ANALYSIS AND DESIGNING OF 1 MW SPV GROSS METERING POWER PLANT IN ODISHA

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ABSTRACT

Facing ever-increasing worldwide energy demand, the reliable and environmentally friendly use of natural energy sources is one of the biggest challenges of our time. Solar energy is a free, clean and a major source for renewable energy which, radiant light and heat from the Sun harnessed using a range of ever evolving technologies such as solar heating, photovoltaics, solar thermal energy, solar architecture and artificial photosynthesis. The large magnitude of solar energy available for free emission of photons makes it a highly appealing and primary source of electricity. How to reasonably utilize green energy and keep sustainable development is the most important challenge. Further, as a huge green energy source generated from the sun, Photovoltaic (PV) industry will gain the best opportunity to grow up. It is well known that the rapid growth of business and population put more and more pressure on world power resources. We should use the opportunity to build the most suitable environmental friendly PV power plant, and welcome to a better tomorrow. Photovoltaics (PV) use solar cells (mostly Si type) bundled in solar panels to produce DC-current. Solar power plants use one of two technologies:

- *Photovoltaic (PV) systems use solar panels, either on rooftops or in ground-mounted solar farms, converting sunlight directly into electric power.*
- *Concentrated solar power (CSP, also known as "concentrated solar thermal") plants use solar thermal energy to make steam that is thereafter converted into electricity by a turbine.*

The design of Grid-connected photovoltaic (PV) systems has a significant impact on the overall process of power generation. This paper demonstrates a detailed analysis, designing and policies of 1MW solar photovoltaic Grid-connected solar power plant in Odisha, India. The price of Photovoltaic solar power plant plays a vital role in the larger development of solar power generation.

Key words: Solar Energy, Photovoltaic (PV), Solar power plant.

1. INTRODUCTION

Bhubaneswar is an ancient city in India's eastern state of Odisha, formerly Orissa. It has a total area of 135 km², Elevation is 58 m, population was 8.38 lakhs (2011) and is located at latitude 20.2961° N, and longitude 85.8245° E. The temperature ranges from 25°C to 45°C in the summer and reaches to as low as 8°C in the winter. The area of Bhubaneswar is characterized as a hot arid zone with vast plain areas. This provides an ideal environment for any Photovoltaic Power plant projects. Solar power plant Energy can suit a wide range of applications such as residence, industry, agriculture, livestock, etc.

World is rapidly moving towards generating Electrical energy from Solar PV system and Scientists are developing solar resources with better technology to maximize energy production as much as possible. One of the prominent models of such a technology is the grid-connected PV system which supplies electricity directly to the power grid [3]. The designer of the system is responsible for selecting the value of the different parameters: number and type of PV modules, inverter type, distribution of components in the installation field, etc. India is facing an acute energy scarcity which is hampering its industrial growth and economic progress. Setting up of new power plants is inevitably dependent on import of highly volatile fossil fuels. Thus, it is essential to tackle the energy crisis through judicious utilization of abundant the renewable energy resources, such as Biomass Energy solar Energy, Wind Energy and Geothermal Energy [2].

2. STUDY AREA

With about 300 clear and sunny days in a year, the calculated solar energy incidence on India's land area is about 5000 trillion kilowatt-hours (kWh) per year (or 5 EWh/yr). The monthly performance ratio in India is ranged from 55% to 85% and annual performance ratio keeps on increasing due to grid availability. India has electricity in 96.7% Villages but in-house supply is only 69% and 4 billion people were deprived of electricity by year of 2014-15 [1]. In Indian electricity sector, renewable energy account for 34.6% of the total installed power capacity. India has installed Solar Photo Voltaic Modules (SPV) Power plant of 28.18 GW as of 31 March 2019. The target was raised to 100 GW of solar capacity (including 40 GW from rooftop solar) by 2022, targeting an investment of US$100 billion. By the end of 2018, Global cumulative installed PV capacity reached about 512 gigawatts (GW), up 27% from 2017. The daily average solar-power-plant generation capacity in India is 0.20 kWh per m^2 of used land area. The annual Solar Power generation is 3.35 TWh, 4.60 TWh, 7.45 TWh, 12.09 TWh and 25.87 TWh with the year 2013-14, 2014-15, 2015-16, 2016-17, and 2017-18 respectively. The International Solar Alliance (ISA), is an alliance of more than 122 countries initiated by India as a founder member, is headquartered in Gurugram, India.

Bhadla Solar Park (1,515 MW, operational) is the largest solar parks in India and second largest in the World, which is spread over a total area of 10,000 acres (40 km^2) in Bhadla, Rajasthan, India. The park has a capacity of 2,255 MW.

