



Development and Simulation of Solar Photovoltaic model using Matlab/simulink

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ABSTRACT: The main purpose of this paper is to develop a photovoltaic simulation system using Matlab/Simulink software in order to simulate and evaluate the behaviours of the real photovoltaic systems. A model of the most important component in the photovoltaic system, the solar module, is the first to have been established. The characteristics of the established solar module model were simulated. After that, a model of a photovoltaic system which was developed by DC-DC buck converter established and simulated and the model of the photovoltaic system that was built in this paper can track the maximum power point of the system successfully and accurately under arbitrary temperature and irradiance conditions.

Keywords: DC-DC buck converter, maximum power point tracking (MPPT), Matlab/Simulink, Photovoltaic simulation system, solar module.

I. INTRODUCTION

Renewable energy sources particularly photovoltaic are proven to be both clean and economical due to new advanced technological and efficient cells. Solar energy is obviously environmentally advantageous relative to any other energy source. The rapid growth of the solar industry over the past several years has expanded the importance of PV system design and application for more reliable and efficient operation. PV module represents the fundamental power conversion unit of a PV generator system. The output characteristics of PV module depends on the solar insolation, the cell temperature and output voltage of PV module. Since PV module has nonlinear characteristics, it is necessary to model it for the design and simulation of PV system applications. Recently, a number of powerful component-based electronics simulation software package have become popular in the design and development of power electronics applications. However, the Sim Power System tool in Matlab/Simulink package offers wind turbine models but no PV model to integrate with current electronics simulation technology. Thus, it is difficult to simulate and analyze in the generic modeling of PV power system. This motivates to develop a generalized model for PV cell, module, and array using Matlab/Simulink.

II. PHOTOVOLTAIC MODEL

The basic structure of solar cells is to use a p-type semiconductor with a small quantity of boron atoms as the substrate. Phosphorous atoms are then added to the substrate using high-temperature diffusion method in order to form the p-n junction. In the p-n junction, holes and electrons will be rearranged to form a potential barrier in order to prevent the motion of electrical charges. When the p-n structure is irradiated by sunlight, the energy supplied by photons will excite the electrons in the structure to produce hole-electron pairs. These electrical charges are separated by the potential barrier at the p-n junction. The electrons will move towards the n-type semiconductor and the holes will move towards the p-type semiconductor at the same time. If the n-type and p-type semiconductors of a solar cell are connected with an external circuit at this moment, the electrons in the n-type semiconductor will move to the other side through the external circuit to combine with the holes in the p-type semiconductor. The phenomenon above shows how currents of the external circuit generate. Because the output voltage of a solar cell is extremely low (about 0.5–0.7V), solar cells have to be connected in series and in parallel in practical applications first.

After connection, solar cells have to be strengthened by a supported substrate and covered by tempered glass in order to comprise the solar module. After this, solar modules can be connected in series and in parallel to create a solar array according to capacity demands [1, 2].

The equivalent circuit of the PV cell is shown in Figure 1[5, 6]. PV cells are grouped in larger units called PV panels which are further interconnected in a parallel-series configuration to form PV arrays. To simulate the array, cell model parameters are properly multiplied by number of cells.

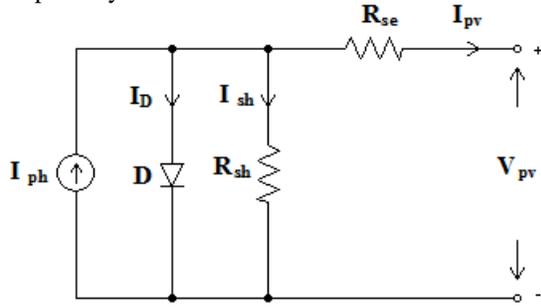


Fig. 1. Equivalent circuit of SPV panel.

The model equations are given from (1) to (5).

$$I = n_p I_{ph} - n_p I_{rs} \left[\exp \left(\frac{q}{KTA} * \frac{V}{n_s} \right) - 1 \right] \quad \dots(1)$$

$$I_{rs} = I_{rr} \left[\frac{T}{T_r} \right]^3 \exp \left(\frac{qE_g}{KA} \left[\frac{1}{T_r} - \frac{1}{T} \right] \right) \quad \dots(2)$$

$$E_g = E_g(0) - \frac{\alpha T^2}{T + \beta} \quad \dots(3)$$

$$I_{ph} = [I_{scr} + K_i (T - T_r)] \frac{S}{100} \quad \dots(4)$$

$$P = IV = n_p I_{ph} V \left[\left(\frac{q}{KTA} * \frac{V}{n_s} \right) - 1 \right] \quad \dots(5)$$

Where,

- I - PV array output current;
- V - PV array output voltage;
- n_s - Number of cells in series
- n_p - Number of cells in parallel;
- q - Charge of an electron;
- K- Boltzmann's constant;
- A -p-n junction ideality factor;
- T- Cell temperature (K);
- I_{rs} -Cell reverse saturation current.

III. IMPLEMENTATION AND SIMULATION OF MODEL

The Buck converter interfaces PV panel and the load. The design equations of the Buck converter are presented from (6) to (8).

