Comparative Analysis of Solar Panels for Central Indian Weather Condition: An Experimental Investigation

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Abstract- Over the past quarter century, India has widely adopted photovoltaic (PV) technologies for social and economic development. India is the world's biggest consumer for small rural solar electric systems used for residential power, refrigeration, irrigation, distance education and hybrid systems. The use of PV systems has increased dramatically from an initial concept pioneered by a few visionaries to many thriving businesses throughout the rural regions today.
Thus, it is important to compare the available technology for the Indian weather condition. The two best available solar energy conversion technology are based on monocrystalline and polycrystalline technology. The aim of the study is to evaluate the performance of the most commercially available PV modules (monocrystalline and polycrystalline) in India; the country in the south-east with wide regions in arid to semi-arid climate conditions and huge potentials for harvesting the solar power. In addition, to provide a recommendation for panel selection to the PV system consumer to choose the panels suitable for different areas in India according to the environmental characteristics in this area.
The parameters consider for the study are module temperature, ambient temperature and solar radiation are considered for the study. The IV characteristics and current voltage curve has been drawn for the comparison.

Keywords: Monocrystalline, Polycrystalline, ambient temperature, module temperature, solar radiation

I-INTRODUCTION

Solar energy is utilized to heat and cool structures (both effectively and inactively), heat water for household and modern uses, heat swimming pools, control iceboxes, work motors and pumps, desalinate water for drinking purposes, generate electricity, for chemistry applications, and many more operations.

Solar energy is the oldest energy source ever used. The sun was adored by many ancient civilizations as a powerful god. The first known practical application was in drying for preserving food (Kalogirou, 2004).

II-LITERATURE REVIEW

The research work carried out by various researchers are as follows:
Muhammad Anser Bashir et.al. (2014) in his paper shows the comparable execution evaluation of three mechanically open photovoltaic modules (monocrystalline, polycrystalline, and single convergence undefined silicon) in Taxila, Pakistan. The experimentation was done at outdoors conditions for winter months. Power yield, module productivity, and performance ratio were figured for every module and the impact of module temperature and sunlight-based irradiance on these parameters was examined. Module parameters demonstrated solid reliance on the sunlight-based irradiance and module temperature.
R.Siddiqu et.al. (2014) summarizes the electrical characteristics of two Polycrystalline silicon PV Modules. Tests are operated in outdoor exposure and natural sunlight located in Gurgaon Region of Haryana (India) as specific composite climate environment, characterized by high irradiation and temperature levels. PV modules performance assessment was performed by International Standard as symptomatic test of information, producer. Information gained by Environmental Operating Conditions (EOC) was changed over into Solar Module Output attributes at Standard Test Conditions (STC) by using technique proposed by A.J. Anderson and G. Blaesser. Then, based on the investigation results of the conversion equations, these methods of translation are distinguished by the type of Solar cell Technology and

the application range. A difference between the tests in indoor situation and in natural environment exists, attributed to various factors including effect of spectral changes over time, module temperature, impact of reflection by PV episode points and furthermore light induced degradation in crystalline silicon.

III-RESEARCH METHODOLOGY

3.1 Climate Data Analysis

Intensity of solar radiation and the price for delivery electricity significantly vary country-by-country resulting in significant differences in assessing cost efficiency of the realization of the systems. Figure 3.1 shows the Monthly Average Solar Irradiance data for Jabalpur.

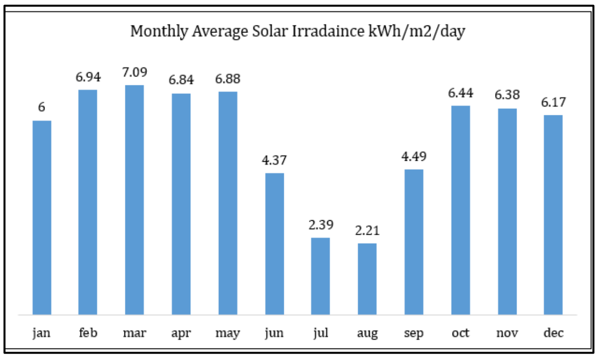

Figure 3.1 Monthly Average Solar Irradiance data for Jabalpur (Source: data.gov.in)

