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Solar Power Generation by Using P.V. Cell

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Abstract: This paper describes the solar power generation by using P.V. Cell which includes the mentioned parameters solar spectrum at the earth surface, solar irradiation under different air mass conditions, solar constants, various parameters of solar modules, open ckt. Vol-tages, short ckt. cur-rent, fill factors, maximum power, efficiency, series resistance, shunt resistance, factor affecting electricity generated by a solar cell standard test con-dition, block diagram of efficient solar power system. Parameters to be consider for efficient solar power generation like air temperature, wind direc-tion, wind speed, direct radiation, diffuse radiations, and global radiation.

Keywords: *Direct & Diffuse Radiations, Global Radiation, P.V. Cells Parameters, Electri-cal Parameters of Modules.*

1. Introduction

India is rich in natural and renewable energy resources and that these sources can supple-ment the existing energy sup-plies but can not substitute the conventional energy sup-plies. Sun is an effective black body whose outer surface has temperature of 6000 k and is emit-ting an incredible amount of solar radiations .The earth intercepts only two billionth of this radiation and saves all life on the planet from freeze to death.

India had large potential for Renewable Energy, an estimat-ed aggregate of over 100,000 MW. In addition, the scope for power generation and thermal applications using solar en-ergy is huge. Renewable energy potential in India has not been fully assessed or ade-quately tapped, while the India's fossil fuel resources are limited compared to global re-serves.

Technology for measurement of solar radiation is costly and problematic. So an alternative method for estimation of so-lar radiation is required. This technique is explained here to simulate the solar radiation system.

The obvious choice of a clean energy source, which is abundant and could provide security for the future devel-opment and growth, is solar energy. A part from sunlight and solar heating, energy of the sun is also available to us indirectly in the form of biomass, wind energy and hydroe-lectric energy, and has many advantages over the conven-tional energy sources. In this paper, a mathematical model is developed to simulate the availability of solar radiation in India.

2. Solar Energy: Advantages

It is an everlasting, renewable energy source. It is clean en-ergy source, no potential dam-age to the environment. It is a very large source of energy. The power from the sun inter-cepted by earth is about 1.8 x 1011 MW, which is many thousand times larger than our current power consumption from all sources.

Additionally, solar energy is free, does not cause pollution and is available to all unlike fossil fuel sources, which are concentrated at some locations only. This fact provides a chance that individual can generate his own energy depend-ing on the requirement, at his place of choice. This equitable availability can also play a role in social development, espe-cially for developing countries such as India. The modular character of technology allows gradual implementation and is easier to finance.

3. Solar Spectrum at the Earth's Surface

Earth continuously receives about 174 x 1015 W of incoming solar irradiation at the upper atmosphere. When it meets the atmosphere, 6% irradiation is reflected and 16% is ab-sorbed. The sun rays outside the earth's atmosphere travel parallel to each other. When the solar radiation passes through the earth's atmosphere it undergoes several interactions (ab sorption and scattering) with the gaseous molecules (CO_2, ozone and water vapours) and other particles in the atmos-phere.

The interaction of solar radiation with earth's atmosphere is shown in Fig. (1) In the ab-sorption interaction, energy of the solar radiation is given to the gaseous molecules and other particles in the atmosphere. Thus, it is a loss of radiation.

Table I: *solar spectrum on the earth's surface*

Type of radiation	*Range of wavelengths (nm)*	*% of energy carried*
Ultraviolet Radiation	150 to 380	7.6
Visible radiation	380 to 720	48.4
Infrared radiation	720 to 4000	43
Other radiation	>4000	1

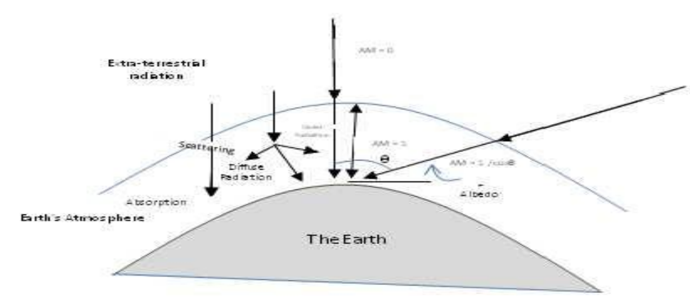

Fig 1: Interaction of Solar Radiation In Earth's Atmosphere (AM = airmass).

