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Statistical Analysis of Solar Energy Resources of polycrystalline silicon module for a Standalone system in Indian context

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Abstract - Various statistical data for different weather condition obtained using metrological reports can be used to analyze and predict the feasibility to set up a standalone photovoltaic system at different geographical locations. Various steps involved in modeling the performance of photovoltaic systems include the physical parameters of the surrounding environment that helps in determining the output power generated. For any standalone system, a design and installation at best location is required to predict the optimal renewable energy capabilities. In this paper we intend to analyze the solar irradiation for a specific period through which we can calculate DC power generated. Solar parameters, power parameters and the Power Loss parameters are determined using system advisor model (SAM) which in turn helps us to predict the actual power generated. This virtual simulation facilitates the initial design consideration to set up a standalone power plant. The gross energy yield is obtained considering all losses and this supports to calculate the output power for a given solar module.

Keywords –Photovoltaic, Modeling, Solar Irradiance, Standalone, Geographical Information system (GIS)

I. INTRODUCTION

The standard approach to validate performance models will improve understanding about the model parameters and provides information to the users [1]. Solar-powered photovoltaic system provides a clean energy solution to current global warming scenario. Research work is been carried at greater pace all over the world in terms of actual applications. The Two types of solar installation typically are stand-alone system and grid connected system [2]. In this paper, analysis of a standalone system is discussed for power parameters. For each system the array mounting, analysis of loads and modules selection are studied. The first step involves choosing a suitable geographical location for a photovoltaic system design. Even a well-established solar system with good component parameters and configuration cannot have desired power output if it is not installed at an appropriate place. PV systems face a variety of technical challenges such as physical mounting at the front end, batteries and inverters at back end, manufacturing defects along with high initial investment[3]. Author S Joshi etal gives the importance of load management system with increasing demand in generating power in a cost effective manner[17]. Authors in this paper have discussed about generation of power using a fuel cell and has indicated that the output power generated from the solar cell is very low when cells are connected in series[18].

II. PERFORMANCE MODELLING

Each predicting model has its own advantages and issues in delivering the required performance. The Performance models and financial models are used to calculate solar energy's hourly energy output with cost effectiveness. System Advisor Model is a tool to implement different renewable models and calculate the performance parameters useful in setting up a local photovoltaic grid. It uses different algorithms and databases provided by various space and metrological agencies. Analysis of modeling parameters for different geographical information system varies to large extent. In this regard few places with less weather variation will have advantage over other's with large variation. The modeling steps of initial input of solar energy, DC characteristics of PV array with current voltage relationship, DC to AC conversions by the inverter and system design approaches is indicated in fig1.

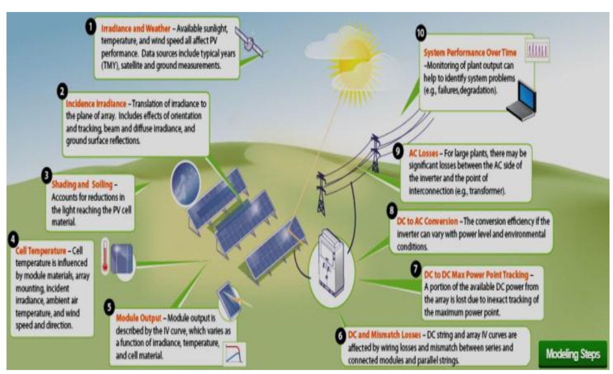

Figure 1 PV modeling steps [4]

A performance model addresses the following details of the PV system such as cell temperature, irradiance and cell material being used for the validation. Description of how the model performs for different parameter values, daily, weekly, monthly and annual statistics of model will provide details of power generated and load requirement, estimate of data losses and model uncertainties [1].
California Energy Commission (CEC) Module Model uses single-diode equivalent circuit model of a photovoltaic module described by De Soto and etal. The reference conditions of CEC model are irradiance of 1,000 W/m2 and reference cell temperature of 25◦C.