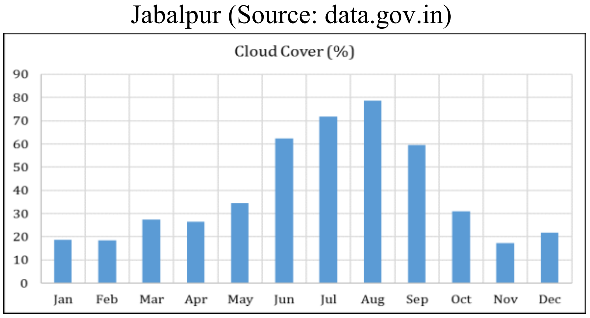

Figure 3.2 Monthly Average Cloud Cover Percentage data for Jabalpur (Source: data.gov.in)

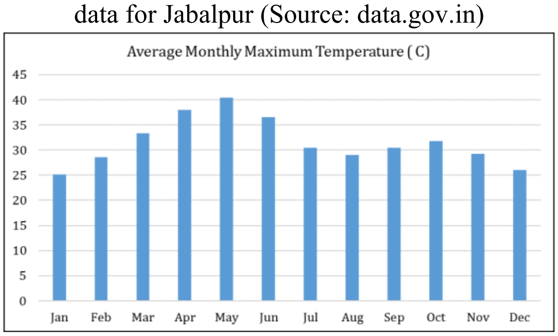

Figure 3.3 Monthly Average Maximum Temperature (°C) data for Jabalpur (Source: data.gov.in)

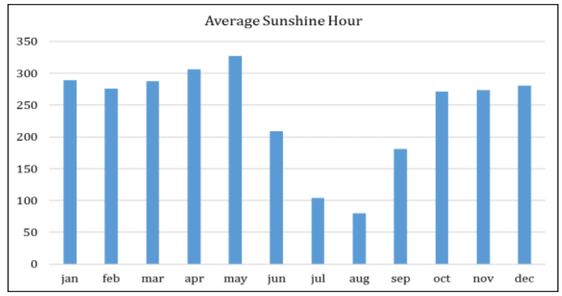

Figure 3.4 Monthly Average Sunshine Hour data for Jabalpur (Source: data.gov.in)

Figure 3.2 shows the Monthly Average Cloud Cover data for Jabalpur city for last 10 years. It can be depicted from the figure that about 8 months are having less cloud cover and beneficial for solar power harnessing.

The climate data of Jabalpur were analysed in terms of solar radiation, Cloud Cover temperature, Sunshine Hour for last 10 years. Figure 3.3 and 3.4 shows the Monthly Average Maximum Temperature (°C) and sunshine time of Jabalpur; according to the meteorological data, the average value of the global radiation ranges between 2.21 kWh/m^2 per day in monsoon season and 7.09 kWh/m^2 per day in summer. The warmest month is May, characterized by the average value of maximum temperature equal to 41°C.

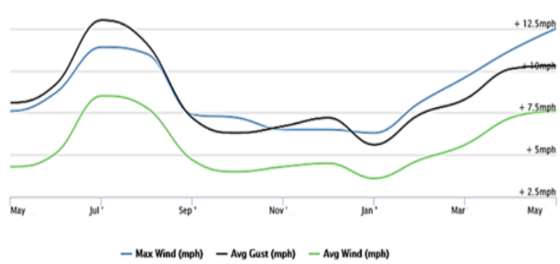

Figure 3.5 Monthly Average Wind Speed data for Jabalpur (Source: worldweatheronline.com)

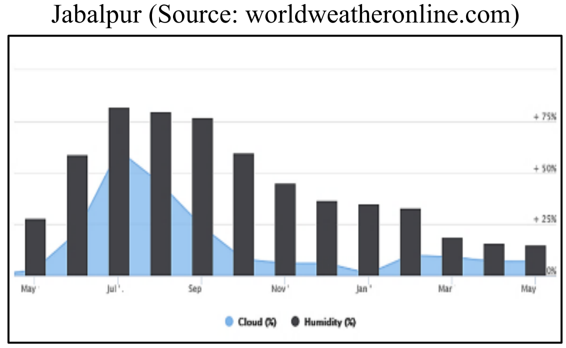

Figure 3.6 Monthly Average Cloud and Humidity data for Jabalpur (Source: worldweatheronline.com)

Another climatic variable which would effect on the productivity of the PV module is the monthly average humidity. The recorded data shows that the humidity is in the low values during the whole year; the humidity values are generally below 25% for three months and vary 25% to 40% in the cold months but reaches up to 75% in rainy season.

