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Impact of Climatic Parameters on Power Generation of A Grid Connected Solar Photo Voltaic System in India

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ABSTRACT
The maximum use of natural resources (like coal, gas, oil etc) for electricity generation and diminishing trend of these resources compelling globally to use the solar photovoltaic (SPV) as a viable and eco-friendly substitute. The commercial PV conversion efficiency is the main hindrance in significant use of SPV generation technology. The geological position (span and available solar insolation) and installation design (inclination, direction, and elevation) is the main aspect for maximum generation of solar power. However, generation efficiency and output power of SPV is the main parameter to examine the performance attainment of the system after addressing the geographic location and installation design aspects. The grid connected and stand alone SPV systems in India has been shooting up in recent years due to government policies, regulation, coming up of higher efficiency solar modules and power electronics advancement. This paper shows the impact of climatic changes like irradiance, temperature, humidity, and rain on the power generation by solar photovoltaic in India.

Keywords: geographic location, Installation design, natural resources, solar photovoltaic, solar insolation

1. Introduction
The solar energy radiated from the sun reaches to the earth has high potential to generate electricity. The photovoltaic technology available for power generation is more promising. When a photon strikes on the top of the solar cell, the electrons get excited, a potential difference is created by which currently starts to flow through a load. The cost of PV module has been reduced in recent years while the efficiency is being increased; still, the main issue with the PV technology is the cost of PV module and the conversion efficiency. The Solar PV technology is more viable due to modular nature of the system, no need for additional energy resource, no rotating parts, no wear, and tear hence less expenditure on maintenance. The cost of manufacturing and installation of SPV has been decreased for the addition of every double installed capacity by nearly 20% in last two decades [1]. India has several climatic zones even though receives a significant amount of solar radiation. Since the Indian economy is largely lean on fuels derived from prehistoric organisms which are mainly imported, due to this reason, the Indian government has set up its own ministry called the ministry of new and renewable energy (MNRE) to exploit more and more renewable energy resources available. The Jawaharlal Nehru Solar Mission (JNNSM) was launched by Indian Government to prosper and advertise solar energy applications in the country. The mission aimed at grid parity by 2022 and addition of 20,000 megawatts (MW) of grid connected solar power has been planned. To fulfill the JNNSM target, it is necessary to get accurate and reliable data of solar radiation all over the country [2]. The government of India took the accord to extend the solar radiation data analysis stations. The Indian Meteorological Department (IMD) has main station taking care about measurement and regulating of weather parameters. Another 51 Solar Radiation Resource Assessment (SRRA) centers equipped with modern technology were established to gather the most accurate radiation data. Additionally, global radiation data set in crude resolution, like National Aeronautics and Space Administration-Surface meteorology and Solar Energy (NASA-SSE) has been made available. Moreover, time-sequence and terrain-based analysis have been made, and metronome software offers the value of Global Horizontal Irradiance (GHI) and Direct Normal Irradiance (DNI). The first version of radiation map measured by satellite for North West India was released in 2009 includes GHI and DNI values. The updated version of radiation map was released by NREL that include the whole country [3-4].

In this paper, the impact of different climatic factors like irradiance, ambient temperature, humidity, rain etc has been studied by simulating a grid connected solar PV system. The integrated simulation environment language (INSEL) software has been used to simulate the model and study.

Figure 1.1: Locations of SRRA stations

2. INSEL Model Development

The meteorological data for New Delhi, India has been taken from Insel Weather database.

Table:1.1 Weatherdata

Month	Irradiance w/m^2	Tambient ^{0}C	Tmin ^{0}C	Tmax ^{0}C	Humidity percentage	Rain mm
January	149	14.3	7.3	21..23	63	22
February	188	16.9	10.1	23.6	55	19
March	210	22.6	15.1	30.2	47	13
April	249	28.6	21.0	36.2	34	7
May	264	33.5	26.6	40.5	33	13
June	234	34.3	28.7	39.9	46	67
July	216	31.3	27.2	35.3	70	202
August	208	29.9	26.1	33.7	73	197
September	209	29.4	24.6	34.1	62	123
October	203	25.9	18.7	33.1	52	18
November	175	20.3	11.8	28.7	55	2
December	147	15.7	8.0	23.4	62	9
Average	204	25.2	18.8	31.7	54	58

New Delhi is situated at latitude 28.58^{0}N and longitude 77.20^{0}E and time zone is 19.The clock gives the actual time simulation with a constant increment of 1 hour. The clock calculates the hour of the year 2016. The hour of the year (HOY) is calculated by the hour of the year block [5]. The solar cell is modeled like two diodes, the voltage and the current density equation is given by:

$$j = j_{ph} - j_S\left(\exp\left(\frac{q\,(V_C + j\,r_S)}{\alpha\kappa T}\right) - 1\right) - j_r\left(exp\left(\frac{q\,(V_C + j\,r_S)}{\beta\kappa T}\right) - 1\right) - \frac{V_C + jr_s}{r_{sh}} \quad (1)$$

Where,

r_s =unit area series resistance (Ω m^2)

r_{sh} =unit area shunt resistance (Ω m^2)

