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Performance Behaviour of PV System Using Matlab Environment

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Abstract:
Photovoltaic (PV) is a method of generating electrical power by converting solar radiation into direct current electricity using semiconductors that exhibit the photovoltaic effect. The performance of the Photovoltaic (PV) system is affected by both temperature and irradiation level. To analyze and understand the relationship between the above effects of PV system and also the output power of the PV system. The objective of this paper is to analyze the effects and performance of PV test system like "Kyocera KD135GX-LP" has been carried out for different module temperature and irradiance levels using MATLAB environment. This paper also presents a Matlab-Simulink based PV module model that includes a controlled current source and an S-Function Builder. The modeling scheme in S-Function Builder is deduced by some pre-digested function. The model is practically validated using different array configuration (PV module in series and in parallel) with nonuniform insolation. The output performance behaviour of the proposed PV system has been validated using the PV Syst database software. The characteristics such as current-voltage (IV) and power-voltage (PV) of the test system have been simulated and validated.

Key words: PV module, Matlab/Simulink, S-Function Builder, PV Syst, Kyocera KD135GX-LP

1. Introduction

Among several renewable energy resources, energy harvesting from the photovoltaic (PV) effect is the most essential and sustainable way because of abundance and easy accessibility of solar radiant energy around the earth. In spite of the intermittency of sunlight, solar energy is widely available during daylight and it is free to use. Recently, photovoltaic system is recognized to be in the forefront in renewable electric power generation because it can generate direct current electricity without heavy environmental impacts and contamination [1].

The output characteristics of PV modules depend on the solar insolation, the cell temperature and the output voltage of the PV module. Since PV modules exhibit nonlinear electrical characteristics, designing and simulation of this system require reliable PV modeling.

Moreover, mathematical modeling of PV module is continuously updated to enable researcher to have a better understanding of its working. Many researchers have been proposed several models for Matlab/Simulink in the

literature. Kun Ding. proposed a model of PV array simulation model allows investigating the characteristics of a PV array under various conditions of different irradiance and temperature levels [2].

Tarak Salmi proposed a model of PV cell based on the fundamental circuit for a solar PV cell considering the effects of physical and environmental parameters [3].

Hiren Patel. proposed a method to obtain the I–V and P–V characteristics of a PV array, having a large number of series- and/or parallel connected modules, under partially shaded conditions [4].

Engin Karatepe. developed a model can take into consideration the effects of bypass diodes and the variation of the equivalent circuit parameters with respect to operating conditions[5].

Jena Chitralekha. developed a model to make best use of the solar PV systems the output is maximized either by mechanically tracking the sun and orienting the panel in such a direction so as to receive the maximum solar irradiance or by electrically tracking the maximum power point under changing condition of insolation and temperature. The overall performance of solar cell varies with varying Irradiance and Temperature .With the change in the time of the day the power received from the

Sun by the PV panel changes. Not only this both irradiance and temperature affect solar cell efficiency as well as corresponding fill factor [6].

The main objective of this work is to analyse the performance behaviour of solar photovoltaic system (PV) by using MATLAB environment. The characteristics of the propose system has been validated by using PV Syst database software. Specifically the main objective of this work as follows, (i) To analyze and understand the relationship between the above effects of PV system and

also the output power of the PV system. (ii) To analyze the effects and performance of PV test system like "Kyocera KD135GX-LP" have been carried out for different module temperature and irradiance levels using
MATLAB environment. (iii) To validated the output performance behaviour of the given PV test system using the PV Syst database software. Also the I-V and P-V characteristics of the test system have been simulated and validated. (iv)The output performance behaviour of the proposed PV system will be validating in S-Function builder scheme. Fig. 1 shows the block diagram of the proposed PV module. The first block, referred as to behavioural PV model performs theoretical calculations based on physics of the PV cell and it yields nominal values of voltage and current generated by the panel through a controlled current source and S function builder. The second block explains the buck boost convertor and MPPT algorithms for reducing the multiple peaks in the I-V characteristics. The maximum power point (MPP), namely the peak power, is limited by approximately P m = V p I p.
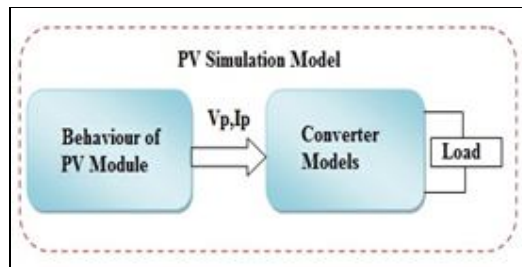

