International Journal of Modern Agriculture, Volume 9, No.4, 2020
ISSN: 2305-7246

PERFORMANCE PARAMETERS, OPTIMIZATION, AND RECOMMENDATION IN LARGE SCALE ON-GRID SPV POWER PLANT, ODISHA, INDIA

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Abstract

Traditional energy from coal, fossil fuel, and hydro power plants are environmental, and beyond human replenishment need to be replaced by renewable sources like solar irradiation, aeolian, tidal, or geothermal. The copious solar power plant (SPP) is the best substitute of ecofriendly energy source is the rank-1 choice for developing country, India. Till June 2020, the Solar power plant installed capacity was 36 GW in India targeted to augment to 100GW by FY-2022.

This present research covers few performance parameters of a SPP and its PR (Performance Ratio), CUF (Cumulative Utilization Factors) contributed by such a unit of one MW at Bhusandpur in Khordha district of Odisha installed during 2010 and is still in operation. The yield of the SPP is integrated with the on-grid of the Khurdha electric power distribution system. To study the performance of the SPP depends upon constraints like the irradiation, temperature, and climate, design parameters, PR, existing vegetation, regular maintenance, and climate to be considered at design stage. The longevity of the SPP is considered for 25 years. The SPP performance measured based on the values of PR or CUF of the plant for the life of span of energy generation. Present research covers and suggest recommendations for better performance of the one MW SPP Project. To improve the performance of SPP, site survey was conducted and performance data for 2020 is collected for analysis,

The present paper is aimed at the performance evaluation and recommendation for improvement of performance in an existing 1 MW on-grid solar power plant at Khurdha, Odisha, established since 2010. The lowest and highest power generation has been found to be in the month of August and May about 97,500 kWh and 1,52,600 kWh respectively. The performance evaluation including performance ratio, capacity utilization factor and payback period of the plant has been carried out, that will support in efficient designing and development of new grid interactive systems in future

Key words: Solar energy; Photovoltaic; On-grid; Solar Power Plant, Performance Evaluation

Introduction

The renewable energy is a continuous, nature abated or clean and can be generated from solar, wind, hydro, bio-mass, oceanic waves and geothermal. The solar energy is based on the topography, global positioning and the sun earth geometry. Amongst all forms, solar is one among the best source of renewable energy. Solar energy is

sustainable, inexhaustible and abundant resource among all forms of energy in the environment [1]. The total amount of solar energy absorbed by earth is approximately 3.85 x 10^{24} J/annum. It has been estimated that the energy used globally per year is the energy radiated from sun in one hour [2]. The energy can be harvested form of luminosity and irradiation from the sun. The solar energy is harnessed by employing various technologies like solar photovoltaic (SPV), concentrated solar power (CSP), solar heating and cooling (SHC) [3]. It does not evolve any greenhouse gases (GHGs) through the processes of generating electricity [4]. SPV is considered suitable and harmless for environment and ecosystem in terms of sustainability, affordability, adoptability, reliability, and very efficient in power generation. Globally, use of SPV technology is about 98% whereas rest is by the CSP technology by 2% [5, 6]. Solar PV module is an assembly of solar cells. Multiple solar modules are arranged in various ways to from either a PV string or an array in a Solar power plant. The amount of power generated can be used commercially or have residential applications through proper synchronization with nearby utility grid [7, 8].

India is positioned in tropics of northern hemisphere, having around 300 clear sunny days per year and receives in an average solar radiation of 5kWh/m^2/day. India is already a leader in both hydro and wind power generation in the world [9-12]. The target for renewable energy (RE) capacity for the country has been assigned to be of 175 GW by MNRE (Min. of New and Renewable Energy out of which 100 GW from solar energy, 60 GW from aeolian forces, 10 GW from bio mass, and 5 GW of small hydro and others by FY-2022. Interim 100 GW of solar energy installation target with proposed investment of Rs. 7156 billion INR includes 40 GW only from rooftop solar power harvest.

India has the lowest capital cost/MW in the world for the solar PV plants installations. The total solar power installed in India is of capacity 35.74 MW by June 2020 [13-16]. The Bhadla solar park with capacity of nearly 2,250 MW is a largest solar power plant in the world, located in Bhadla village, Rajasthan's [17]. Solar Power Plant installations in Odisha are highly efficient and economical in India. The OERC (Odisha Elec. Regulatory Commission) has been established during 1995, is in sole control of supply of electricity including solar power in Odisha [18-21]. The electricity consumers in the state are around 9.6 million and peak power demand is about 5641 MW in the fiscal year of 2018-19 [22-24].