3. METHODS AND METHODOLOGY

Solar Power plant installation capacities from few watts to gigawatts range. The construction material, Silicon is the second most available material of the earth. Modern technology and mineralogy advances made the cost of SPV modules cheaper and solar installation is growing popular particularly on roof tops and inaccessible hilly areas. The SPV converts light energy (photons) to electrical energy (DC) using silicon solar photovoltaic cells. It is a PN junction device created by process of doping on a silicon wafer with p-type and n-type silicone materials [6].

SPV system: On-Grid systems are solar PV systems that only generate power when the utility power grid is available. They must connect to the grid to function. Off-Grid systems allow you to store your solar power in batteries for use when the power grid goes down or if you are not on the grid.

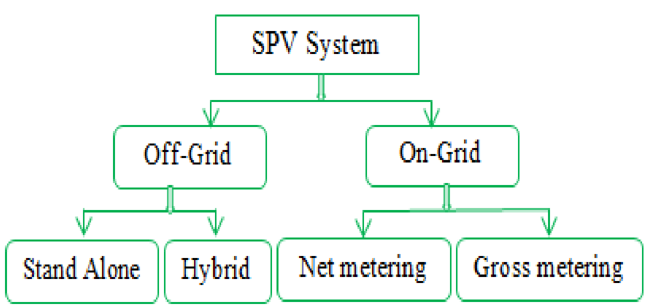


Figure 3.1 Classification of SPV System

From the above Figure I will focus on Gross metering Solar power plant concept.
Gross metering- The total energy generated by the solar rooftop/ground plant is to be injected into the grid without allowing the generated solar energy to be consumed directly by the consumer.

3.1. Solar Photovoltaic (PV) Power Plants

Grid connected PV power plants without battery backup consists of just two major components, a PV array and a Grid-tied inverter.

In addition, the array frames can be installed as:

1. Fixed, where the frame is fixed at the optimum angle.
2. Adjustable, where the frame can be adjusted manually during the year (often not carried out as year's progress).
3. Tracking, where the frames automatically move to receive optimal sunlight during the day and throughout the year.

While trackers are most efficient, they are more expensive and require maintenance.

Depending on the design of the photovoltaics-plant several panels are connected to an Inverter through Junction box to convert the produced DC to AC current [8]. In the next step, Transformers transmits the energy to medium voltage level up to 36 kV. Then it is bundled and a medium power transformer steps it further up to high voltage level. The major components of Grid connected (Gross metering) Solar power plant are;

1. Solar PV Module
2. Solar Inverter
3. Transformer
4. Solar Energy meter
5. Utility Grid
6. Electrical Appliances

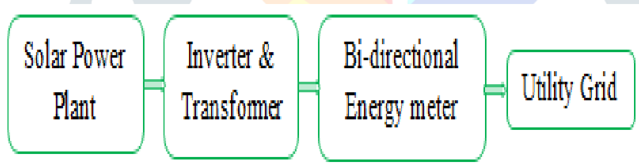


Figure 3.2 Block diagram of Gross metering Solar power plant

3.1.1 Solar PV Module

Solar Photovoltaic (PV) is an assembly of photovoltaic cells. In India, Poly-crystalline panel is more used as compare to other type. To achieve a required voltage and current, a group of PV modules (also called PV panels) are wired into large array that called PV array. Solar modules use light energy (photons) from the sun to generate electricity through the photovoltaic effect.

Mathematically, $I = I_L - I_D$

$$I = I_L - I_0 \left[exp\left(\frac{eV}{KT}\right) - 1 \right] \quad \ldots \qquad (3.1)$$

Where, I= electric current

I_L= solar light generated current

I_D= diode current

I_0= saturation current

e= electron charge

V= voltage across the junction

K= Boltzmann's constant and

T= absolute temperature.

The majority of modules use wafer-based crystalline silicon cells or thin-film cells based on cadmium telluride or silicon. System incorporates photovoltaic panels, inverter system, and control circuit depending on the application. PV modules can be wired together in series and/or parallel to deliver voltage and current in a particular system requires [4].

Materials used for making of solar panels are, Wafer based Si Solar Cell technologies- Mono-crystalline and Multi-crystalline. (Comparatively High efficiency High cost) [2] Thin film Technologies- Amorphous Si, Cd, Te, CIGS and many more. (Comparatively Low efficiency Low cost) [3] Future Technology- Thin film Crystalline Si. (High efficiency Low cost) More than 90% of the solar cells produced at present are of crystalline silicon [14].

