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Photo Voltaic (PV) Cell Characteristics Design Using M.File In Matlab

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Abstract*: Solar energy is an emergent trend suitable for power production in both industrial and household appliances. The distributed renewable resource like solar energy is projected to act as a major responsibility in the forthcoming smart grid applications and technology. For the generation of electricity from solar power, it is essential to analyze the performance characteristics of the solar Photo Voltaic (PV) module, for instance, the power output of a PV panel and the prominent conversion efficiency. The performance of the electrical characterisation of a Photo Voltaic (solar) cells or module delivers the bond among the generated current and voltage on a typical solar PV cell which is termed as a V-I characteristic curve of solar cells. In this paper, a single diode correspondent circuit has been considered to inspect Voltage (V-I) and Power (P-V) characteristics for different insolation levels of a typical 100 W polycrystalline solar PV module. In order to validate the graphical depiction of the solar cell or module operation, M.file in MATLAB software was used. The generated characteristic curves summarise the connection between the current (I) and voltage (V) at the existing state of temperature with different irradiance. The obtained Power-Voltage (P-V) characterisation grant the essential information for building a solar electric power system to drive close up to its maximum peak powerpoint while feasible. The resulted graphs reveal that while considering the single diode model, the level of insolation varies with series resistance and by the generation of photo-current which in turn delivers the rapport of efficiency of solar cells. The proposed system is the initial step to learn a hybrid power system where some other renewable sources can be combined along with a solar power generation system.

***Keywords*: Characteristic Curves, Efficiency, Irradiance, M.file, Photovoltaic Cell, Power Output, Solar Energy**

I. INTRODUCTION

Photovoltaic (PV) modules based renewable energy generation systems, nowadays signify the most appropriate and outstanding solution, for both domestic and industrial power levels, to reduce CO_2 emissions and the energy consumption formed by oil and gas. These sources are sustainable and generate clean energy. One of the most essential renewable sources is solar energy.

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It has been attracting the awareness of many engineers, scientists and researchers. Every day the earth receives an enormous quantity of energy from the sun. The vast amount of solar radiation received by the earth can be employed to produce electrical energy with the help of Photo Voltaic (PV) modules (Photo Electric effect).The unique design has to be considered for modelling a PV system because the solar power system is dynamic in nature which in turn results in unpredictable power output and also the V-I parameters are affected by ambient conditions like the temperature and the intensity of radiation. Hence the efficiency of a solar cell is not stable at all the epoch, and so a simulation should be carried out by means of the required parameter setting to learn, analyze and to develop the PV system model based on the fluctuations of solar radiation values along with the obtained operating temperature [1].

The solar photovoltaic system physically reveals a nonlinear Voltage-Current (V-I) and Voltage-Power (V-P) output plots that diverge with the rise in illumination level, cell temperature, load current, and load potential. Hence on shady location, the efficiency of a solar PV power output characterisation has an exponential attribute related to facilitate the diode ideality factor. When solar energy (photons) is absorbed by a solar chamber which is a semiconducting material, it boosts up the energy of electrons in the valence band causes the thrusting of electrons in the conduction band. This process happens only when the incident photon energy is higher than that of the bandgap energy and it leads to developing a combination of electrons and holes. These free carriers are swept at a distance which is concealed with the ability of the centralized electric fields of the p-n junction (depletion layer) that results in the generation of current which is proportional to the intensity of incident radiation [2]. This paper describes the vital modelling along with simulation for a photovoltaic (PV) panel. For developing the system, module LE12P100 has been considered. This module generates a maximum electrical power output of 100 W. The M.file script in MATLAB software was used to study the Solar Photovoltaic Characterisation which generates the required power (Voltage x Current) for different intensity levels and by keeping the cell temperature as constant. The resulted plots deliver the Photovoltaic (PV) panel or module's capacity for the conversion of sunlight into electric power.

II. PV MODULE MODELLING

A model solar cell can be considered as a current source where the current produced is directly proportional to solar radiation declining on it. The realistic performance of the solar cell is diverged from an ideal model because of its optical and electrical form of losses [3].