The generation of solar electricity plants were installed from Apr. 2019 to Mar. 2020 was 50.1 TWh, which is 3.6% of total generation i.e. 1,391 TWh in India. The state of Odisha has achieved installation capacity of 394.73 MW of solar power including the present existing installation of one MW solar power plant during March 2019 [25-28]. The leading agencies generating, distributing and stakeholders are GEDCOL, GRIDCO, NTPC, OPTCL, Sunark solar, MGM solar and many others.

Methodology

The optimum utilization of the capital invest ment in a solar power plant vests on the site investigations, performance parameters, effective design, appropriate investment resolutions with improved regulatory structure, and advanced technological boosts.

The empirical data used for present study were collected at site by observation, calculation and experimentation of operational 1 MW SPV power plant at Bhusundapur, Khurda **(Fig 4).** The plant with latitude and longitude values of 19.9585° N and 85.4692° E respectively. The political map of khorda is given in the **Fig 1**. The annual average global horizontal irradiance (GHI) of this place is 5.31 kWh/m^2/day figure **Fig 2** (average of 5 kWh/m^2/day in almost all the districts) [1-4] and average monthly data is given in **Fig3**.

Fig. 1(a): The political map of Khorda district

Fig. 1(b) the annual average GHI, Khordha(MNRE)

Generally, the design and development of a solar power plant followed by site survey, premilinary work and approval, design and engineering, order finalization by EPC, material delivery, civil and mechanical works, DC works and AC works [5-7]

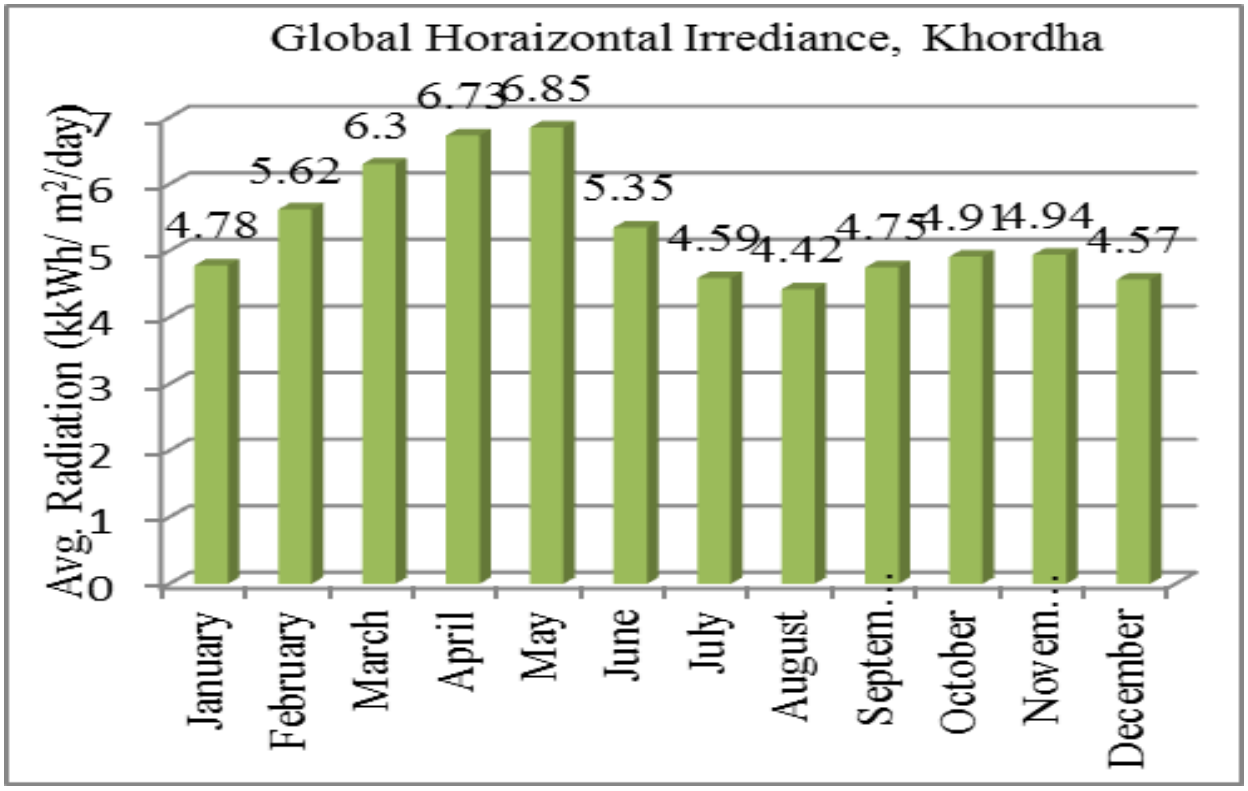

Fig. 3**:** Monthly global horizontal irradiance of Khordha, Odisha

The present study aims at:

- To compute the performance of 1MW SPP.
- The Parameters that is influencing the deteriorated performance of the present SPP plant;
- To analyze the design and resolve improvement criteria for better performance of the SPP.
- Prepare the strategic plan for optimization of the performance of present SPP.