Table 3.1 Commercial efficacies of PV Modules

Wafer-based c-Si		Thin Films		
Mono-Si	Multi-Si	a-Si; a-Si/μc-Si	CdTe	CIS/CIG
15-28%	15-25%	6-11%	9-13%	10-15%

3.1.2 Solar Inverter

This is the device that takes the dc power from the PV array and converts it into standard ac power and feed this power into the network. To improve the quality of inverter's power output, many topologies are incorporated in its design such as Pulse-width modulation (PWM) and Maximum power point tracking (MPPT).

3.1.3 PV Distribution Transformers

Step-up transformers connect photovoltaic plants to the grid. As the conditions in solar power plants are rather severe, those transformers need to withstand high temperatures as harsh weather conditions. Sizing of these transformers is a crucial factor when planning a PV power plant, as too large rated power can lead to instabilities and economic disadvantages as well as too small transformer power might not exploit the whole capability of the plant erected.

3.1.4 Bi-directional Smart Energy meter

Metering includes meters to provide indication of system performance. The term bi-directional metering refers to the fact that the meter can measure the flow of electricity in two directions. It measures how much energy comes from your electric company–"kWh delivered." It also measures the difference between the generators production and the customers load demand – "kWh received."

3.1.5 Utility Grid

An electric Grid is a network of synchronized power provides and consumers that are connected by transmission and distribution lines and operated by one or more control units.

3.1.6 Load

Load is electrical appliances that connected to solar PV system such as lights, fans, TV, computer, refrigerator, and accessories etc.

3.1.7 Auxiliary energy sources

It may be diesel generator or other renewable energy sources.

3.2 Implementing MW Solar Power Plants

The steps below provides more details on the key drivers and actionable for implementing MW Solar power plants.

Step-1 Getting a PPA for a MW Solar power plant
Step-2 Financing options for a MW Solar power plant
Step-3 Site selection for a MW Solar power plant
Step-4 EPC selection for a MW Solar power plant
Step-5 Design and Construction of a MW Solar power plant
Step-6 Discussion regarding Owner's Engineering and O & M Owner's Engineer
Step-7 Commissioning of the plant

The **land** required for a 1 MW **power plant installation** is around 4.5-5 acres for Crystalline technology and around 6.5-7 acres for Thin-Film technology. This is only a rough benchmark and may vary based on technology and efficiency of panels.

3.3 Performance of Solar Power Plants

The performance of solar power plants is best defined by the Capacity Utilization Factor (CUF), which is the ratio of the actual electricity output from the plant, to the maximum possible output during the year [13].

The following factors are considered key performance indicators:

1. Radiation at the site
2. Losses in PV systems
3. Temperature and climatic conditions
4. Design parameters of the plant
5. Inverter efficiency
6. Module Degradation due to aging
7. Operation & Maintenance

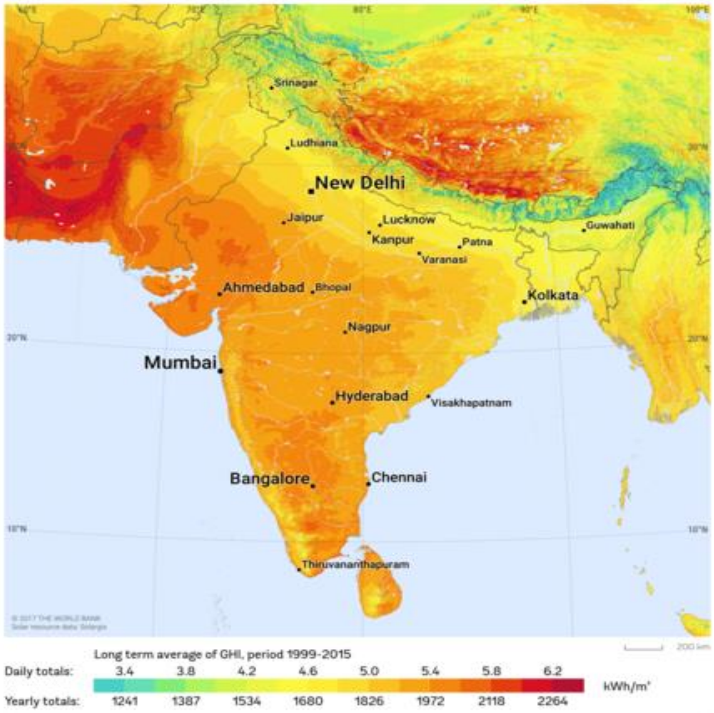
3.4 Performance of Operating Solar Power Plant

The performance of the Solar power plants fully depends on the inverter efficiency. The generation of Solar plant depends on many factors such as:

1. Location

2. Solar irradiation

3. Climatic Conditions



Source: *Solar Power in India*

4. DESIGN AND CALCULATION OF SOLAR POWER PLANT

4.1 Determine Power Consumption Demands

The first step in designing a solar PV system is to find out the total power and energy consumption of all loads that need to be supplied by the solar PV system as follows:

4.1.1 Calculate total watt-hours per day each appliance used

Add the Watt-hours needed for all appliances together to get the total Watt-hours per day which must be delivered to the appliances [10].