That radiation which does not go through either absorption interaction or scattering inte-raction, reaches the earth sur-

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face directly, and is known as direct radiation or beam radiation. Once the radiation reaches the earth's surface some of it (diffuse and direct as well) gets reflected by the ground and other objects on the ground. This reflected component is called albedo radiat ion. Thus, the total radiation reaching a given point on the earth sur-face is the sum of the diffuse radiation, direct radiation and albedo radiation. This sum is known as global radiation. On a normal sunny day diffuse radiation is about 15% to 20% of that of direct solar radiat ion.

The solar radiation spectrum that reaches the earth's surface is shown in fig. (1) On com-parison with extra - terrestrial radiat ion spectrum, one can notice that the peak irradiance is reduced to about 1600 W/m2 –nm from an extra-ter restrial irradiance value of over 2000 W/m2 –nm. This happens due to the absorption and re flection losses in the earth's atmosphere.

The solar radiation spectrum that reaches the earth's surface is shown in fig. (2) mainly consists of visible and infrared radiat ion.

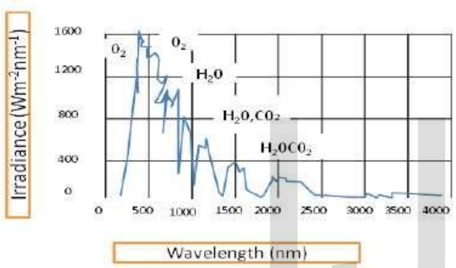

Fig. 2: Solar radiation spectrum at the earth's surface.

The UV component in the spectrum is small. The distribution of solar spectrum on the earth's surface is given in Table 1.

4. Direct, Diffuse and Global Solar Irradiation

Earth continuously receives about 174*1015 W of incoming solar irradiation at the upper atmosphere. When it meets the atmosphere, 6 percent of the irradiation is reflected and 16 percent is absorbed. The sun rays outside the earth's atmosphere travels parallel to each other. When the solar radiation passes through the earth atmosphere it undergoes several interactions (absorption and scattering) with the gaseous molecules (CO2, Ozone, water vapours) and other particles in the atmosphere. The interaction of solar radiation with Ea rth's atmosphere . In the absorption interaction, the energy of the solar radiation is given to the gaseous molecules and other particles in the atmosphere. Thus, it is a loss of radiation. Typically, about 16 % of the radiat ion gets absorbed in the atmosphere while passing through it. Due to scattering interaction, the direction of sun rays changes . This results in re-distribution of scattered radiation randomly in all direct ions. The scattered radiation is called diffuse radiation. Those radiation which does not go through either absorption interaction or scattering interaction, reaches the earth surface directly, and it is known as direct radiat ion or beam radiation. Once the radiation reaches the Earth's surface some of it (dif-fuse and direct as well) get reflected by the ground and other objects on the ground. This reflected component is called as albedo radiation. Thus, the total radiation reaching a given point on the earth surface is sum of diffuse radiation, direct radiation and albedo radiation. This sum is knows as global radiation. In a normal sunny day the diffuse radiation is about 15 to 20 percent of that of direct solar radiation. On cloudy days, diffuse radiation depends on type of clouds, and it could be very large fraction of the global radiation. The amount of albedo radiation generally depends on the nature of the surface coverage; whether there is water, snow, tall buildings, etc.

5. Air Mass

Spectrum with irradiation of 1000 W/m2. When solar radiation travels through earth's at-mosphere or the air mass (AM), the amount of sunlight scattered or absorbed depends on the length of the path of the rays. Less solar radiation will reach to the surface if rays have to travel longer distance though the air mass. This can be noticed during the morning and evening times when the solar irradiation is less than the noon. Radiation spectrum just out-side the earth's atmosphere is referred as AM0 spectrum (the number with 'AM' refers to the distance travelled by sunrays in the earth's atmosphere). When sun is at the overhead position, during noon, radiation travels a minimum distance through air mass before reach-ing the surface. In this condition the spectrum reaching earth's surface is known as AM1 When the sun is at a position other than the overhead position, rays will have to travel longer distance in the air mass (as compared to overhead position of AM1) to reach the surface. If the sunrays are ma king an angle θ with the vertical at a given point on the earth's surface, then AM that the sunrays have to travel is given by the following equation:

$$AM = \frac{1}{\cos\theta} \quad (1)$$

Solar irradiation reaching the surface under different air mass conditions are summarized in table 2. Not only the irradiation, but the spectral contents also depend on the air mass. Therefore, for characterization of solar cells irradiation as well as spectrum is defined. It is a worldwide standard to test solar cells under AM 1.5 global solar

Inclination of the axis can take several values. In particular case where ψ = Ø, meaning surface is inclined at an angle equal to the local latitude of the location. This rotation scheme is known as polar tracking, as the collector rotation axis and axis around which the earth rotates becomes same. In this case,

$$\cos\theta = \cos\delta \text{ and } \cos\beta = \cos\omega\cos\phi \quad (2)$$

From Equation 2, It can see that for polar axis tracking with constant speed of rotation θ =

δ, i.e., angle of incidence depends only on declination angle. Thus, collector rotation speed is equal to earth's rotation speed, collector's perpendicular will always be in the plane of line joining the sun-earth and its projection on horizontal plane (but not exactly perpendi-cular).

6. SOLAR CONSTANT (S):

Solar constant denoted by S is the energy from sun per unit time received on a unit surface area perpendicular to the direction of propagation of radiation at earth mean distance from sun outside the atmosphere. S value according to NASA/ASTM is 1353 watt per square meter

Factor affecting electricity generated by a solar cell

Five common operating conditions affecting the power generated by a solar cell are as follows:

- The conversion efficiency (□),
- The amount of light (Pin),
- The solar cell area (A),
- The angle at which day light falls (□), and
- The operating temperature (T).

TABLE 2. *Solar Irradiation under Different Air Mass Conditions*

Air mass	Solar irradiation reaching the surface (W/m2)
AM0(extra terristrial)	1376
AM1(sun at overhead position)	1105
AM1.5 (sun at about 48 degree from overhead position)	1000
AM2 (sun at about 60 degree from overhead position)	894

Solar photovoltaic cell parameters -

Voc - open circuit voltage, Isc - short circuit current, Pm - maximum power point,
Im, Vm – current and voltage at maximum power point FF – Fill factor,
η – Efficiency,
Rs – series resistance, Rsh – shunt resistance

Short-Circuit Current: Isc

The short-circuit current is the current through the solar cell when the voltage across the solar cell is zero (i.e., when the solar cell is short circuited). The short-circuit current is due to the generation and collection of light - generated carriers. The short-circuit current is the largest current which may be drawn from the solar cell

At

$$V=0 \rightarrow I_{total} = - I_L = I_{sc} \quad (3)$$

$$I_{sc} = q\, AG\, (W+L_p+L_n) \quad (4)$$

$$I_{total} = I_0(e^{qV/kT} - 1) - I_L \quad (5)$$

Open Circuit Voltage: Voc

It is the maximum voltage available from a solar cell, and this occurs at zero current. The open-circuit voltage corresponds to the amount of forward bias on the solar cell junction due to illumination.

$$V_{oc} = \frac{kT}{q} \ln\left(\frac{I_L}{I_0} + 1\right) \quad (6)$$

$$I_{total} = I_0(e^{qV/kT} - 1) - I_L \quad (7)$$

When

$$I_{total} = 0 \quad (8)$$

Maximum power: P_m
Power out of a solar cell increases with voltage, reaches a maximum (P_m) and then decreases again.

$$P_m = I_m \times V_m \quad (9)$$

Fill Factor: FF The FF is defined as the ratio of the maximum power From the actual solar cell to the maximum power from a ideal solar cell Graphically, the FF is a measure of the "squareness" of the solar cell

Efficiency: η

Efficiency is defined as the ratio of energy output from the solar cell to input energy from the sun.

$$FF = \frac{Max\ power\ from\ real\ cell}{Max\ power\ from\ ideal\ cell} = \frac{V_m I_m}{V_{oc} I_{sc}} \quad (10)$$

Efficiency: η

Efficiency is defined as the ratio of energy output from the solar cell to input energy from the sun.

$$\eta = \frac{Max.\ Cell\ Power}{Incident\ light\ Intensity} = \frac{V_m I_m}{P_{in}} \quad (11)$$

$$\eta = \frac{V_{oc} I_{sc} FF}{P_{in}} \quad (12)$$

The efficiency is the most commonly used parameter to compare the performance of one solar cell to another.