Figure 1: Block diagram of PV simulation model

2. Photovoltaic Modeling

2.1. Behaviour of PV Modelling
The physics of the PV cell is very similar to that of the classical diode with a PN junction. When the junction absorbs light, the energy of absorbed photons is transferred to the electron-proton system of the material, creating charge carriers that are separated at the junction [7].   An ideal PV cell is assumed to have no series loss and no leakage to ground. However, due to its non-ideal structure in nature, there are some losses occurred in real PV cells. Therefore, these losses are expressed by using resistances in equivalent circuits. Fig. 2 shows an equivalent electrical circuit modelling of PV System.
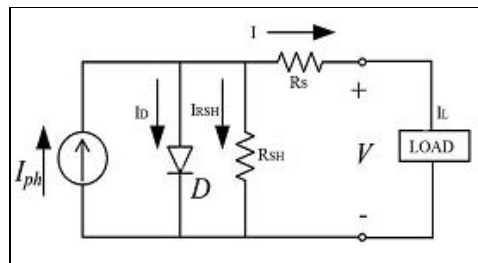

Figure 2; Equivalent electrical circuit model of PV cells

The Fig. 2 depicts how a PV cell behaves in terms of typical electronic components. This model only consists of a (i) Current source dependent on the incoming irradiance (ii) Reverse- diode, which regulates the voltage of the cell (iii) Series resistor Rs, which determines the downward slope of the I-V curve of the module, near Voc. This value represents the internal resistance of the cell, and controls the internal losses. (iv) Shunt resistor R SH , which determines the slope of the line at the top of the I-V curve, near Isc. This value controls the leakage current from the cell to ground, and is usually small enough to be neglected. To derive the I-V curve equation for a single solar cell, in terms of its open-circuit voltage (V oc), the incoming irradiance (G) and the ambient temperature (T). The Equation (1) describing output current of the non- ideal PV cell was derived using Kirchhoff's current law as follows

$$I = I_L - I_D - I_{RSH} \tag{1}$$

The I-V equation of equivalent circuit as follows,

$$I = I_L - I_S(e^{q(V+Rs*I)/nkT} - 1) - (V+R_S*I)/R_{SH} \tag{2}$$

The overall current, which the PV cell can provide, was formulated by Equation (3), where G and G_r are active and the reference radiation, T_c and T_{cr} are module temperature and reference temperature of the module, respectively [8].
Manufacturers usually provide electrical specifications of the PV module at standard conditions, namely solar radiation of 1000 W/m^2 and cell temperature of 25°C. These values correspond to G_r and T_{cr}, respectively [8].

$Vcell = -\beta[Tc - Tcr]\, Rs\Delta I + Vr$ (3)

$$\Delta I = \left[\alpha\left(\frac{G}{G_r}\right)(T_c - T_{cr}) + \left(\frac{G}{G_r} - 1\right)I_{sc}\right]$$ (4)

Where, R_s is used to represent the voltage drop at the output of the PV cell. The parameters I_r and V_r are reference values taken from *I-V* curve [9].PV module is formed by connecting PV cell in series and parallel to each other. In this case, the output current and voltage of PV module is expressed in Equation (5) and Equation (6), respectively.

$V_p = N_{sc}V_{cell}$ (5)
$I_p = N_{pc}\, I_{cell}$ (6)

2.2. Simulink Model of Proposed System
The PV module of "Kyocera KD135GX-LP" was implemented in Matlab- Simulink using the equations had been presented previous section. The block diagram of the PV module KD135GX-LP model is shown in Fig. 3. A S Function Builder is used to built a PV module with the parameter of KD135GX-LP, and it is called KD135GX-LP PV module model. There are three inputs and one output ports in this model, where S1 is insolation, T is temperature of PV module, V is output voltage of PV module, Iout is output current of PV module. Iout is connected to a controlled current source to simulate output current of PV module. A resistance (R1) connected in series with the positive output of the controlled current source, and a resistance (R2) is connected in parallel with both of them. A bypass diode is also included.
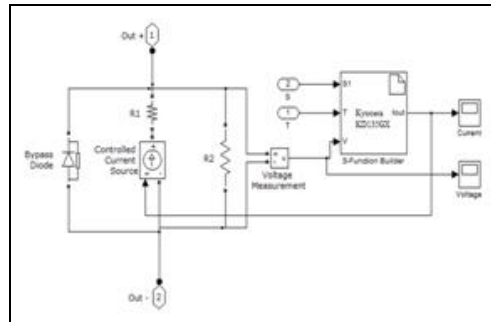