3.2 Theoretical Framework

As discussed by H.M.S. Hussein et. al. to analyze the performance of PV modules as a power source, their main parameters, such as short circuit current, open circuit voltage, maximum output power and instantaneous efficiency, should be determined. For simplicity, the analysis is based on the following assumptions:

The shunt resistance of the PV modules is infinite. So, the current in the shunt resistance can be neglected. (A shunt resistance is the reason for power losses it is due to manufacturing defects, rather than poor solar cell design.)

The short circuit current of the PV modules is assumed to be equal to their light generated current. (The generation of current in a solar cell, is known as the "light-generated current")

The resistance of the PV module is assumed to be not dependent on the incident solar radiation and the module surface temperature.

As a result of the above assumptions, the output current of a group of PV modules (I) connected in series-parallel combinations can be calculated as follows

$I = I_1 - I_0[\exp\left(\frac{V_t + IR_s}{V_t}\right) - 1]\, A$…….. (3.1)

The light generated current of the PV modules can be calculated according to the following equation

$I_1 = N_P\left(\frac{G}{G_t}\right)\{I_{lr} + \mu_{sc}(T_{pv} - T_{pvr})\}$……….. (3.2)

The saturation current of the PV modules (I_0) can be calculated as

$I_0 = CN_pT_{pv}^3\{\exp\,(-N_cN_sV_g/V_t)\}A$ …………. (3.3)

3.3 Experimental Frame work

3.3.1 Location of study

The experiments have been carried out in solar site of Gyan Ganga Institute of Technology and Sciences of Jabalpur. The two tested panels were installed on the same stand-alone frames in a similar inclination angle of PV modules. Based on the location of Jabalpur city (23.1815° N, 79.9864° E), the PV modules were placed on a south facing structure at a fixed tilt angle of 10° with the horizontal plane; this angle is near the yearly optimum tilt angle of Jabalpur for Summer season, which yields the maximum annual incident solar radiation.

3.3.2 Experimental Set-up

The test-bed consisted of two identical open-rack mounted polycrystalline and mono crystalline silicon photovoltaic panels installed side-by-side and tilted at 10° to the ground facing southwards (Figure 3.7). Both panels experienced the same instantaneous insolation levels, ambient temperatures and wind incidence the experimental set-up for finding the mass of dust settling and its effect on electrical output of the solar panels was performed in the following way. Experimentation occurred between March 2015 and May 2015.

The design specification of Mono crystalline and Poly crystalline solar panel is given in Table 3.1 and 3.2 respectively.

Figure 3.7(a) Lux meter used for measuring the solar radiation

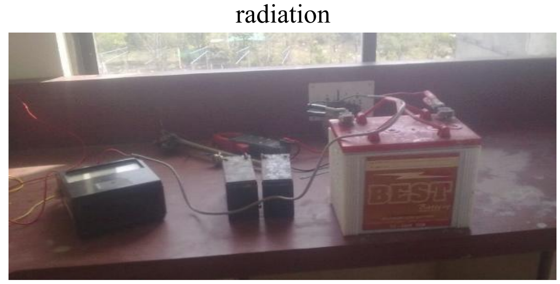

Figure 3.7 (b) Instruments used for completing the Circuit

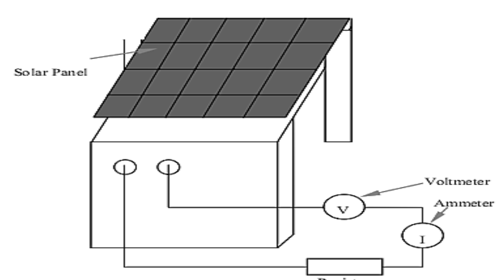

Figure 3.8 Circuit Diagram

To measure irradiation on the solar panel, a Lux meter was used (figure 3.7(a)). For the measurements of voltage and current, ammeter and voltmeter were used in the arrangement as illustrated in Figure 3.7 (b). The system's load was simulated by using different resistors.