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Efficiency of a cell also depends on the solar spectrum, intensity of sunlight and the tem-perature of the solar cell.

Standard Test Condi tion (STC) refers to the following condi tion:

- Irradiation: 1000 W/m2, AM 1.5G global solar radi ation
- Cell or module temperature: 25 0C.
- Wind speed: 1m/s.

Parameters to be considered for designing &development of efficient solar power systemusing P.V.Cell

1	Air Temperature
2	Wind Direction
3	Wind Speed
4	Relative Humidity
5	Global Radiation
6	Direct Radiation
7	Diffuse Radiation
8	Rain (Accu)
9	Solar Azimuth

6. Modules Types

About PV modules: A solar cell produces small power, in range of less than a watt to few Watts. But for our applications we need the power in tens of Watts, kilowatts and some-time megawatts. Therefore, in order to generate larger power using solar cells, many solar cells are connected together to make a PV module. A solar PV module comes in various power ratings, ranging from few watts to few hundred watts. The most common technol ogy for solar PV modules uses crystalline Si solar. cells. The crystalline Si solar cells are fabricated using two types of crystalline Si wafers (1) mono□ crystalline and (2) multicrys-talline.

The mono □ crystalline Si solar cells are either circular in shape of pseudo square, while the multi □ crystalline Si cells are normally square or rectangular. Due to their shape the solar PV modules made using mono□ crystalline cell have empty space between the cells while the solar PV modules made using multi□ crystalline Si cells will be tightly packed and will not have empty space between the cells. The crystalline Si solar cell technology is known as first generation solar cell technology. There is also a second generation solar cell technology which include CdTe (cadmium telluride), CIGS (copper indium gallium sel-lenide) and a Si (amorphous Si). These second generation technologies are also referred as thin film technologies. These technologies are also commercially available. The PV modules that are made using crystalline Si appears bluish in color and also have thin metal contact lines (appear white) on the top. These metal contact lines are separated by few mm. In case of thin film solar PV modules these visible metal contacts are not there, because instead of metals, transparent oxides are used to make metal contacts. The colours of thin film PV module can be dark grey. PV modules of different types are shown in Figure 3.

Figure 3: Different types of solar PV modules

Various parameters of a solar P.V. module:

The various parameters of a solar PV module includes Short Circuit Current (ISC), Open Circuit Voltage (VOC),

Fill Factor (FF),

Efficiency (η), Peak Power (Pm),
Series Resistance (Rs) an
Shunt Resistance (Rsh).

Short Circuit Current:

Short circuit current ISC is the maximum current produced by a solar PV module when its terminals are shorted

Mostly Isc = IL

Open Circuit Voltage:

Open circuit voltage VOC is the maximum voltage that can be obtained from a solar PV Module when its terminals are left open.

Maximum power

This is defined as the maximum power (Pmax or Pm) output of a PV module under stan-dard test condition (STC), which corresponds to 1000 W/m2 and 250C cell temperature in PV module. Under the STC the power output of a PV module is maximum; therefore it is also referred as peak power or Watt (peak) or Wp.

Fill Factor:

The Fill Factor (FF) is defined as the squareness of the *I-V* curve and mainly related to the resistive losses in a solar module. It can be defined as the ratio of actual maximum power output to the ideal maximum power output. In ideal case, its value can be 100% corres-ponding to square *I-V* curve. But it is not feasible to have square *I-V*. There are always some losses which reduces the value of FF. The best value of FF that can be obtained for a solar module can empirically be written as a function of VOC

Efficiency:

The module efficiency is written as: Formula where, Pin is the input power. The efficiency is given in %. Normally efficiency of a PV module is specified at Standard Test Condi-

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tion (STC), which is corresponding to input power density of 1000 W/m2 and 250C cell tem-perature in PV module.