4.1.2 Calculate total Watt-hours per day needed from the PV modules

Multiply the total appliances Watt-hours per day times 1.3 (the energy lost in the system).

4.2 Size the PV modules

The peak watt (Wp) produced depends on size of the PV module and climate of site location. We have to consider "panel generation factor" which is different in each site location [5].

4.2.1 Calculate the number of PV panels for the system

Divide the answer obtained in Calculate total Watt-hours per day needed from the PV modules by the rated output Watt-peak of the PV modules available to you. Result of the calculation is the minimum number of PV panels (Best for India is Poly-Crystalline Si Panel). If more PV modules are installed, the system will perform better and battery life will be improved [9].

Table 4.1 Design of 1 MW Solar PV Power Plant

1 MW Solar PV power plant design	
Power Plant Capacity	1 MWp
Avg. Sun hrs per Day Whole Year	6 Hours
Total Power/ Day	1 MWp
Total Watt-hrs per Day	10,000,000 W-h/day
Maxi. Solar Isolation at the site	6.18 KW-h/m²/day
Total Watt-hrs per Day / Isolation	1618122.98
Total PV panel Energy needed (1.3 time energy lost in system)	2103559.88 W-h/day

Solar PV arrangement	
Watt (Wp)	300 Wp
DC Voltage (Vmp (V))	36.72 V
DC Current (imp (A))	8.17 A
Open Current Voltage (Voc (V)	45.5 V
Short Circuit Current (Isc (A))	8.65 A

Number of PV Panels needed= (2103559.88) W-h/day /300Wp=7,012 number of 300W PV panels or modules needed for the system.

No of PV Panel Group	
No of Group of PV Panel	5 nos
Each Group containing No of Panel	701 nos
No of Strings/Arrays	35 nos
Each Strings/Arrays contains No of solar Panel	4 nos

4.3 Inverter size

An inverter is used in the system where AC power output is needed. The inverter must be large enough to handle the total amount of Watts you will be using at one time [7]. For grid tie systems or grid connected systems, the input rating of the inverter should be same as PV array rating to allow for safe and efficient operation. Inverter size = 1MW/1.3 = 1.3MW or two numbers of 500 KW Inverter (Fronius or ABB type) with 3 phases line can be chose. The grid/ the transformer specification for 1MW model are in Table 2.

Table 4.2 Details of Grid and Transformer specification for MW Solar plant design

Sl. No.	Grid Specification	
1	No of phases	3-phase
2	Voltage rating	400 Volts AC
3	Frequency	50 Hz

Transformer specifications (KVA)		Use
No of phases	3 phase	The use of on grid distribution is optional from 1MW to 5MW. But higher SPV plants must use grid power distribution.
Frequency	50 Hz	
Primary voltage	11 kVA	
Secondary Voltage	440 V	
Efficiency	Almost 95 %	
Extra Features	Air cooled	

5. RESULTS AND DISSCUSION

Actual Power generation at MGM Solar Power Plant, Khurda, Odisha is given below Table. As per their tariff agreement per unit was Rs 18.72, but now it is reduce to tariff Rs. 4.30.

Month, 2018-19	**Generation (KWh)**
April, 2018	1,20,200
May, 2018	1,17,600
June, 2018	1,00,400
July, 2018	99,550
August, 2018	97,600
September, 2018	98,200
October, 2018	98,450
November, 2018	1,00,600
December, 2018	1,08,650
January, 2019	1,10,350
February, 2019	1,12,600
March, 2019	1,17,350
Total	12,81,550 Units/Year

Figure 4.1 1 MW Gross metering Solar power plant, Khurda and Cuttack, Odisha

Figure 4.2 1 MW Gross metering Solar Power Plant Control room, Khurda, Odisha

6. RENEWABLE ENERGY REGULATORY FRAMEWORK

Renewable energy (RE) in India comes under the purview of the Ministry of New and Renewable Energy (MNRE). India was the first country in the world to set up a ministry of non-conventional energy resources, in the early 1980s.The development of grid interactive renewable power took off with the coming into force of the Electricity Act 2003 (EA 2003), which, among other things, provides for regulatory interventions for promotion of renewable energy (RE) sources through a) determination of tariff; b) specifying renewable purchase obligation (RPO); c) facilitating grid connectivity; and d) promotion of development of market [12].