Measurements were taken in real time with standard testing condition values. Standard testing conditions account for the differences in parameters for different testing days including temperature, air mass, wind speed, and sunlight strength.

Figure 3.9 shows the monocrystalline solar panel consider for the study and figure 3.10 shows the polycrystalline structure consider for the study.

Figure 3.9 Monocrystalline module.

3.3.3 Field Measurements

To begin testing, the battery was turned off as a safety parameter, allowing for safe cleaning. Then the panels were cleaned with water. Water was used to give a more thorough reading since it removes the smallest particles from the panel. Another data is also recordd like temperature wind velocity and humidity. The following steps are followed.

With the beginning with short-circuit the output terminals of the PV panel are shorted with a wire. Then the short circuit current and panel output voltage are measured.

A heavy-duty variable resistor is then connected to the panel, starting from lower resistance to higher one so that the panel voltage increases from zero toward open circuit in steps of approximately 2~3V. Voltage and current for each resistor are measured and recorded in the table. The data recorded is used to draw the I-V curve. This procedure is repeated.

IV-RESULT ANALYSIS

4.1 Effect of Ambient Temperature on the Efficiency of Solar Panel

The ambient temperature is an important factor in the efficiency of the PV modules, because the temperature of PV module depends directly on the internal and external heat transfer coefficients which can directly or indirectly depends on the ambient temperature and irradiance.

To find out the temperature effect on the performance of the PV module of both monocrystalline and polycrystalline, the module efficiency is considered for some working conditions during which, the solar radiation is kept constant (G = 700 ± 10 W/m^2) and the ambient temperature varies.

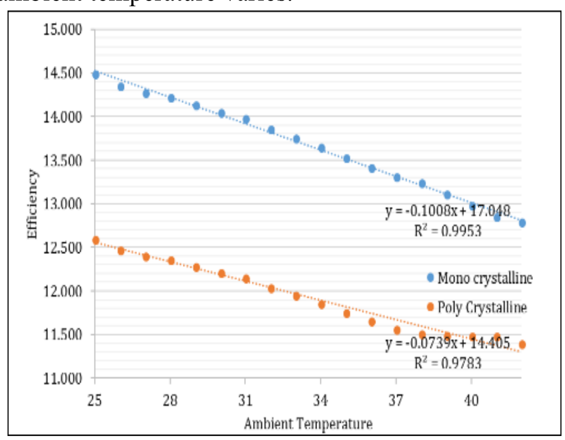

Figure 4.1 Variation in Efficiency with respect to Ambient Temperature

Figure 4.1 shows the variation in Efficiency while changing the Ambient Temperature. The R^2 value obtained from both the curve fitting is about 0.9953 and 0.9783 for Mono and poly crystalline solar panel shows the close relation in between both the parameters.

If both the panels compare on the basis of electrical efficiency at particular ambient temperature the Mono-crystalline solar panel shows higher efficiency compare then other one. But the decrement of electrical efficiency for increment of 17°C temperature from 25°C to the 42°C is less in Polycrystalline solar panel i.e. 9.52% and more in Monocrystalline solar panel i.e. 11.5%.

The equation obtained after curve fitting are as

$$Electrical\ Efficiency_{monocrystalline} = -0.1008 \times Ambient\ Temperature + 17.048 \quad \ldots\ldots\ldots\ldots\ (4.1)$$

$Electrical\ Efficiency_{polycrystalline} = -0.0739 \times Ambient\ Temperature + 14.045$……….. (4.2)

4.2 Effect of Solar radiation on the Module Temperature

Figure 4.2 shows the relation between the module's temperature and the intensity of solar radiation. It can be observed that the relationship between module temperature and the irradiance is linear in both modules; the proportionality factor in the results obtained during the experiments is about 0.039°C/W/m² and 0.053°C/W/m² for both modules i.e. Monocrystalline and Polycrystalline modules respectively.