Figure 3: The block diagram of the PV module KD135GX-LP

Fig.4 can be created as a subsystem that is a basic PV module model in this paper. The applications of the test systems are residential roof systems, water pumping systems, and high voltage standalone systems. The weight of the module is 13.0kg. The operating temperature of this test system is -40°C to 90°C. In the test system model containing the following parameters number of cells in series, Maximum power (W), Irradiance W/m2 ,Temperature C, Open circuit voltage (V),Short circuit current (A), Series resistance of PV model (ohms), Parallel resistance of PV model (ohms) , Diode quality factor of PV model, Open circuit voltage temp. Coefficient (V/deg.C), Short circuit current temp. Coefficient (A/deg.C), Electron charge Coulombs (q), Boltzmann's Constant (k) and Joules/Kelvin.
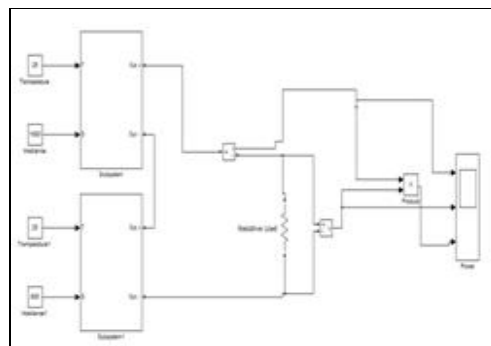

Figure 4: Subsystem of KD135GX-LP

3. Simulation Performance of Proposed Model
This section illustrates PV module simulation examples. The module parameters were largely configured according to Kyocera KD135GX-LP specifications for solar radiation of 1000 W/m^2 and cell temperature of 25°C. Parameter settings are listed in Table 1. It is important to understand how the model working under different condition.

Module parameters	Values
Maximum power (W)	135.004
Irradiance W/m^2	1000
Temperature C	25
Open circuit voltage (V)	22.099
Short circuit current (A)	8.3
Series resistance (ohms)	0.21
Parallel resistance (ohms)	120
Diode quality factor	1.36
Open circuit voltage temp. coefficient (V/deg.C)	-8.000e-003
Short circuit current temp. coefficient (A/deg.C)	5.002e-003
Electron charge Coulombs(q)	1.60×10^{-19}
Boltzmann's Constant(k)	1.38×10^{-23}

Table 1: Parameter Settings Used PV Module in Simulations

3.1. Illustration 1

The current voltage characteristics (I-V) and power voltage (P-V) characteristics of Kyocera "KD135GX-LP" are simulated in MATLAB. The model fig. 5. generated around 135W. From the Fig. 5 & Fig. 6. solar irradiation was changed, the generated current will be changed but voltage remains same. Given a single PV module to obtain the *I–V* characteristics of the Standard temperature conditions are shown in Fig. 5.
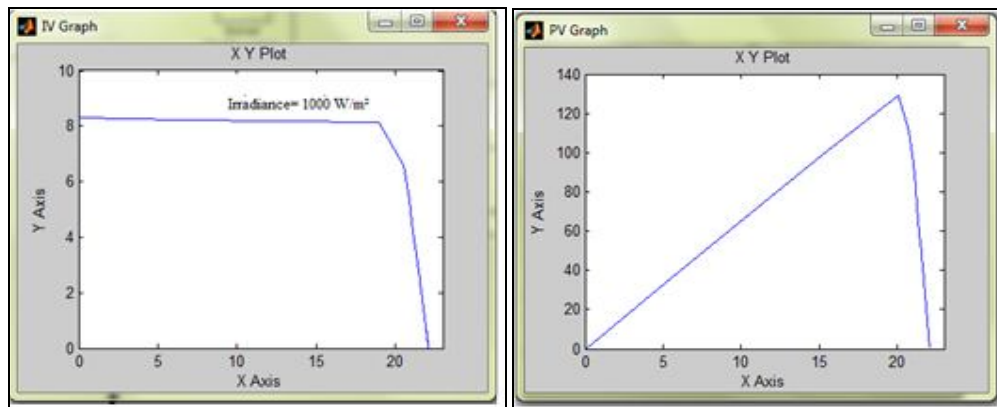

