To study of effect of temperature, angle of incidence, Air mass and Pollution factor on generation of solar roof top system by polycrystalline solar panel

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Abstract:
India is one of the most polluted countries in world and among the topmost polluted country. India is located on north of the equator between 8°4' north to 37°6' north latitude and 68°7' east to 97°25' east longitude. Due to this geological location solar radiation directly fall on the Indian cities. Looking to the other facts, India also comes under top populated countries after China. Hence it is obviously consider some facts like pollution, CO_2, NO_2, SO_2, CO and NO_3 emission and other toxic gases which opposes the light that directly falling on the ground. In this paper the effect of temperature, angle of incidence and similar other factors are studied.

Keywords Solar panels, Poly crystalline, angle of incidence.

1. Introduction

Solar power generation is most non polluted generation among all type of generation. Hence is becoming the first choice of the electricity generating authority all over the world. Still it is under research and development stage. Solar cell has very low efficiency and due to above facts these efficiency decreases which ultimately effects the power generation.

Solar polycrystalline panels are made up of multi crystal silicon in which there are less mobility for electrons to move hence the efficiency of such panels are less as compared to mono crystalline panels. Moreover the dimensions area for these panels is nearly same. In this paper effect of pollution and incidence angle of solar panels along with temperature on roof top systems by using poly crystalline panels are discussed.

The panel has significantly reduction in cost since the year 1975 to 2020. [1]. While calculating the power generation of solar roof top power plant, there are some points are to be considered. 1) Total energy required or utilizes by load. 2) Power Backup required for how many number of hours. 3) Future expansion of load in coming few years. According to that technical analysis are done. While installing solar roof top system these points are also consider. 1) Angle of incidence 2) Pollution level of the area in last 5 to 10 year and other point like Future expansion of load in coming next 20 year, Available space for roof top, Total shadow free area, Type of roof available at premise, longitude and latitude location of premises, Total sunny days available in that location, Air density and air pollution, Optimum temperature of location.

2. Materials And Methodology

Solar roof top system consist of solar electrical equipments which mainly of two different sections, AC section and DC section where as lighting and earthing equipment come in the category of surge and leakage voltage, current protection. The main system component are PV arrays called as PV panels, DC to AC converting inverter called as solar string inverter, DC distribution control box which include surge protecting device and DC fuse or DC MCB with a comparative rating similarly for AC side AC distribution box which consist of AC surge protective device and AC MCB
In this research paper a case study of 5 kw roof top system is consider. Total panel required for 5kw solar project is calculated by formula given below

No of panel required = P_n
Power consumed = P_c
Power rating of Solar panels=P_{wp}
Total no. of days in month = N
No of panel required $P_n = (P_c)/ P_{wh}$
Assuming total no of day in months are 30 as a standard. And solar panels rating are of 330Wp,.
Weather in India as per the meteorological department, are 2196 hr to 3020 hr. across the country. That mean total sunny days are between 220 days to 290 days across the country. Assuming 10 hr. per day as total sunshine hours. This will generate 880 unit to 1160 unit per kw.[2] For 5kw the total unit generated will be 4400 units to 5800 units per year. If we consider for a month then that would come in the range of 366.66 units to 483.33units.
According to Indian climatically condition and present panel efficiency, one kilowatt panel can generate 3.5 to 4 units per day, [2]

3. Effect of temperature on generation of solar panel: Power generation of solar cell depends of the material by which it is made. These panels are tested under standard test condition (STC). Standard cell output is tested under 25^0 degree celsius. It is clearly mention on the name plate of solar panels. Solar cell are made up of silicon which is a semiconductor material. As per the basic property of semiconductor material, conduction in semiconductor decreases as the temperature increases.
The effect of temperature can be effectively seen from the value of V_{oc} , where this voltage depends on the reverse saturation current I_o. The current I_o can vary significantly with temperature.

$$I_o=1.5 \times 10^5 e^{-E}g/kT \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

From eq. (1) it can be clearly stated that with increase in band gap, I_o decrease, which results in increase in V_{oc} . where kT is thermal energy, and ^{E}g is energy band gap.
Similarly from the equation V_{oc} , relationship of Temperature with V_{oc} can be identify

$$V_{oc} = (kT/q) \ln (I_L/K_2) + (E_g/q) \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

On differentiating eq. no (2) with respect to T and replacing k_2 in term V_{oc}. Resulting the final equation of V_{oc} as a function of temperature.

$$[d(V_{oc})/dT] = [(1/T)(V_{oc}-(E_g/q))] \ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

Term (E_g/q) will be always higher than the open circuit voltage Voc in equation no (3) therefore the change in Voc due to the temperature will be always negative, hence it can be seen that when Voc decreases the temperature of the cell increases. Where E_g is a band gap linearly extrapolated to absolute zero
Efficiency of solar cell can be written as

$$\eta = V_{oc} \times I_{sc} (FF/P_{in}) \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

And peak power output

$$P_{max} = V_{oc} \times I_{sc} \times FF \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

Conclusion from the above equation " If the temperature increases significantly, efficiency (η) and power output P_{max} decreases. Or it can be also seen from the equation (6) [3]

$$\eta\downarrow = [(I_{sc}\uparrow V_{oc}\downarrow FF)/P_{in}] \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (6)$$

