Design and Analysis of Structure for 5KW Rooftop Solar Power Plant

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Abstract— The article presents basic data on a 5 kW (rooftop) solar PV plant need to install on the building of the Faculty of Mechanical Engineering (ME building) in GF's GCOE Jalgaon and the equipment for the estimation of its performance and energy efficiency depending on the real climate conditions (inverter, communication system, automatic meteorological station, etc.). The aim of the article is to design the Rigid structure or frame having long life & to obtained results in the integration of solar energy generation into a MSEB transmission network in order to increase the use of the solar PV plants for the commercial purposes in Maharashtra. The results of the experimental determination of energy efficiency and other characteristic parameters of the solar PV plant installed on the ME building in GCOE Jalgaon on April 2017 (global solar energy, ambient temperature, wind speed, generated electrical energy, etc.). It was found that the integration of this renewable energy generation into the MSEB transmission network in Jalgaon was considered satisfactory in 2017, Which saves Rs.10000 amount per month of building. The obtained data could be used as guidelines for the application of solar PV plants in other countries with a similar cli-mate.

Key words: Solar PV plant, Energy efficiency of solar PV plant, Performance Ratio (PR) of solar PV plant, Yield factor of solar PV plant (Yf), Capacity factor (CF) of solar PV plant

I. INTRODUCTION

A. Power Scenario in India

The electricity sector in India supplies the world's 6th largest energy consumer, accounting for 3.4% of global energy consumption by more than 17% of global population. About 70% of the electricity consumed in India is generated by thermal power plants, 21% by hydroelectric power plants and 4% by nuclear power plants.[1] More than 50% of India's commercial energy demand is met through the country's vast coal reserves. In 2010, India's installed wind generated electric capacity was 13,064 MW. Additionally, India has committed massive amount of funds for the construction of various nuclear reactors which would generate at least 30,000 MW. In July 2009, India unveiled a $19 billion plan to produce 20,000 MW of solar power by 2020. Some large projects have been proposed, and a 35,000 km² area of the Thar Desert has been set aside for solar power projects, sufficient to generate 700 to 2,100 giga watts. Over the span of three years more than 16,000 solar home systems have been financed through 2,000 bank branches, particularly in rural areas of South India where the electricity grid does not yet extend. Earth's orbit, the average solar radiation intensity is 1367 kw/m^2.Circumference of the Earth's equator is 40000 km, thus we can calculate the energy the earth gets is up to 173,000 TW. At sea level on the standard peak intensity is 1 kw/m^2, a point on the earth's surface 24h of the annual average radiation intensity is 0.20 kw/m^2, or roughly 102,000 TW of energy. The total amount of solar energy resources is ten thousand times of the energy used by humans, but the solar energy density is low, and it is influenced by location, season, which is a major problem of development and utilization of solar energy.

II. REVIEW OF LITERATURE

The following survey is taken from ("Solar power plant optimization" Tinton Dwi Atmaja and Ghalya Pikra**)** A Research Centre for Electrical Power and Mechatronics – Indonesian Institute of Sciences, Bandung 40135, Indonesia. . For the last several decades, there is a significant increased investment for investigation, research, and development to produce sunlight derived clean electricity. There are two main device categories utilized to generate electricity from sunlight i.e. photovoltaic and concentrated solar power (CSP). Photovoltaic use solar cells to generate electricity directly via photovoltaic effect, while CSP captures solar thermal energy to produce heat and thermally convert in to electricity. Concentrated solar power has been developed based on a simple general scheme: sunlight captured by mirrors and absorbed by receiver at focal point, and heat can be collected to generate electricity. Solar collector will produce high temperature steam to drive turbine of the common Rankine cycle or of an integrated combined cycle. To operate during cloudy weather, low solar irradiation hours, or during night time, the system can be implanted with several methods of heat storage or directly supplied with conventional fuels (usually natural gas). Recent research states that parabolic dish with a Stirling engine at the focal point have the highest solar-to-electric efficiency of 31.25%; Nowadays there are 20 active parabolic trough power plants worldwide with 27 more CSP plants are being constructed, five active solar tower power plants worldwide with two more solar tower are being constructed, three active power plants with Fresnel reflectors plants worldwide with one more Fresnel reflectors power plant is being constructed, and only one active parabolic dish power plant in USA with one more parabolic dish power plant is being constructed in Spain. More details about these systems can be found in.