The single diode correspondent circuit diagram of a PV cell is represented in fig.1.

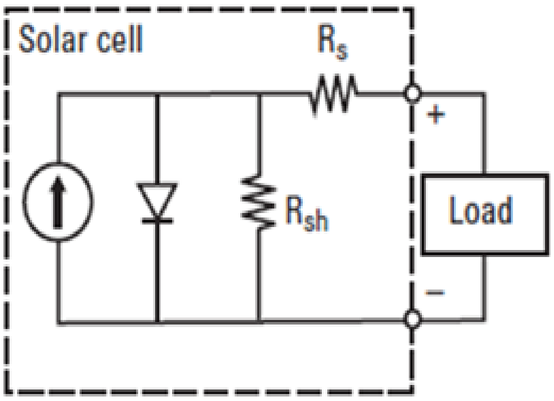

Fig.1 The single diode correspondent circuit diagram of a PV cell

Photovoltaic (solar) cells are made with semiconducting materials that have the capability of converting radiation which incident in the solar PV spectrum into the electric currents. The increase in the intensity of light will proportionally increase the emission of photoelectrons rate generated in the photovoltaic material.

This paper proposes the mathematical modelling with the aid of numerical equations of a PV module and is described through a single diode correspondent circuit of the solar cell. The parameters such as the photocurrent, the diode current, and also the series and shunt resistor have been taken to build an electrical power output curves from the system designed. The governing equation of a photovoltaic (solar) cell is represented in equation (1) [4].

$$I_o = (N_p.I_{ph}) - (N_p.I_{rs}) * (\exp\left(\frac{q}{KTA}\right) * \left(\frac{V_o}{N_s}\right) - 1) \quad (1)$$

Where

$$I_{ph} = I_{scr} + k_i (T - T_r)(\frac{S}{100}) \quad (2)$$

$$I_{rs} = I_{rr} * \left(\frac{T}{T_r}\right)^3 * \exp\left(\frac{q * E_g}{KA}\right) * (\frac{1}{T_r} - \frac{1}{T}) \quad (3)$$

I_{rs} - reverse saturation current of a photovoltaic (solar) cell
T – the cell temperature in Celsius
k - Boltzmann's constant - 1.381 * 10^{-23} J/K
q - Elementary charge - 1.602*10^{-19} C
K_i - Short circuit current temperature coefficient at Iscr
S - Solar irradiation
I_{scr} - Short circuit current at 25^0 C
I_{ph} - Photon current
E_g - Bandgap energy, Tr - Reference temperature
R_{sh} –parallel shunt resistance, Rs - Series resistor

III. RESULT ANALYSIS AND DISCUSSION

A. Reference module

The photovoltaic module used here is LE12P100 which generates a maximum electrical power output of 100 W. The table.1 gives of the key specifications of a photovoltaic module LE12P100 (Polycrystalline) at STC 25^0C. The given structure is implemented by using the M.file script in MATLAB.

Table-1: Typical rating of Lubi 100 W Photovoltaic Module

CHARACTERISTICS	DETAILS
Model	LE12P100
Maximum electrical power rating (P_{max})	100 W
Rated Operating Voltage (V_{max})	17 V
Rated Operating Current (I_{max})	5.88 A
Open-circuit voltage (V_{oc})	21.5 V
Short-circuit current (I_{sc})	6.2 A

B. Simulation results

Mathematical Modelling of solar PV cells has been done using MATLAB/m.file script. For developing an m.file script, the necessary governing equations of a solar photovoltaic cell has been considered as specified in the equations from (1) - (3) and also taking account of electrical and physical parameters, for instance, solar irradiance (insolation), the cell temperature, and the electrical resistance, etc. PV cells are modelled and the resulted from the V-I plot of an illuminated photovoltaic cell where depends on the spectrum of the incident light and the temperature. The conversion of solar energy into the form of electrical energy gives the power output characteristics of the solar photovoltaic module which can be computed by means of corresponding parameters.

