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Performance Analysis of Grid Connected Solar Photovoltaic Power Plant in Integral University-Lucknow Campus, Uttar Pradesh-India

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Abstract
The energy which can be renewed or replenished on a human time scale is called renewable energy. Renewable energy resources occur naturally, such as solar energy, wind energy, tidal energy and geothermal energy. Hydrocarbon based fossil fuels such as coal and petroleum are non-renewable sources of energy i.e., they are finitely available and will gradually dwindle becoming exhaustible or quite expensive to afford. On the contrary, the renewable energy sources replenish constantly and will never run out. Renewable energy is a source of clean energy as it does not cause pollution unlike nonrenewable energy resources which are majorly responsible for global warming and green-house effects. In this paper analysis of a grid-connected solar photovoltaic power plant at Medical Residential Complex, Integral University-Lucknow campus is carried out.

I. INTRODUCTION

India is one of the most populated country in the world and predominantly most of this population lives in villages, many of which are located quite remotely and thus it becomes nearly impossible to supply continuous electricity to these areas. Apart from this agriculture is the main occupation of the villagers and this agriculture sector is the base of Indian economy, so it becomes a necessity for the government to ensure that there is a proper electric supply for the purpose of irrigation and thus renewable sources of energy such as low cost wind-turbines and solar powered water pumps become vital for such remote areas (1).
During the last six decades, India has emerged as a country which has the largest production of energy from renewable energy resources. According to the Central Electricity Authority, Government of India, the total installed power capacity concerning renewable energy sources is 1,20,455.14MW or 34.4% of the overall energy mix as of 17 March 2019 (2).
The Government of India has launched various schemes, there is an implementation of a subset for setting up a 1000MW solar photovoltaic power plant which is connected in grid under the Jawaharlal Nehru Solar Mission. There is an amendment in the guidelines for setting up 2000MV solar photovoltaic power plant under batch 3 of phase 2 of the NSM.
Under the National Solar Mission, there is a scheme for setting up 15000 MW of solar photovoltaic power plant which is connected in grid. A scaling up of solar photovoltaic power plant connected in grid, projects from 20,000MW to 1,00,000MW by the year 2021-2022 (3).
A grid connected solar photovoltaic power system uses the solar energy to generate electricity which has a grid connection for its utility. It consists of solar panels, inverters, power conditioning unit and the equipment for grid connection.
The present paper analyses the detailing of the solar photovoltaic power plant installed on the Medical

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Residential Complex, Integral University as shown in Fig.: 1 from March-2018 to April-2019.

Fig.1: 76.8 KW Solar-photovoltaic power plant installed at Medical Residence Building, Integral University-Lucknow.

II. COMPONENTS USED IN PHOTOVOLATAIC POWER PLANT

1. *Solar Panels, Foundation and Structure Specifications*

The solar photovoltaic power plant which is installed in the Medical Residence building of Integral University, Lucknow is of 76.8 KW.

Starting with the foundation of the solar power plant, there are 52 foundations in all, thus making the number of structures at 26 as depicted in Fig.2. 21 out of 26 structures have 10 panels each in 2*5 alignment, the other 5 structures have 6 panels each in 2*3 alignment which sums up together constituting 240 panels all together. Each panel has 72 cells and the power rating of each cell is 4.5V. The dimension of each cell is 16*16 cm square. The gap between 2 panels is 5cm whereas the gap between two panel sets is 14cm.

Fig.2: Foundation and panel spacing of the Solar-photovoltaic power plant.

DESERV 3M6-320 is the model number of the panels installed by Renewsys India Pvt. Ltd. having a rated power of 320Wp, Voc (Open Circuit Voltage) is 46.18V, Isc (Short Circuit Current) rates 9.06A, Vmp (Voltage at Maximum Power) rating is 37.20v, Imp (Current at Maximum Power) is rated 8.61A, the series fuse rating and the diode rating of the module is 15A each. The modules are mounted at the fixed tilt angle of 15 degrees. The panel grid connected is done in series since we require voltage. The structure of the solar photovoltaic power plant is made up of galvanized iron which can resist the wind speed of 100km/hr. The panel is composed of polycrystalline, the horizontal one being called rafter and the vertical one purlin. The length of foundation when measured is 8 feet 6 inch each, width of each foundation is 1 foot 8 inch and height measured is 9 inches respectively. The distance between two foundations is 8 feet 20 inch.