4. Effect of angle of incidence on generation of solar cell: Sun continuously radiate 174×10^5 watt toward earth. These incoming solar irradiations are at the upper atmosphere. When it meets the atmosphere, out of these 6% get reflected and 16% is absorbed. When solar radiation passes through the earth's atmosphere, it undergoes several interactions with gases like CO_2, Ozone, Water vapours and other atmosphere particles.[4] This is actually loss of radiation. Remaining solar radiation falling on the earth are absolved by solar cell and it is then converted into photovoltaic energy. During this processes amount of radiation falling on the solar cell (solar collector) which are converted into solar energy mainly depends on the angle by which it is falling on the collector is known as angle of incidence. To absolved maximum radiation from the sun, solar collector are put perpendicular to the sun. The angle of incidence θ is define as the angle between the direct sunbeam or sunrays and normal of the solar collector. Generation of solar energy depends on the intensity of beam or direct

radiation making an angle θ with a solar collector normal. Which is shown in fig. 1. The total amount of radiation incident on the solar collector surface, I is given by equation (7)

$$I = I_b \cos\theta \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (7)$$

Where Ib is the instantaneous value of beam,

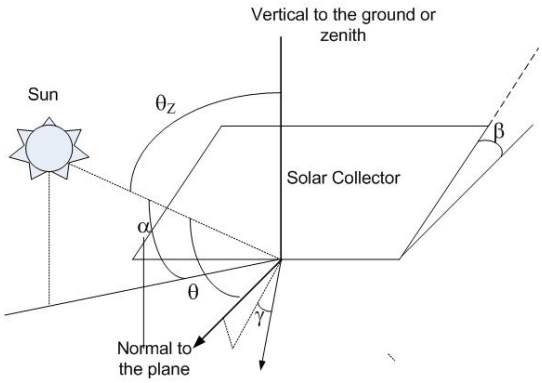

Fig 1. Schematic representation of angles α
Angles b, Angle γ

Where θ is the in the incidence angle, which depends on the many parameters like 1) Location of collector or Latitude of locationΦ. 2) Time of the year δ and 3) Time of the year ω. 4) Inclination of surface β 5) Orientation of collector γ. [5]. Incidence angle & other angle can be given in the form of equation (8) as

Cos θ = sinϕ (sinδ cosβ + cosδ cosγ cosω sinβ) + cosϕ (cosδ cosω cosβ- sinδ cosγ sinβ) + cosδ sinγ sinω sinβ)..----------(8)

When the collector surface is facing towards south, azimuth angle becomes zero. Hence equation (8) becomes

Cos θ = sinδ sin (ϕ-β) + (cosδ cosω cos(ϕ-β)……(9)

Similarly when collector surface is lying flat on the ground, its angle with horizontal plane becomes zero. i.e. angle β becomes zero. Hence equation (8) becomes

Cos θ = sinϕ sinδ + cosϕ cosδ cosωβ ……..…….(10)

From equation (9) and (10) it can be concluded that total amount of radiation incident on the solar collector surface affected by the term Cosθ. Similarly the generation of solar which is given by equation (5) also affected, resulting variation in efficiency.

5. Effect of air pollution on solar power generation : Generation of photovoltaic energy mainly depend on the clean solar radiation falling on the solar panels. While reaching to the ground, these radiation are abstracted by air particles, water vapours and other factors like air mass. In this paper effect of air pollution is studied. Power generation in photovoltaic process is that process in which solar radiation are absolved by the solar cells and the by the effect of photovoltaic, it is then converted in solar energy. Atmosphere contains lot of air dust particles and moisture which oppose the wave length of light or radiation falling on the ground. Similarly some particles get deposited on

the collector surface. Due to deposition of these moisture particle led to decreasing the temperature of PV panels which result in increase in potential difference and help to increase power output by 5.6% [6] But this is only case when the ambient temperature is more than 27 to 29 degree celsius. Specially this will help in summer where normal temperature is above 40 to 45 degree celsius. But accumulation of dust particles reduces the power output by 8.80% tending to decrease in efficiency by 11.86% [6]. Comparison of dusted panel vs clean panel is shown in fig. 2 (a) and Fig. 2 (b).

Fig. 2 Dusted Solar Panel (a) **Vs** Fig. 2 Clean Solar Panel (b)

6) Effect of Air density factor AM on Solar power Generation:

Solar radiation travels through the earth's atmosphere or air mass. The amount of sunlight scattered or absorbed depends on the length of the path of the rays. If rays have to travel a longer distance through air mass then lesser solar radiation will reach the surface. The solar irradiation in the morning & evening is less than during noon times. The radiation spectrum outside the earth's atmosphere is referred as AM0 spectrum. When sun is at overhead position, during noon, radiation travels a minimum distance through the air mass before reaching the surface. In this condition, spectrum reaching the earth surface is known as AM1. When the is at a position other than the overhead position, rays will have to travel a longer distance in the air mass to reach the surface. If sun rays are making an angle θ with the vertical at a given point on the earth's surface, then the AM that the sunrays have to travel is given by following equation.

$$AM = 1/\cos\theta$$

Suppose it is given that AM=1.5 & we have to calculate zenith angle θ

$$\theta = \cos^{-1}(1/AM)$$

$$\theta = \cos^{-1}(1/15)$$

$$\theta = 48.1896°$$

For various values of θ, cosθ will change, and corresponding value of current I. Equation (7) for the amount of radiation incident on the solar collector surface will change correspondingly.

Table 1 shows the different values of Air Mass (AM) at different sun position

Table 1: Solar Irradiation Under different Air Mass conditions

Sr. No	Air Mass	Solar irradiation reaching the surface(W/m^2)
1	AM0 (extra-terrestrial)	1376
2	AM1(sun at overhead position)	1105
3	AM1.5(sun at about 48° from overhead position)	1000
4	AM2(sun at about 60° from overhead position)	894

7) Conclusion : This study is related to the different factors affecting the generation of solar power and analysis is done for increasing efficiency of solar power generation. Angle of inclination effect the cosθ value which in turn affect the current I, and generated power, efficiency. While in summer moisture droplet help to reduce the temperature and resulting increase in power generation.

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