In view of the aforesaid provisions, regulatory framework for renewable power is evolving and all major States, Central Electricity Regulatory Commission (CERC), Central Electricity Authority (CEA) etc are declaring, revising, and modifying renewable power regulatory framework such as RE policy, RPOs, Feed in Tariffs (FiTs), Renewable Energy Certificate (REC) mechanism, grid connectivity and forecasting provisions etc. on a regular basis. Ministry of New & Renewable Energy (MNRE) has initiated an exercise to track the evolving renewable power regulatory framework and develop a repository of information in a consolidated manner.

6.1 Energy Security

India needs to focus on developing its own sources of energy. Our major energy sources, oil and coal, are imported in large quantities. Even with the development of nuclear energy, India will be dependent on other nations for fuel. To sustain economic growth, to come out of the energy deficit situation and ensure that energy is available in every town and village, India must utilise its immense potential in solar energy.

6.2 Solar Scheme and Policies

Today India is fast becoming one of the world's most attractive markets for Renewable Energy investments. India's rise has been due to the effective Scheme, Policy and Regulatory support for development of Renewable Energy Technologies (RETs).

The National Solar Mission was launched on the 11th January, 2010 by the Prime Minister. The Mission has set the ambitious target of deploying 20,000 MW of grid connected solar power by 2022 is aimed at reducing the cost of solar power generation in the country through (i) long term policy; (ii) large scale deployment goals; (iii) aggressive R&D; and (iv) domestic production of critical raw materials, components and products, as a result to achieve grid tariff parity by 2022. Mission will create an enabling policy framework to achieve this objective and make India a global leader in solar energy.

Further, Government has revised the target of Grid Connected Solar Power Projects from 20,000 MW by the year 2021-22 to 100,000 MW by the year 2021-22 under the National Solar Mission and it was approved by Cabinet on 17th June 2015.

In order to achieve a sustainable development path with UN Framework Convention on Climate Change (UNFCCC) that simultaneously advances economic and environmental objectives, on 30 June 2008, the National Action Plan for Climate Change (NAPCC) was framed with eight core missions:

1. National Solar Mission – renamed Jawaharlal Nehru National Solar Mission (JNNSM)
2. National Mission for Enhanced Energy Efficiency
3. National Mission on Sustainable Habitat
4. National Water Mission
5. National Mission for Sustaining the Himalayan Ecosystem
6. National Mission for a Green India
7. National Mission for Sustainable Agriculture

8. National Mission on Strategic Knowledge for Climate Change

Various states have come up with their state Solar policies to provide an enabling framework for growth of Renewable Energy in India.

6.2.1 Policies supporting Off-Grid Renewable Power

- *National Rural Electrification Policy 2006*
- *Rajiv Gandhi Gramin Vidyutikaran Yojana (RGGVY)*

6.2.2 Policies supporting On-Grid Renewable Power

- *Remote Village Electrification Programme*
- *Special Area Demonstration Project Programme*
- *Renewable Energy Supply for Rural Areas*
- *Renewable Energy for Urban, Industrial and Commercial Applications*

As far as the Odisha state is concerned, there are ample opportunities for implementation of Renewable Energy projects both in rural and urban sectors. In connection to this some Renewable Energy policies and projects for the State of Odisha are mentioned below;

- Odisha Renewable Energy Policy draft, 2015-22
- Odisha Solar Policy, 2013
- Odisha to tender 500 MW Solar Power
- Odisha Plans PV Projects in 198 Villages
- 10 MW Solar PV Project at Paradip port
- Solar Park in Balasore and Khurda districts

7. CONCLUSION

The paper studies how to establish photovoltaic (PV) solar power plant design as well as design calculation of power production, based on that to find recommendation and techniques to optimized cost of PV solar power plant. In order to establish green and sustainable development of solar PV power plant, there is a need to estimate the power requirement of the load, which is followed by calculation of Solar Panel, Solar Inverter and Transformer. Further, more cost-effective and efficient design of Solar Power Plants in metering concept will be developed with Indian Solar policies and Operation & Maintenance process. Thus, there is a significant need to grasp the opportunity to build the most suitable environmental friendly and most efficient PV power plant to welcome a better tomorrow.

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