The linear regression constant R obtained is about 0.95 and 0.85 respectively for Monocrystalline and Polycrystalline modules, which shows good relation among the parameters.

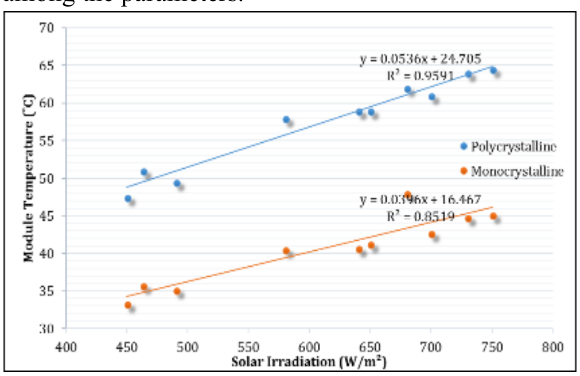

Figure 4.2 Variation in Module Temperature with respect to Solar Irradiation

The equation obtained after curve fitting are as

$Module\ Temperature_{monocrystalline} = 0.0396 \times Ambient\ Temperature + 16.467$ ……….. (4.3)

$Module\ Temperature_{polycrystalline} = 0.0536 \times Ambient\ Temperature + 24.705$……….. (4.4)

From the figure 4.2 It is obvious that the module temperature increment or heating is maximum in Polycrystalline module compare then monocrystalline module, thus more cooling is required for the Polycrystalline module and it is also the reason for lower efficiency at same ambient temperature.

4.3 Effect of Solar radiation on the IV Characteristics of Module

To find out the performance of both the solar module the IV characteristics has been find out at three different solar radiation.

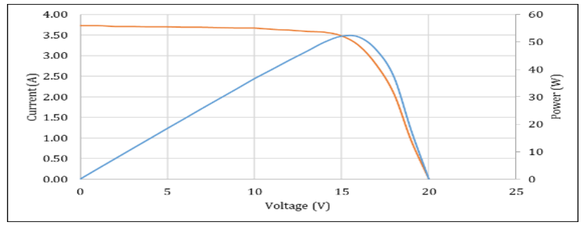

Figure 4.3 IV curve for Monocrystalline Solar Module at Solar Irradiation 690 W/m²

V.CONCLUSION

A comparative analysis of monocrystalline and polycrystalline solar panel has been carried out with the help of experimental analysis for arid to semi-arid condition of Jabalpur region. The parameters considered for the study are ambient temperature, module temperature and performance at different solar radiation. The following conclusions has been made:

1. If both the panels compare on the basis of electrical efficiency at particular ambient temperature the Mono-crystalline solar panel shows higher efficiency compare then other one. But the decrement of electrical efficiency for increment of 17°C temperature from 25°C to the 42°C is less in Polycrystalline solar panel i.e. 9.52% and more in Monocrystalline solar panel i.e. 11.5%.
2. It can be observed that the relationship between module temperature and the irradiance is linear in both modules; the proportionality factor in the results obtained during the experiments is about 0.039°C/W/m² and 0.053°C/W/m² for both modules i.e. Monocrystalline and Polycrystalline modules respectively.
3. The module temperature increment or heating is maximum in Polycrystalline module compare then monocrystalline module, thus more cooling is required for the Polycrystalline module and it is also the reason for lower efficiency at same ambient temperature.
4. while optimizing the three solar radiation conditions i.e. 690 W/m², 645 W/m² and 590 W/m². It can be observed that for monocrystalline solar panel the maximum power obtained are 53-Watt, 50-Watt and 40-Watt for solar radiation about 690 W/m², 645 W/m² and 590 W/m² respectively. While considering the polycrystalline solar panel the maximum power output reduced and about 48.5-Watt, 45 Watt and 38-Watt power is obtained for solar radiation about 690 W/m², 645 W/m² and 590 W/m² respectively.

5. The power reduction obtained about 8.4%, 10% and 5% for solar radiation about 690 W/m^2, 645 W/m^2 and 590 W/m^2 respectively. Thus, it can be concluded that monocrystalline solar panel is producing more power compare then polycrystalline solar panel.
6. It can be concluded that for monocrystalline solar panel the maximum value of current can be obtained while considering the polycrystalline solar panel the lower value compare then monocrystalline panel is obtained.