Solar PV systems are On-grid and Off-grid types [8-10]. On-grid solar power system is an electricity generation system which includes solar PV modules, inverters, transformer and electrical appliances. The solar PV module consists of solar cells which is fitted on a mounting structure. Each Si-cell is able to produce a maximum open-circuit voltage (Voc) between 0.5 to 0.6 volts, short-circuit current (Isc) between 28 to 40 mA/cm^2 and efficiency lies between 10 to 22% [11-16]. A solar PV array is the total power-generating unit, including all the PV modules and strings. The transformer is synchronized with utility grid for further power utilization through transmission and distribution.

system. An off-grid system is not synchronized to the utility grid, therefore requires storage system for further power use by customer during need [17-19]. A block diagram of a grid-connected SPV power plant is presented in figure 3.

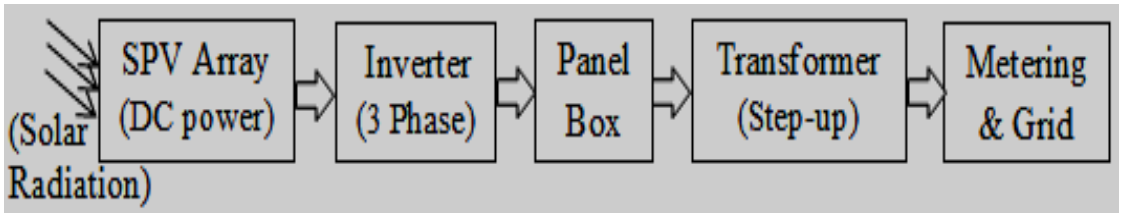

Fig.4(a): Block diagram of power yield from a SPP

The complete structure of 1 MW solar power plant is given in the **Fig 4 (a) and Fig 4(b).**

Fig. (b): One MW on-grid SPV power plant at Khordha, Odisha

The observation, calculation and experimentation data of one MW on-grid SPV power plant is given in **Table 1**.

Table1. Project details of installed one MW on-grid SPV power plant.

Type of Installation	Ground Mounted
Shading Consideration	Shadow free
Maximum Solar Insolation at the site	6.85 kWh/m^2/ day
SPV Power Plant Capacity	1 MWp
PV Module type	Polycrystalline
Efficiency	15%
Tilt angel	Approx. 25^0 N
Facing of Modules	South-East
No. of SPV Modules	1MWp/250Wp = 4,000
No. of SPV String	40
PV Modules Connection in each String	Series
Inverter	Two numbers of 500 kW, 3 phase & MPPT type
Transformer	1250 kVA
Circuit Breaker	Inverter to Panel box = 1000A 3p; Panel box to Transformer = 1600A 3p
Isolator	Vmax= 12 kV; Imax=1250 A
Cables (Copper)	DC Side= 10 mm^2; AC Side = LT: 15 mm^2 & HT: 180 mm^2
Grid Voltage	11 kV
Phase Connection	3-phase
Grid Frequency	50 Hz
Occupied Area	5.5 Acres

Operation

The SPV power plant consists of three main units, such as generation unit, control unit and transmission unit figure 4 [20]. The function of generation unit is to generate electricity and it consists of Solar PV modules (each of 250 Wp, polycrystalline) laying on the mounting structure, array junction box, copper cables etc. The solar PV module is an assembly of solar cells and each Si-cell can able to produce a maximum Voc of approximately 0.6 volt. The main intermediate and operational part of the solar power plant is control unit. It consists of grid-tied inverter (ABB central inverter-PVS800), lightening arrestor, grounding, control panel board and monitoring section. The last one is transmission unit and function is to transmit the available power through step-up transformer into utility grid [21, 22].

Result And Discussion

Polycrystalline modules are commonly used in solar PV power plant, as it has medium cost, widely available, high generation, more efficient and high durability [23].