Figure 5: I-V characteristics of Kyocera "KD135GX-LP" under 1000W/m^2 irradiance
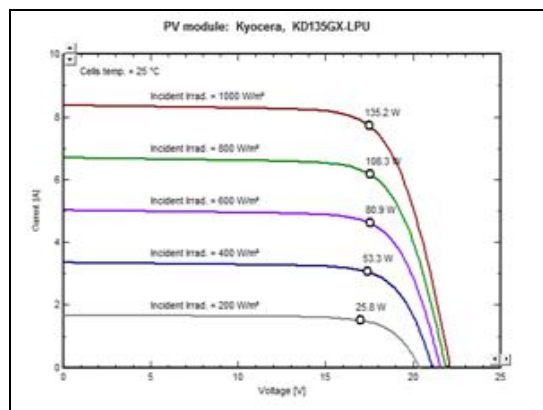*Figure 6: P-V characteristics of Kyocera "KD135GX-LP"*

Figure 7: I-V characteristics of Kyocera "KD135GX-LP" in PV Syst

The module temperature increased the current of the solar cell will varied corresponding output power decreased [10]. From this I-V and P-V characteristics to understand the effect of temperature and solar irradiance.

The PV Syst is the analysis tool for solar PV system. This PV Syst software contains all manufacturers of solar data with standard temperature conditions (STC). The test system model were simulated using MATLAB and the simulated IV and PV curves were verified this software like PV Syst.

Figure 7 and figure 8 shows the *I–V* and *P–V* characteristics under the different insolation as follows S1=1000W/m^2 ,S2=800W/ m^2, S3=600W/ m^2, S4=400W/ m^2, S5=200W/ m^2 respectively.

3.2. Illustration 2
In this section illustrates the two PV modules are connected in series with the converter circuits. The boost circuit is a typical buck boost converter and set the parameters values before the simulation.
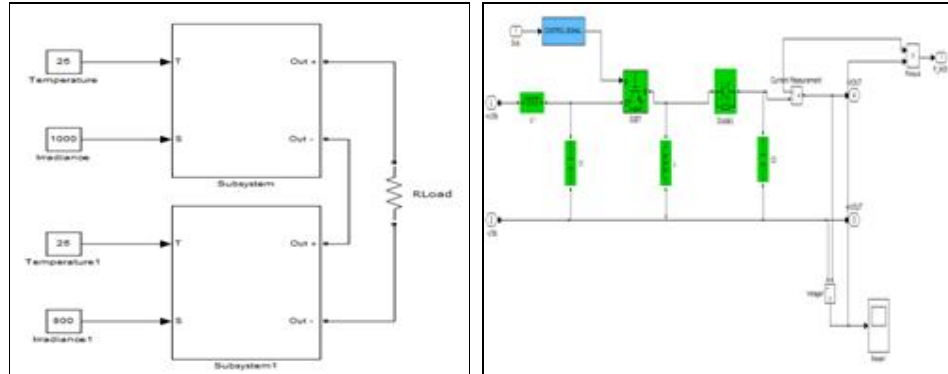

Figure. 8: Two PV Modules connected in series   Figure 9: Booster circuit parameters.

3.3. Illustration 3
Fig. 10 shows the details of the screen shot of a S-Function builder block. The pane of port/parameter displays the ports and parameters that the dialog box specifies for the target S- function. They are S1, T, V, and I$_{out}$. All ports are in complexity of real and dimension of 1-D.
The behaviour model estimates voltage and current potential of PV panel for a given solar radiation and module temperature conditions. The proposed PV module can be employed in transient analysis of power system supplied with PV panels. It is also useful for testing MPP tracking methods.

4. Conclusion
The performance behaviour based PV module model was presented in this paper. The model includes a controlled current source and an S-Function Builder. Using the proposed model of a Kyocera "KD135GX-LP" Simulink allows the investigate the performance characteristics of a photovoltaic (PV) system under different module temperature and irradiation. The performance characteristics like current- voltage (I-V) and power- voltage (P-V) characteristics of the test system were simulated in MATLAB Simulink environment. The output performance behaviour of the given PV test system was validated using the PV Sys database software.

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