While considering the overall performance on the basis of three parameters, the monocrystalline solar panel is more efficient compare the polycrystalline panel for the weather condition of Jabalpur i.e. arid to semi-arid condition. But the cooling can be the player that can increase the efficiency.

REFERENCES

[1] Alexander Phinikarides et.al. (2014) "Review of photovoltaic degradation rate methodologies" Renewable and Sustainable Energy Reviews 40 (2014) 143–152

[2] Badia Amrouche et.al. (2014) "Improvement and experimental validation of a simple behavioural model for photovoltaic modules" Solar Energy Materials & Solar Cells 128 (2014) 204–214

[3] Carlos Eduardo Camargo Nogueira et. al. (2015) "Performance of monocrystalline and polycrystalline solar panels in a water pumping system in Brazil" Renewable and Sustainable Energy Reviews 51 (2015) 1610–1616

[4] Dietl J, Helmreich D, Sirtl E, Crystals: Growth, Properties and Applications, Vol. 5, Springer (1981) p. 57

[5] F. Z. Kessaissia et. al.(2015) "Comparison of Two PV modules Technologies Using Analytical and Experimental Methods" Energy Procedia 74 (2015) 389 – 397

[6] Henrik Zsiborács et..al. (2016)"Technical-economic study of cooled crystalline solar modules"Solar E nergy 140 (2016) 227–235

[7] Karim Menoufi et.al. (2017) "Dust Accumulation on the Surface of Photovoltaic Panels: Introducing the Photovoltaic Soiling Index (PVSI)" Sustainability 2017, 9, 963; doi:10.3390/su9060963

[8] Kalogirou,S.,1997.Solar water heating in Cyprus current status of technology and problems Renewable Energy (10),107 –112.

[9] Kalogirou, S.,2004Solar thermal collectors and applications. Prog. Energ. Combust. Sci.30

[10] Mohsen Mirzaei et.al. (2017) "A comparative analysis of long-term field test of monocrystalline and polycrystalline PV power generation in semi-arid climate conditions" Energy for Sustainable Development 38 (2017) 93–101

[11] Muhammad Anser Bashir et.al. (2014) "Comparison of Performance Measurements of Photovoltaic Modules during Winter Months in Taxila, Pakistan" Hindawi Publishing Corporation International Journal of Photoenergy Volume 2014, Article ID 898414, 8 pages

[12] M. Akhsassi, et.al. (2017) "Experimental investigation and modeling of the thermal behavior of a solar PV module" Solar Energy Materials and Solar Cells http://dx.doi.org/10.1016/j.solmat.2017.06.052

[13] Mahfoud Abderrezek, et.al. (2017)" Experimental study of the dust effect on photovoltaic panels energy yield" Solar Energy 142 (2017) 308–320

[14] Palm J, Lerchenberger A, Kusian W, Kr¨uhler W, Endr¨os A, Mihalik G, Fickett B, Nickerson, Jester T, Proc. 16th European Photovoltaic Solar Energy Conf., Glasgow (2000) p. 1222

[15] R.Siddiqu et.al. (2014) "Performance Analysis of Polycrystalline Silicon PV Modules on the basis of Indoor and Outdoor Conditions" International Journal of Current Engineering and Technology E-ISSN 2277 – 4106, P-ISSN 2347 - 5161

[16] Ulrich Stutenbaeumer et.al. (1999) "Equivalent model of monocrystalline, polycrystalline and amorphous silicon solar cells" Renewable Energy 18 (1999),

[17] Wei Luo et.al. (2017) "Potential-induced degradation in photovoltaic modules: a critical review" The Royal Society of Chemistry 2017 Energy & Environmental Science pg 43--68

[18] Yang Hu et. al. (2013) "Comparison of multi-crystalline silicon PV modules' performance under augmented solar irradiation" Mater. Res. Soc. Symp. Proc. Vol. 1493 © 2013 Materials Research Society

[19] Z. Abdin et. al. (2018) "Simulation of large photovoltaic arrays" Solar Energy 161 (2018) 163–179