2. *String Inverter Specifications*

An inverter is an electronic device which is connected with the solar panel via copper cable which converts direct current electricity into alternating current electricity (4). The Delta company has installed the string inverter of the model number RPI M50A 12s on the building rooftop. The DC input is 200-1000Vdc, MPPT 520-800Vdc, 1000Vdc max and the AC output is 220/380, 230/400, 3P3W or 3P4W, 50/60Hz, 50KW/50kVA nom. There are 20 modules which are connected to the inverter, the solar panels being 240 in number thus consist of 12 strings, where each string has a positive and negative wire terminal, this makes the fault detection of the system easier and simpler. The cables of the panel which are connected to the inverter are single core made up of copper and of 6mm square in dimension.

3. AC Distribution Box(ACDB)

The ACDB Panel-1 (125 OG+ 1*100A IC+1*63A IC) has rating of 125A with the serial number 580. An aluminum cable of 35mm square is connected from the inverter which converts the DC supply to AC consisting of 4 cores. The main purpose of ACDB is distribution of current and in times of power failure it provides protection in Load AC side. The ACDB also monitors the energy and power parameter using a multifunction energy meter. It also has the distribution facility to the LT panel. There are 2 inverters of 50KW of 100A FP MCCB and 30KW of 63A FP MCCB which are connected respectively in the ACDB as the total load is 76.8KW. A buzzer is also installed, in case of any fault. A data logger which is installed at the bottom of the ACDB is an electronic device that records data with a built-in chip installed by the manufacturing company or via external instruments or sensors, partially they are based on a digital processor.

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4. *Switch Phase Unit(SFU)*

The switch phase unit is for the purpose of safety in case of any faults detected (5). The SFU installed by the Clean Max Solar with the serial number 583 has a rating of 125A/415V. The SFU is also used to cut off the DC supply fully.

5. *LT Panel*

An LT Panel is an electrical distribution board or panel which receives the ac power supply from the solar photovoltaic panel via ACBD and mainly functions to distribute the same and thus the power is supplied to various individual panels via LT Panel for electric supply.

6. *Earthing and Lightening Arrestor*

Earthing of the solar panels is required if the panels are in the surrounding areas of a lightening conductor system which means that the distance between the panel and the lightening conductor is less than 60cm. 5 earthing pits and pure zinc is used in this photovoltaic power plant as illustrated in Fig.3. The earthing rod is composed up of copper with the rod length 10 feet and its diameter being 17.2mm. The distance between each earthing rod is 3m and the minimum resistance is of 1 ohm. The depth of earthing is 10 feet where 5 feet of depth is considered minimum. To prevent the solar photovoltaic power panels from lightening damages, lightening arrestors are being used. A lightening arrestor of 2 -AC, 2-DC has been used in this solar power plant.

Fig.3: An Earthing pit installed for the Solar-photovoltaic power plant.

III. METHODOLOGY

A grid connected solar panel requires performance analysis and in order to check in the performance of the solar panel (6). Certain parameters have been taken into consideration by the International Energy Agency to analyze the performance of the photovoltaic power plants. Some parameters are mentioned below:

1. *Total energy generated by the PV system*

The total energy generated by the photovoltaic power plant is obtained via data handling which is 103668KWh.

2. *Final Yield*

The final yield is defined as the ratio of the total AC energy generated by the photovoltaic system for a definite period of time to the rated output power of the photovoltaic plant (7). Final yield is denoted by:

Final yield=total AC output (in years)/rated output power

=103668KWh/320Wp

=323.9625KW

3. *Reference Yield*

The reference yield can be defined as the ratio of total in plane solar isolation at annual average to the array reference radiance (8).