The monthly power generation of one MW on-grid SPV power plant at Khurdha is given in Table 2. As per their tariff agreement with government, the cost is Rs 18.72 per unit. Month wise generation of power through Bhusundapur, Khurdha SPP is in **Fig 5**

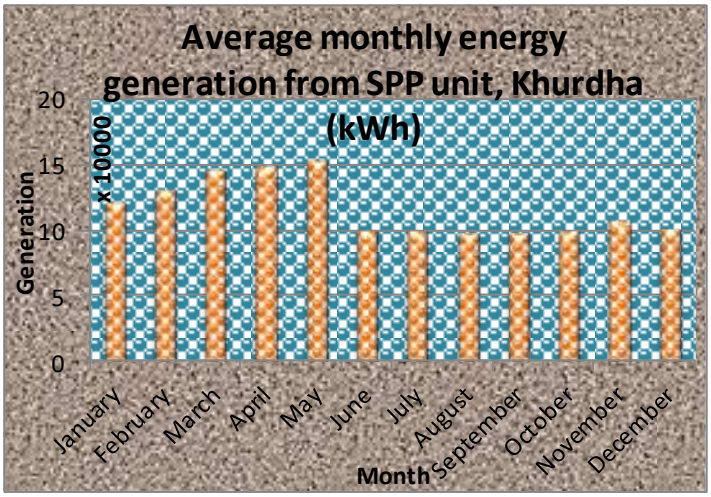

Fig. 5: The average monthly generation of the SPP, 2020, Khurdha(Dec-2020 data is estimated)

In the Indian solar context, Performance Ratio (PR) and Capacity Utilization Factor (CUF) are used for performance evaluation of a plant. PR is an enhanced way than CUF to determine the quality of plants on yearly basis. It also helps to calculate the Payback Period (PB) of the total installed system [24-26]. The PR, CUF and PB are evaluated using "equations (1), (2) and (3)".

$$PR=\frac{Energy\ Measured\ (kWh)}{Installed\ Plant\ Area*PV\ Module\ Efficiency*Irrediance\ Measured} = 78\% \quad (1)$$

$$CUF = \frac{Energy\ Measured\ (kWh)}{365*24*Installed\ Plant\ Capacity} = 15.98\ \% \quad (2)$$

$$PB = \frac{Total\ Installed\ System\ Cost}{Annual\ Units\ Generated*Cost\ of\ one\ Unit} = 8\ \text{years} \quad (3)$$

The above calculated data indicates a huge demand on installation of MW level SPV power plant across the country and also in the world [27].

Influencing Factors for PR of SPP:

The performance of a solar PV generation system is influenced by equipment, location, topography, and environment condition. Few major factors are:

- PV module degradation – Regular wear and tear with climatic anomalies the SPV panels deteriorate gradually and after a long span the performance decline at a faster rate. In practice rated power generation from a SPP made of solar panels degrade at @ 0.5% per annum [28, 29] , is in **Table 2**.

Table 2. Average output loss/year of solar cell

Solar Cell type	Output loss/ Year in %
Mono-Silicon	0.36%
CdTe (Cadmium Telluride)	0.4%
Poly-Silicon	0.64%
Silicon (Amorphous) (a-Si)	0.87%

- PV module temperature - temperatures reaching greater than Nominal Cell operating temperature(NOCT) can de-rate performance by 0.45% for every degree rise in temperature.
- PV module orientation and tilt angle being disturbed during Preventive maintenance activities or while doing seasonal tilt changes.
- Solar irradiance – Under varying solar radiation, the performance of modules (PV) fluctuates remarkably. This variation has a Considerable impact on the generation of heat and electricity of the PV systems [30].
- UV radiation at a place when become high degrades the performance of the PV system.
- There is shading effect due to mismatching and influence the voltage generation and individual cell's current of the PV module. Partial shading effect can be produced over single cells and that can lessen the output power of the module.
- Soiling occur due to accumulation of dirt, dust, and weathering contaminants on the PV module. There is formation of a thin layer over the module which reduces the quantum of incident light falling on one or many cells. The soiling or weathering effect can lead to 5-17% or more loss of power generation per year.
- The PID effect – Materials and it's ingredient of the modules can also deteriorate the yield of SPP. The process of encapsulation have impact on Potential Induced Degradation (PID) of the materials of SPV unit.

Conclusion and Recommendation

Based on the empirical study, the main observation, calculation and experimentation values are as follows:

- The annual average global horizontal irradiance of the Plant area is having 5.31kWh/ m^2/day.
- The table-2 depicts the losses that occurs due to material component over the total power generation which is about 1400180 kWh in 2020.
- Average output power loss/year of the panel is around 0.64%.
- The annual PR and CUF value of the plant existing has ≈78 %, and ≈15.98 % and payback period of about 8 years.

The above data indicates that the plant output is degraded in every year. A good O&M process, a good monitoring system, a good trouble shooting process and above all is very crucial for the success of the plant and can mitigate the energy crisis in future.

Acknowledgement

The authors express their hearty thanks to the administrations of the One MW SPP at Bhusandpur, Khordha constructed under RPSSGP guidelines of MNRE, Odisha for providing the data for preparation of this empirical study

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