	337,905	315,185	22720	3524425.3	3461667.7	62757.6	
March	364,061	337,905	26156	3621450.2	3524425.3	97024.9	
April	383,562	364,061	19501	3742048	3621450.2	120597.4	
May	403,848	383,562	20286	3882557.3	3742048	140509.7	
June	422,151	403,848	18303	3993077	3882557.3	110519.7	
July	390,871	422,151	18036	4145930.3	3993077	152853.3	
August	414,013	390,871	23142	4265294.2	4145930.3	119363.9	
September	433,501	414,013	19488	4399278.9	4265294.2	133984.7	
October	454,521	433,501	21020	4538040.3	4399278.9	138761.4	
November	475,732	454,521	21211	4682810.6	4538040.3	144770.3	
December	492,061	475,732	16329	4794957.3	4682810.6	112146.7	
Total Power Consumption			249306			1398709.6	
Average Power Consumption			20775.5			116559.1333	

Total solar Consumption.....249306...(KWH), Total Generator Power Consumption1398709.6.....(KWH).

Yearly power consumption

Appendix C



PVsyst V7.1.1
Simulation date:
05/01/21 11:13
with v7.1.1

Project: Noman Tarry Towel Mills limited 2

Variant: New simulation variant

Project summary

Geographical Site	Situation	Project settings
Mirzapur Bangladesh	Latitude 24.08 °N Longitude 90.36 °E Altitude 11 m Time zone UTC+6	Albedo 0.20
Meteo data		
Mirzapur Meteonorm 7.3 (1981-2010), Sat=100% - Synthetic		

System summary

Grid-Connected System	No 3D scene defined, no shadings	
PV Field Orientation	Near Shadings	User's needs
Fixed plane Tilt/Azimuth 30 / 0 °	No Shadings	Daily profile Constant over the year Average 0.0 kWh/Day
System information		
PV Array	Inverters	
Nb. of modules 770 units Prnom total 200 kWp	Nb. of units 8 units Prnom total 200 kWac Prnom ratio 1.001	

Results summary

Produced Energy 319.9 MWh/year	Specific production 1598 kWh/kWp/year	Perf. Ratio PR 82.44 %
		Solar Fraction SF 100.00 %

Table of contents

Project and results summary	2
General parameters, PV Array Characteristics, System losses	3
Detailed User's needs	4
Main results	5
Loss diagram	6
Special graphs	7
Cost of the system	8
Financial analysis	9
CO ₂ Emission Balance	12



Project: Noman Tarry Towel Mills limited 2

Variant: New simulation variant

PVsyst V7.1.1

Simulation date:
05/01/21 11:13
with v7.1.1

General parameters

Grid-Connected System		No 3D scene defined, no shadings											
PV Field Orientation		Models used										Horizon	
Orientation		Transposition					Perez					Free Horizon	
Fixed plane		Diffuse					Perez, Meteonorm						
Tilt/Azimuth		30 / 0 °					Circumsolar					separate	
Near Shadings		User's needs											
No Shadings		Daily profile											
		Constant over the year											
		Average											
		0.0 kWh/Day											
Hourly load	0 h	1 h	2 h	3 h	4 h	5 h	6 h	7 h	8 h	9 h	10 h	11 h	W
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	W
	12 h	13 h	14 h	15 h	16 h	17 h	18 h	19 h	20 h	21 h	22 h	23 h	W
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	W

PV Array Characteristics

PV module		Inverter	
Manufacturer	Generic	Manufacturer	Generic
Model	ND-RJ260	Model	Sunny Tripower2500TL-30
(Original PVsyst database)		(Original PVsyst database)	
Unit Nom. Power	260 Wp	Unit Nom. Power	25.0 kWac
Number of PV modules	770 units	Number of inverters	8 units
Nominal (STC)	200 kWp	Total power	200 kWac
Modules	35 Strings x 22 in series	Operating voltage	390-800 V
At operating cond. (50°C)		Phom ratio (DC:AC)	1.00
Pmpp	179 kWp		
U mpp	603 V		
I mpp	297 A		
Total PV power		Total inverter power	
Nominal (STC)	200 kWp	Total power	200 kWac
Total	770 modules	Nb. of inverters	8 units
Module area	1260 m ²	Phom ratio	1.00