α= 1 for two diode model

β= 2 for two diode model

T =Absolute cell temperature (K)

Q= Charge of an electron (1.6021 × 10^{-19}A-s)

k =Boltzmann constant (1.3854 × $10^{-23}JK^{-1}$)

Hence, the operating point of the PV generator is given

$$V = Vc \times Ns \quad (2)$$

$$I = jAc \times Np \quad (3)$$

Where,

Ac = Cell area (m^2)

Ns = Total number of cells connected in series

Np = Total number of cells connected in parallel

The current density J_{ph} (A/m^2) generated by light is proportional to the global radiation G (W/m^2) and is assumed to be directly lean on the absolute temperature of a cell T (K) [6-8].

$$J_{ph} = (c_{ph} + c_t T)G \quad (4)$$

Where

c_{ph} =current density coefficient (V^{-1})

c_t =current density temperature coefficient (V^{-1} K^{-1}).Js and Jr are the saturation current densities dependent on temperature is given by:

$$j_s = c_s T^3\, exp\left(-\frac{q\,V_{gap}}{\kappa T}\right) \quad (5)$$

$$j_r = c_r T^{\frac{5}{2}}\, exp\left(-\frac{q\,V_{gap}}{2\kappa T}\right) \quad (6)$$

Where

c_s = saturation current density coefficient (Am^{-2} K^{-3})

c_r = saturation current density coefficient (Am^{-2} K$^{-5/2}$)

Vgap = Potential difference of band gap (Silicon 1.12V).The potential difference of band gap is independent on cell temperature.

The maximum power point tracker (MPPT) is simulated by maximum power point (MPP) block. The maximum power point lower limit is 0.0 and the maximum point is 800. The error tolerance is 0.1. The MPPT calculates the maximum power point under different radiation and temperature condition. In this case, the MPP determines the maximum product of the naturally unimodal function $P = V \times I$ for a given I-V characteristic in the interval [Vmin, Vmax] as given by the parameters [9-10].

An inverter of sunny Boy 1100 SMA Datasheet is given below has been used in this model.

Table: 1.2 Inverter datasheet

Nominal Power/W	1000.0
Maximum DC power/V	400.0
Maximum DC current/A	10.0

Table 1.3: The parameters of the inverter have been taken into account as:

Nominal DC power/W	1100.0
Self-consumption/W	0.01000
voltage drop/V	0.02825
resistive losses	0.05735

3.Results and Discussion

The DC power generated by the photovoltaic module under different climatic condition has been plotted in figure 1.2 for the year 2016. In the mid of the year, the generation of electrical power is lesser due to high temperature. An inverter of sunny Boy 1100 SMA has been used to simulate the model. The datasheet of the inverter has been given in Table 1.3. The output power at the point of common connection has been plotted and with respect to an hour of the year as shown in figure 1.3. The inverter gives constant output AC power irrespective of the DC power generation. Following results have been concluded from this simulation model.

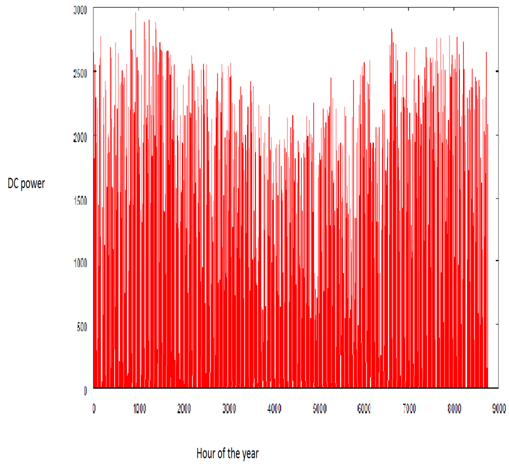

Fig 1.2: DC power generation versus HOY

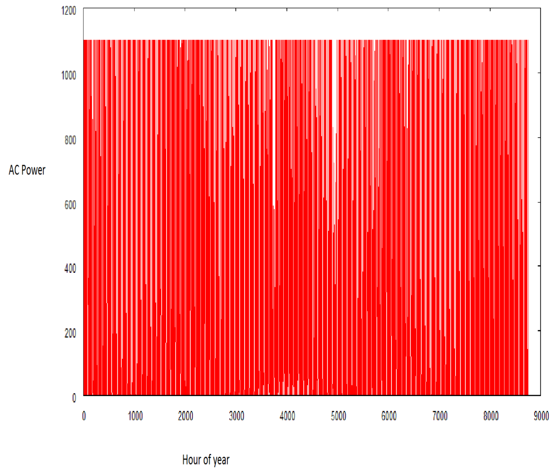

Fig 1.3: AC power generation versus HOY

(i) From figure 1.2 it has been concluded that the DC power generation is the minimum from mid-May until July, when the temperature is maximum between 40^0C-35^0C.

(ii)The irradiance alone does not affect more on the power generation by the solar photovoltaic system.

(iii) In the month of May, the irradiance is highest even though the power generation is lowest because the only irradiance does not play role in PV power generation, the humidity and rain also affects the generation.

(iv) Figure 1.3 shows that the AC power converter converts the PV power generation round the year at its maximum value which is connected to the grid.

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