The five-parameter single-diode equivalent circuit equation for the module current I at a given voltage V is

$I=I_L-I_o\,[\exp(V+IR_S/a)-1]-(V+IR_S)/R_{sh}$

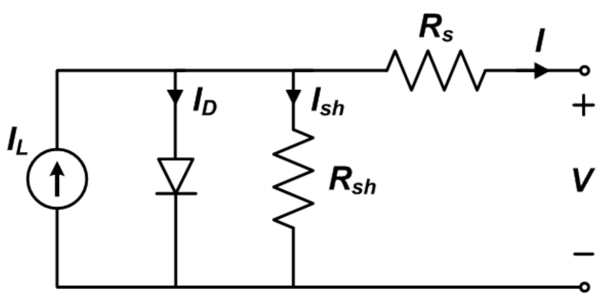

Figure 2 single-diode equivalent circuit

SAM's CEC Module Model stands as a reference in implementing the single-diode equivalent circuit model shown in Fig2 as described by De Soto. The current-voltage equation is governed by the following five parameters

i. The modified diode non ideality factor a,
ii. The light current I_L,
iii. The reverse saturation current I_o,
iv. The series resistance R_s, and
v. The shunt resistance R_{sh}.

Inverters - The function of an inverter is to transform direct current power to alternating current power. It is widely used in the systems that contain AC appliances. In real system design the inverters also integrates other components to form power conditioning unit (PCU) [5]. Power conditioning units can act as DC to DC converters and maximum power point trackers. PV inverters can be divided into stand-alone inverters and grid-connected inverters. Stand-alone inverters connect with batteries and operate independently from PV array. Grid-connected inverters connect PV array and operate in parallel with utility grids. The single diode model is a straightforward way to characterize the current voltage (I-V) of a PV module, and has been widely studied in the work ([7], [8], [9]) and deployed in several commercial software models.

Temperature response – With increase in the temperature, voltage decreases but current increases slightly. Output electrical Power reduces beyond a threshold level of temperature. Material is also subjected to decrease in performance with higher temperature in the environment leading to damage of PV modules. Places like Bangalore will have an added advantage as there are no extreme weather conditions. Voltage current at different temperature on modules are shown in the fig3 [10] [11][12][13]

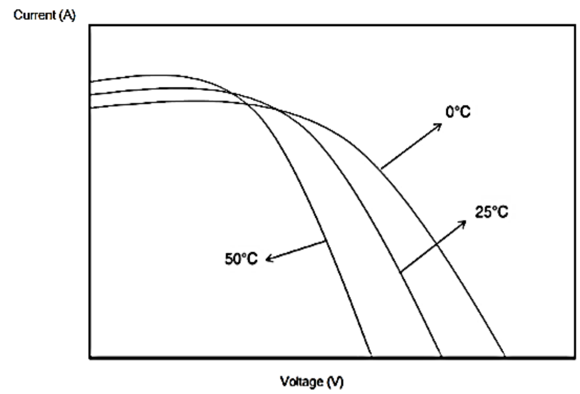

Figure 3 current and voltage response at different temperature

Solar irradiance response -Solar irradiance variation has less impact on voltage but it affects the current majorly as shown in Fig4

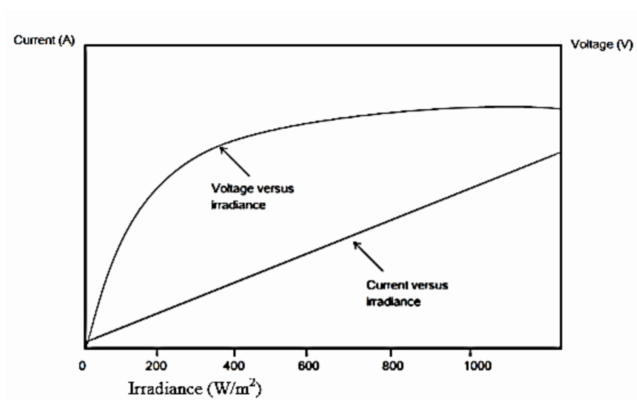

Figure 4 Output open circuit voltage and short circuit current as a function of irradiance. [14]