Array losses

Thermal Loss factor		DC wiring losses		Module Quality Loss	
Module temperature according to irradiance		Global array res.		Loss Fraction	
Uc (const)	20.0 W/m ² K	34 mΩ		-1.3 %	
Uv (wind)	0.0 W/m ² K/m/s	Loss Fraction		1.5 % at STC	
Module mismatch losses		Strings Mismatch loss		IAM loss factor	
Loss Fraction	2.0 % at MPP	Loss Fraction		ASHRAE Param: IAM = 1 - bo*(1/cos(i) - 1)	
		0.1 %		bo Param.	
				0.05	



Project: Noman Tarry Towel Mills limited 2

Variant: New simulation variant

PVsyst V7.1.1

Simulation date:
05/01/21 11:13
with v7.1.1

Cost of the system

Installation costs			
Item	Quantity units	Cost USD	Total USD
PV modules			
ND-RJ260	770	215.00	165'550.00
Inverters			
Sunny Tripower 25000TL-30	8	2'953.00	23'624.00
Studies and analysis			
Engineering	1	100.00	100.00
Installation			
Transport	1	1'185.00	1'185.00
Accessories, fasteners	1	2'500.00	2'500.00
Wiring	1	700.00	700.00
Settings	1	700.00	700.00
Grid connection	1	100.00	100.00
Total			194'459.00
Depreciable asset			194'459.00
Operating costs			
Item			Total USD/year
Maintenance			
Salaries			5'680.50
Total (OPEX)			5'680.50
System summary			
Total installation cost		194'459.00 USD	
Operating costs		5'680.50 USD/year	
Unused energy		0.0 kWh/year	
Energy sold to the grid		319'941 kWh/year	
Cost of produced energy (LCOE)		0.048 USD/kWh	



PVsyst V7.1.1
 Simulation date:
 10/01/21 02:10
 wth v7.1.1

Project: Noman Tarry Towel Mills limited 2

Variant: New simulation variant

Financial analysis

Detailed economic results (USD)

	Gross income	Run. costs	Deprec. allow.	Taxable income	Taxes	After-tax profit	Self-cons. saving	Cumul. profit	% amort.
2021	29'115	1'183	9'723	18'208	910	27'021	0	-97'438	13.9%
2022	29'115	1'183	9'723	18'208	910	27'021	0	-540'417	27.8%
2023	29'115	1'183	9'723	18'208	910	27'021	0	-113'397	41.7%
2024	29'115	1'183	9'723	18'208	910	27'021	0	-86'376	55.6%
2025	29'115	1'183	9'723	18'208	910	27'021	0	-59'355	69.5%
2026	29'115	1'183	9'723	18'208	910	27'021	0	-32'334	83.4%
2027	29'115	1'183	9'723	18'208	910	27'021	0	-5'314	97.3%
2028	29'115	1'183	9'723	18'208	910	27'021	0	21'707	111.2%
2029	29'115	1'183	9'723	18'208	910	27'021	0	48'728	125.1%
2030	29'115	1'183	9'723	18'208	910	27'021	0	75'749	139.0%
2031	29'115	1'183	9'723	18'208	910	27'021	0	102'770	152.8%
2032	29'115	1'183	9'723	18'208	910	27'021	0	129'790	166.7%
2033	29'115	1'183	9'723	18'208	910	27'021	0	156'811	180.6%
2034	29'115	1'183	9'723	18'208	910	27'021	0	183'832	194.5%
2035	29'115	1'183	9'723	18'208	910	27'021	0	210'853	208.4%
2036	29'115	1'183	9'723	18'208	910	27'021	0	237'874	222.3%
2037	29'115	1'183	9'723	18'208	910	27'021	0	264'894	236.2%
2038	29'115	1'183	9'723	18'208	910	27'021	0	291'915	250.1%
2039	29'115	1'183	9'723	18'208	910	27'021	0	318'936	264.0%
2040	29'115	1'183	9'723	18'208	910	27'021	0	345'957	277.9%
Total	582'292	23'669	194'459	364'165	18'208	540'416	0	345'967	277.9%

Yearly net profit (Electricity sale USD)