Series Resistance:

The series resistance is the sum of resistances due to all the components that come in the path of current. This includes the base, emitter, semiconductor metal contact resistance and resistance of metal contact. It is desirable to have the value of series resistance as low as possible. The effect of series resistance is to reduce the Fill Factor and hence efficiency of PV modules.

Shunt Resistance:

The shunt resistance is due to the leakage across the P-N junction. It could be due to a shunt around the periphery of cell or due to the crystal defect or precipitates of impurities in the junction region. It is desirable to have the value of shunt resistance as high as possi-ble. The effect of series resistance is to reduce the Fill Factor and hence efficiency of PV modules.

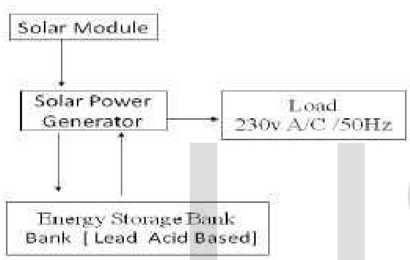

Fig. 4 Block Diagram of solar power system

7. Detailed Description of solar power system

System of this embodiment shown in fig. 4 is broadly consists of a photovoltaic array, an energy storage bank and Alternating Current Generator electrically connected to a load. Photovoltaic array a conventional design and typically consists of plurality of photovoltaic cells, which generate a potential upon absorption of radiation energy. The arrangement and connection of photovoltaic cell is for illustrative purpose only. These cells may be ar-ranged and connected as desired to obtain whatever potential is necessary. Typically, how-ever, such photovoltaic arrays so connected as to provide approximately 12 volts D.C. out-put. A 12V dc is then converted to 230V ac by Alternating Current Generator. On that any ac-operated device can work. That may be for outdoor as well as indoor purpose. Under no sun condition, Energy Storage Bank would discharge through photovoltaic array. A block-ing diode in between photovoltaic array and energy storage bank,.

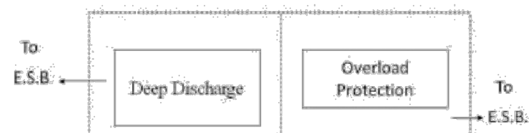

Fig. 5 explains various protections provided for energy storage bank (ESB), which is in built feature of solar power generator. First important protection provided to safe guard the ESB is trickle charging. With trickle charging, this specially designed circuitry will also disconnect battery if charging voltage increases beyond the preset level so that overcharging of ESB can be prevented.

Fig. 5 Block Diagram of Controller

If the Energy storage bank is allowed to discharge below a certain level, recharging is dif-ficult and occasionally impossible. Therefore the present invention provides a low voltage protection circuit named as deep discharge [10] for preventing Energy storage bank to sink below predetermined voltage level. Overload protection is also provided to prevent the SPG to get damaged in case of overload above certain limit. Current transformer is used to sense the over current caused by overloading and is converted to voltage by means of current to voltage converter and compared with reference voltage through differential amplifi-er to provide signal for disconnection of load from SPG. This system of present invention is a combination photovoltaic module of ac-operated load. CONCLUSION: For develop-ing and designing the efficient solar power system by using Automatic solar radiation monitoring station parameters are air temperature, wind speed, global radiation, direct rad-iation, diffuse radiation, pv cell & modules parameters are Short circuit current (ISC), Open circuit voltage (VOC), Maximum power point (Pmax), Current at maximum power point (Im), Voltage at maximum power point (Vm), Fill factor (FF), and Efficiency ( ). This system of present invention is a combination photovoltaic module of ac-operated load, Energy Storage Bank and on electronic control to circuitry to operate the load. It con-sists of a photovoltaic array capable of producing electricity from sunlight to an Energy Storage Bank A blockings device in series with that panel prevents the power storage de-vice from discharging through the photovoltaic array during periods when that array is not producing electricity e.g. on cloudy days or at night. Provision is also made to prevent the Energy Storage Bank from overcharging. This system is automatically as well as manually operated. It produces ac power.

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