Statistical Analysis of various solar parameters is useful for power generation and utilization capability. Global horizontal irradiance is the total short wave solar irradiance on a surface parallel to ground or horizontal. Direct normal irradiance is the portion of solar irradiance received per unit area that is normal to sun in a direct line on a surface perpendicular to ground. Diffuse horizontal irradiance is an indirect path of arrival of solar irradiance to the surface. If even one percent of irradiance is harnessed it would be enormous amount of global energy production. Geographical information system is crucial in determining the energy production capacity for any location. Combination of geographical information system and performance modeling of various physical parameters will lead to better prediction of energy generation.

The choice of solar panel depends on power conversion efficiency and investment. Mono crystalline solar panels are made from a single crystal of silicon whereas Polycrystalline solar panel has many silicon fragments melted together and is less efficient. In this paper poly crystalline silicon is used as it is more widely used because of lesser cost and better availability for standalone systems.

III. RESULTS AND DISCUSSION

Poly crystalline silicon manufacturing process is simple and cost effective with less e-waste and is the most widely used PV panels in India. The procedures outlined provide a method of predicting the long-term performance of PV array from data taken during field test and the data is imported from weather monitoring stations [15]. Solar PV system parameters are calculated for the data obtained from the station located at Bangalore (12.9500 N, 77.6682E), India. Simulation has been carried out using System Advisor Model (SAM) [6] by National Renewable Energy Laboratory, USA. Fig5 indicates the monthly variations of different irradiance for the above mentioned location.

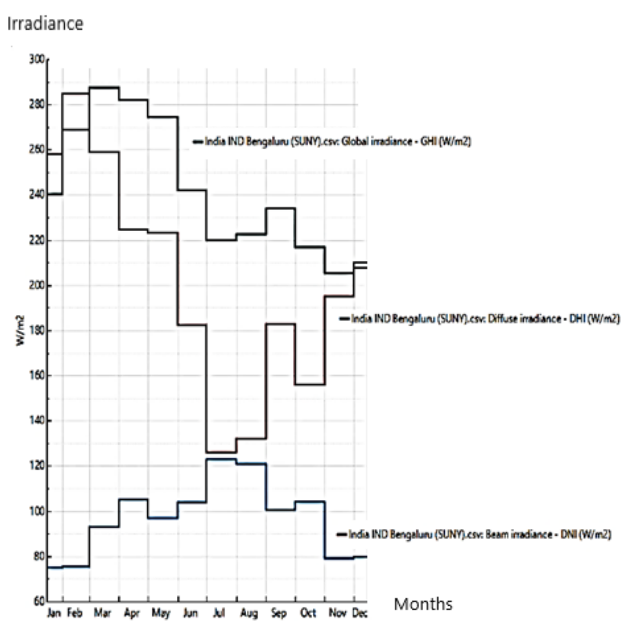

Figure 5 Bangalore's Average monthly irradiance in w/m^2

The simulation results of various solar parameters are tabulated in table1

Table 1 Solar parameters

Parameter	Value
Irradiance beam nominal (kWh/yr)	29909.8
Irradiance total nominal (kWh/yr)	49771.5
Irradiance beam after shading and soiling (kWh/yr)	28414.3
Irradiance total after shading and soiling (kWh/yr)	47283
Irradiance total after shading only (kWh/yr)	49771.5
Soiling loss (%)	5
Performance ratio	0.770895

In the VI curve shown in Fig6, the maximum power point is the module operating point at which the power output of modules reaches maximum value; the corresponding current and voltage are called maximum power current and maximum power voltage respectively. The value of maximum power point can be used to evaluate performance of PV modules under standard test condition.