Reference yield=total in plane solar isolation, annual average/array reference radiance

$=51.98(KWh/m^2)/12$ months$/1KW/m$^2

$=4.33(KWh/m^2)/(1KW/m^2)$

=4.33 hours.

The reference yield merely represents the number of hours per day during which the solar radiation would require to in reference irradiance (the power per unit area received by the sun) level in order to produce the similar monitored incident.

4. *Performance Ratio*

The ratio of the final yield to the reference yield is called the performance ratio. It also indicates the overall effect of loses on the output power.

Performance ratio = final yield/reference yield =323.9625KW/4.33hrs =74.81%

The performance ratio is referred to as a dimensionless property that indicates the total amount of net output energy. The performance ratio is also one of the major indicators to detect the quality of a photovoltaic system in operation (9).

5. *Capacity Factor*

The capacity factor is defined as the ratio of the output generated energy measured in KWh to the

amount of energy, the photovoltaic system would generate if it operates at full rated power for 24 hours a day for a year. It is given by the formula:
Capacity factor=generated energy measured in KWh/(365*24)* installed capacity.

=103668/(365*24*76.8)
=103668/672768
=0.1540
=15.40%

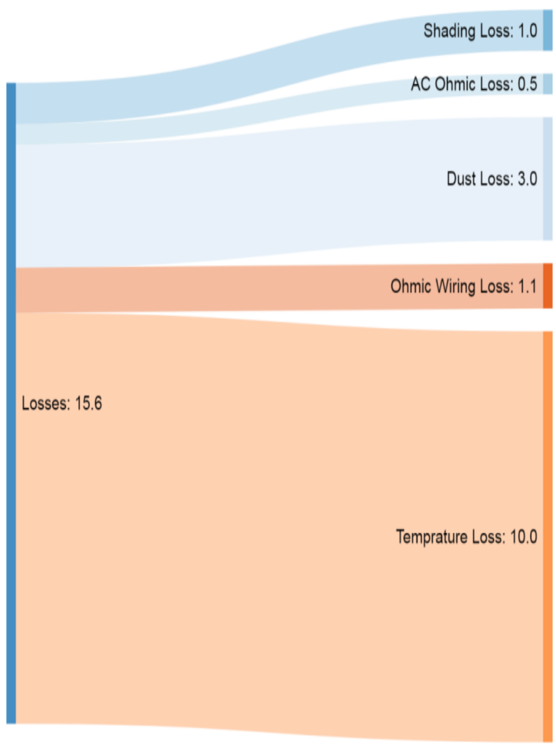

Fig.4: Sankey diagram representing the various losses in percentile of the solar photovoltaic power plant.

IV. CONCLUSION

To overcome the losses of the solar photovoltaic power plant as demonstrated in Fig.4 and make the plant more efficient, several improvement techniques can be taken under consideration:

1. At the installation areas of the power plant, the shaded areas can be avoided in order to ensure no shading loss.
2. Cleaning the plant on a regular basis can avoid the dust loss in the solar power plant .
3. An increase in temperature can intervene with the efficiency of the power plant resulting in temperature loss so an increase in temperature should be prevented.
4. Introducing the perovskite cell instead of the regular solar floor cells can reduce the costs dramatically according to David Fenning, Professor of Nano-engineering at the University of California, San Diego (10).
5. The stacking of two kinds of solar cells can be done for a higher efficiency gain in the power plant and is referred as tandem photovoltaics (11).
6. The concentrated photovoltaic technology uses optics such as mirrors and lenses to focus direct sunlight on the power plants. The advantage of the concentrated photovoltaic cell over the non-concentrated one is that it requires the usage of a smaller number of solar cells for the same power output.
7. The rotatory solar panels can be introduced for the power efficiency of the plant. The panels can rotate along the sun so as to ensure the maximum penetration of the sunlight and thus ensuring the maximum power output (12).

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