CT	Parabolic Trough Collector	Linear Fresnel Reflector	Solar Tower Collector	Parabolic Dish Reflector
OTR	50-400	50-300	300-2000	150-1500
RTE	low	low	high	high
RC	Low	Very low	High	Very high
CR (sun)	15-45	10-40	150-1500	100-1000
TM	Very mature	mature	Most recent	recent
T	One axis	One axis	Two axis	Two axis

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Table 1: Description and Specifications of the Four Main CSP Technologies

Where,

Collector Types : CT
Operating Temp. Range : OTR
Relative Cost : RC
Concentration Ratio (Sun) : CR
Technology Maturity : TM
Tracking : T

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India is yet to gain experience in building and operating solar thermal power plants on the megawatt scale. Solar energy account for less than 1% of the total energy produced in India. While photovoltaic power plants continue to dominate in India, the Concentrated Solar Power (CSP) market has yet to build, operate and maintain its first large scale solar thermal power plant in India. The Jawaharlal Nehru National Solar Mission (JNNSM) was introduced in 2010. The aim of this mission is to create an enabling policy framework for the deployment of 20,000 MW of solar power by the year 2022. In the first phase of the national solar mission, out of the 620 MW allocated by the federal government, 470 MW was allocated to solar thermal power and 150 MW to solar photovoltaic power. The majority of these projects are located in the desert state of Rajasthan, the sunniest region in the country. This project with its sets of vagaries and triumphs has been a maiden attempt to pave the way for understanding and institutionalising the CSP market in India.

A. *Existing Solar Technology*

PV cell technologies are broadly categorised as either crystalline or thin-film. Crystalline silicon (c-Si) cells provide high efficiency modules. They are sub-divided into mono-crystalline silicon (mono-c-Si) or multi-crystalline silicon (multi-c-Si). Mono-c-Si cells are generally the most efficient, but are also more costly than multi-c-Si. Thin-film cells provide a cheaper alternative, but are less efficient.6 There are three main types of thin-film cells: Cadmium Telluride (CdTe), Copper Indium (Gallium) Di-Selenide (CIGS/CIS), and Amorphous Silicon (a-Si). The performance of a PV module will decrease over time due to a process known as degradation. The degradation rate depends on the environmental conditions and the technology of the module. Modules are either mounted on fixed-angle frames or on sun-tracking frames. Fixed frames are simpler to install, cheaper and require less maintenance. However, tracking systems can increase yield by up to 45 percent. Tracking, particularly for areas with a high direct/diffuse irradiation ratio also enables a smoother power output. Inverters convert direct current (DC) electricity generated by the PV modules into AC electricity, ideally conforming to the local grid requirements. They are arranged either in string or central configuration. Central configuration inverters are considered to be more suitable for multi-MW plants. String inverters enable individual string Maximum Power Point Tracking (MPPT) 7 and require less specialised maintenance skills. String configuration offer more design flexibility. The performance ratio (PR) of a well-designed PV power plant will typically be in the region of 77 percent to 86 percent (with an annual average PR of 82 percent), degrading over the lifetime of the plant. In general, good quality PV modules may be expected to have a useful life of 25 to 30 years.

III. Design

A. *Location Details*

Sr.No.	Station name	Jalgaon
1	Station id	2450
2	District	Jalgaon
3	State	Maharashtra
4	Latitude	$21^{0}0^{'}6.52''$ N
5	Longitude	$75^{0}32^{'}56.11''$ E
6	Elevation	254m AMSL
7	Altitude	18m AGL
8	Site address	P-51 additional MIDC Bhusawal road Jalgaon-425003

Table 2: Location Details

B. *Dimensions & Material Required For Plate Mounting*

Sr. No.	Parameters	R.M.S.	Material	Qty
1	Length of M1	1210mm	GS	1
2	Length of M2	1135 mm	GS	1
3	Length of M3	465mm	GS	1
4	Nut	□□□10mm	GS	6
5	Bolt	□8□70mm	GS	6
6	Washer	□10□2mm	GS	6
7	Solar Angle	20.22°	-	-
8	Solar Plate Weight	22.5 kg	-	-
9	Solar plate dimensions	1860□□□□□42 mm	Si-Ci	16
10	Frame	5.5 Kg	GS	17

Table 3: Raw Data for Structure Design

C. *Material*

1) *Galvanized Steel*

The galvanizing process has no effect on the mechanical properties of the structural steels commonly galvanized. The mechanical properties of 19 structural steels from major industrial areas of the world were investigated before and after galvanizing in a major 4-year research project by the BNF Technology Centre, UK, under the sponsorship of International Lead Zinc Research Organization. Included were steels to Australian Standard 1511 grade. A specification, and British Standard 4360 series steels. The published BNF report 'Galvanizing of structural steels and their weldments' ILZRO, 1975, concludes that 'the galvanizing process has no effect on the tensile, bend or impact properties of any of the structural steels investigated when these are galvanized in the "as manufactured" condition. Nor do even the highest strength versions exhibit hydrogen embrittlement following a typical pretreatment in inhibited HCl or H_2S0_4. 'Changes in mechanical properties attributable to the galvanizing process were detected only when the steel had been cold worked prior to galvanizing, but then only certain properties were affected. Thus the tensile strength, proof strength and tensile elongation of cold rolled steel were unaffected, except that the tensile elongation of 40% cold rolled steel tended to be increased by galvanizing. 1-t bends in many of the steels were embrittled by galvanizing, but galvanized 2-t and 3-t bends in all steels could be completely straightened without cracking'.