Fig. 2 shows the curves of output current and output voltage under different insolation levels for the Lubi 100 W PV panel.

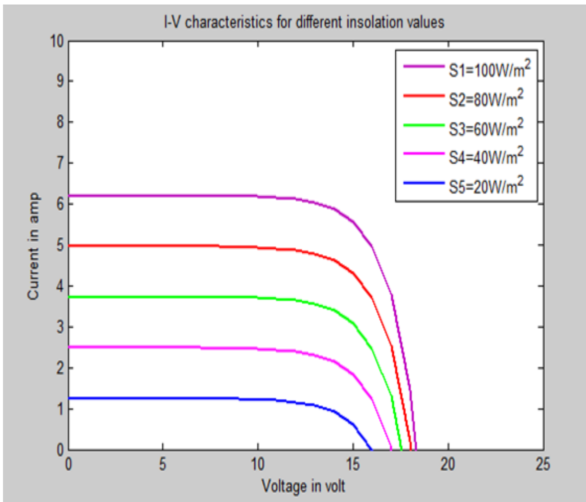

Fig. 2 V-I characterisation for various insolation values

Fig. 3 shows the curves of output power and output voltage under different insolation levels for the Lubi 100 W PV panel.

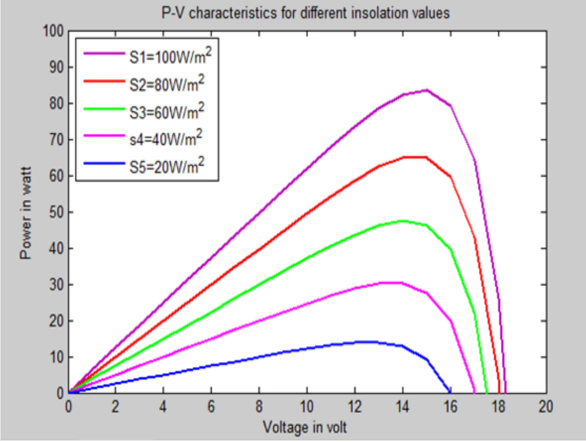

Fig. 3 P-V characterisation for various insolation values

Fig. 4 shows the curves of output power and output current under different insolation levels for Lubi 100 W PV panel.

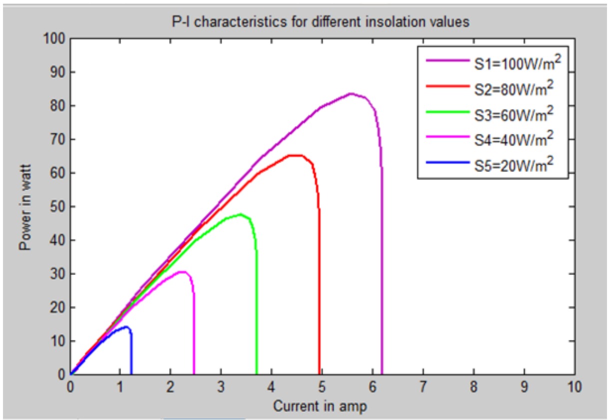

Fig. 4 P-I characterisation for various insolation values

IV. CONCLUSION

Based on the literature assessment and theories, mathematical modelling of the PV module has been considered and developed using the M.file script in MATLAB software by considering the single-diode correspondent model of a photovoltaic (solar) cell. The proposed model referred to the datasheet ideals of a classic 100 W solar PV module along with the various sunlight/insolation. This paper also delivers an apparent and brief perceptive of the bonding between current, power and the potential developed in the solar PV module and the consequences of changes in solar insolation levels on the parameters involved. Moreover, the proposed model serves as a contrivance for the prediction of the responses which includes a photovoltaic (solar) cell, solar panel and a solar array under the variations of the environmental and electrical parameters. The obtained plots also reveal that the voltage-current characterisation persists several steps where the voltage-power characterisation delivers plenty of local peaks with the maximum peak powerpoint which can be termed as the global peak. This proposed model helps to build a hybrid power system in the future using some other renewable sources along with the proposed solar energy system.

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