Model parameters result from simultaneously solving the diode equation on the I-V curve:

Short circuit (V = 0, I = Isc) along y axis

Open circuit (V =Voc, I = 0) along x axis

Maximum power (V =Vmp, I = Imp)

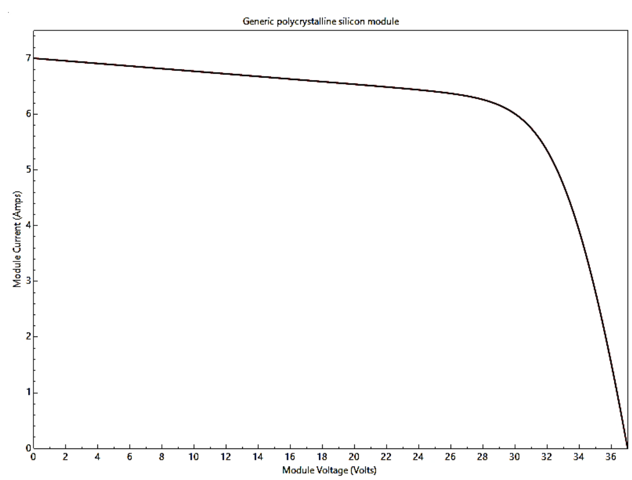

Figure 6 PV Module voltage vs Module current for a polycrystalline silicon

Simulation of model results in measured data of solar irradiance, various losses, gross energy yield and inverter performance parameters. The average load consumption in any residential location determines the necessary system design for a standalone system. The system is designed to meet the energy consumption throughout the year. The various performance parameters are shown in table 2 and 3

Table 2 Power parameters

Parameter	Value
Annual AC energy gross (kWh/yr)	7965.21
Annual DC energy (kWh/yr)	8333.03
Annual DC energy gross (kWh/yr)	8720.22
Annual DC energy nominal (kWh/yr)	9717.65
Annual GHI (Wh/m2/yr)	2.12E+06
Annual energy (kWh)	7885.56

Table 3 Power Loss parameters

Parameter	Value
AC inverter power clipping loss (%)	0.000679
AC wiring loss (%)	1
AC wiring loss (kWh)	79.6521
DC diodes and connections loss (%)	0.493356
DC diodes, connections loss (kWh)	43.0217
DC mismatch loss (%)	1.97342
DC mismatch loss (kWh)	172.087
DC module modeled loss (%)	10.264
AC inverter efficiency loss (%)	4.41332
DC wiring loss (%)	1.97342
DC wiring loss (kWh)	172.087
Inverter clipping loss AC power limit (kWh/yr)	0.056619

IV. CONCLUSION & FUTURE SCOPE

When assessing solar radiation of a certain area, it is necessary to consider landscape features to build a solar radiation model integrated with Geographic information system. Hence integrating solar radiation model with GIS is very helpful for analysis and improvements of application.

Although renewable energy deployment for a standalone system is developing fast, the electricity generated by solar energy takes only a small percentage in the world's energy distribution. So, the prospect of photovoltaic system is enormous. With the meteorological data collected from diverse ways one can get immediate weather information and long-term climate conditions to determine whether solar energy solution is feasible in the location. Installation of a battery bank for the loads is required during off production. While in the case of the energy produced by PV array exceeds loads demand, the system can transmit extra energy into power grid.

So residential building can get data from various meteorological and energy sites which is available both for short and long terms variations. This will effectively optimize the power for a standalone system at any given location. Thus performance modeling method will be useful in planning and deciding to install a standalone system at residential locations. Except for initial cost, solar power has advantages in the fields of sustainable development and environmental protection.

Considering various power losses, the gross yield of electric power can be determined in short and long tenure so as to check for reliability and financial feasibility to further proceed for solar plant setup.

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