D. Flow Chart

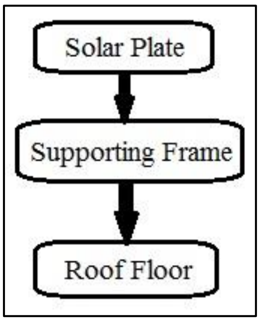

Fig. 1: Direction of Supports

E. F.B.D. of Structure

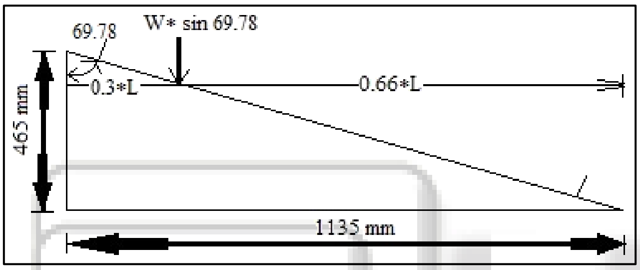

Fig. 2: Free Body Diagram

IV. CALCULATIONS

a) Mass of Plate is 22.5 kg
b) Weight of Plate is 22.5∗9.8 = 220.5 N
c) Vertical Component of Self Wt. of Plate =W∗sin69.78
 = 220.5∗ 0.93
 = 206.9 N
d) Designing of Screwed Joints of Angular Frame :

<u>Required values of stresses for M8 & ϕ8 are</u> :

1) Stress Area (σ_α) = $0.25\pi((d_p + d_c)/2)^2$
2) Shear Stress Across the Thread (τ_s) = P/($\pi * d_c * b * h$)
3) Compression or Crushing stresses on Threads (σ_c) = P/($\pi * n(d^2 - d_c^2)$)

<u>Available Data</u> : Diameter of Bolt (d) = 8mm.

Data as per Design Dimensions of Screw Threads, Bolt & Nut, According to IS : 4218 (part III) 1976 (Reaffirmed 1996) Table

d_p = 7.188 mm, π = 3.14, b = 0.25 mm
d_c = 6.466 mm, n = 8, d = 8 mm
P = 206.9 N,

$\sigma_\alpha = 0.25\pi((7.188 + 6.466)/2)^2 = 36.58$ N/mm^2

$\tau_s = 206.9 /(3.14*6.466*0.25*8) = 5.09$ N/mm^2

$\sigma_c = 206.9 / (3.14*8(8^2 - 6.466^2) = 0.37$ N/mm^2

V. VIRTUAL MODEL OF STRUCTURE USING CATIA V5 R19 SOFTWARE

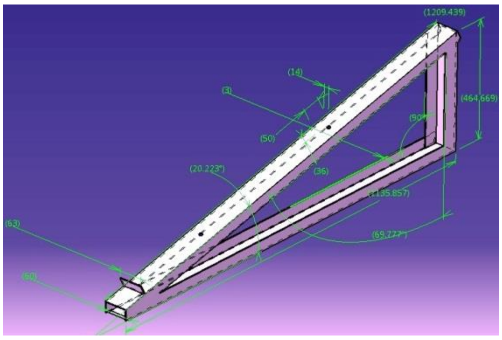

Fig. 3: Supporting GS Structure of Solar Plate

VI. STRESS ANALYSIS OF STRUCTURE USING CATIA V5 R19 SOFTWARE

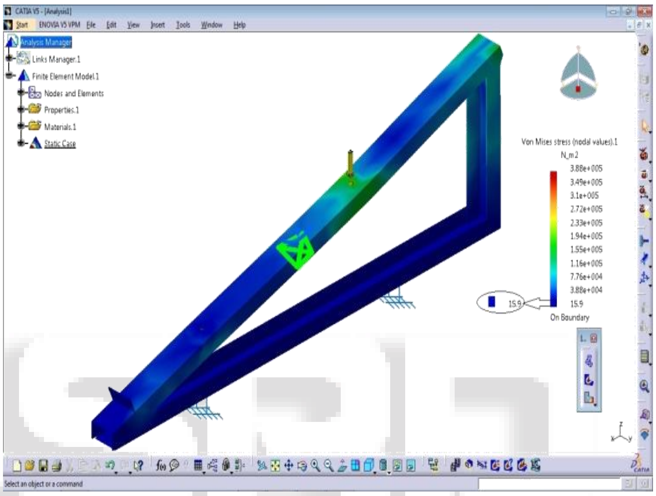

Fig. 4: Stress Analysis of Supporting GS Structure of Solar Plate

VII. RESULTS

As shown in Stress Analysis Fig.4., most of the surface area is having Blue & Green colour, which means there are formation of Normal Vonmisses stresses as Shown in colour band.

VIII. CONCLUSION

Rooftop solar PV systems offer an attractive option for future development. While using a roof space introduces some degree of complexity to a project, there are also technical and commercial benefits. Commercial benefits for developers include avoidance of land costs, offsetting electricity consumed on site at a higher value than exporting, and the opportunity for an onsite grid connection point. Consenting timeframes and costs for the project may be reduced due to avoidance of land impact. There are also educational, marketing, and entrepreneurial opportunities introduced by implementing renewable energy at the point of use as well as local job demand.

All the values of deformation and von misses stress calculated with CATIA V5 R19 software is comparatively lower than Standard values and hence, we can conclude that design is safe.

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