The voltage ratio of the Buck Converter is given as, Conversion ratio,

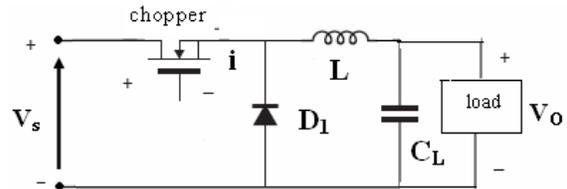
$$M_V \equiv \frac{V_O}{V_S} = D$$

The inductor and capacitor is designed based on the following equations to operate converter in Continuous Current Mode(CCM).

$$L_b = \frac{(1 - D)R}{2f} \quad \dots(7)$$

$$C_{min} = \frac{(1 - D) V_O}{8V_r L f^2} \quad \dots(8)$$

The SIMULINK diagram of the buck converter is shown in Figure 8.The design parameters used in simulation are $L=25\mu H, C=25\mu F$ and $f_s=100$ kHz.



(a) Circuit diagram

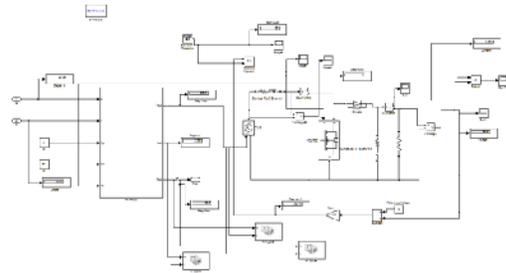


Fig. 2. The complete simulink circuit model showing the coupling of PV array with the buck converter.

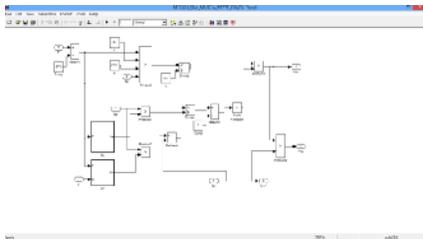


Fig. 3. The subsystem of PV panel.

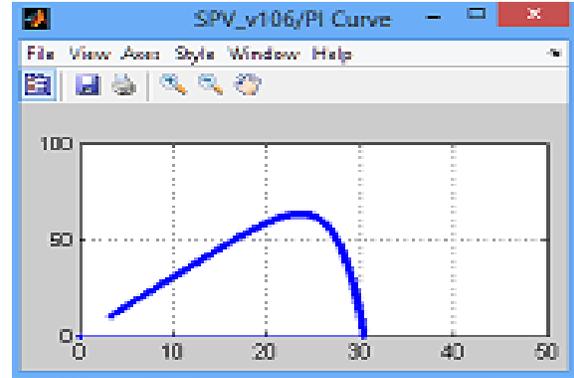


Fig. 3. PI characteristic of solar panel.

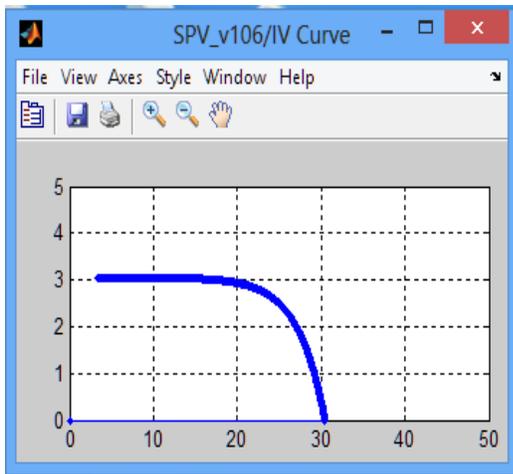


Fig. 4. IV characteristic of solar panel.

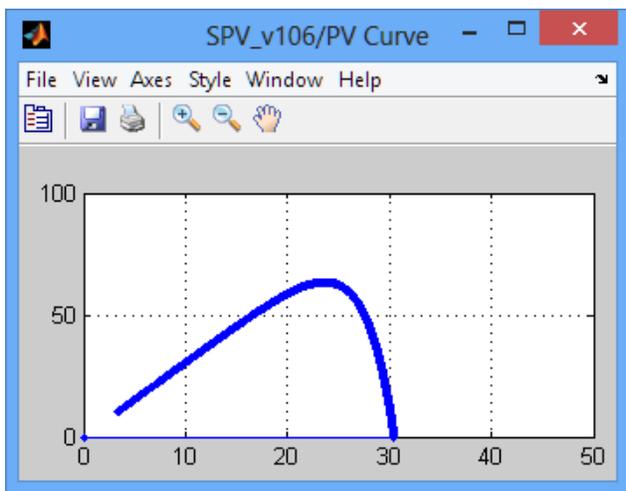
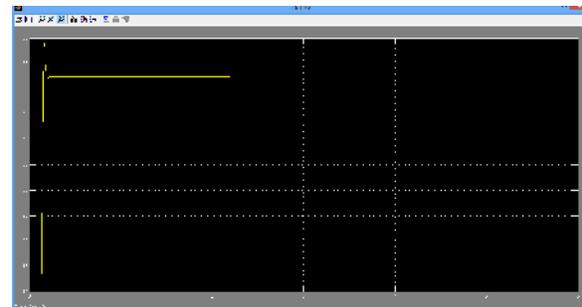
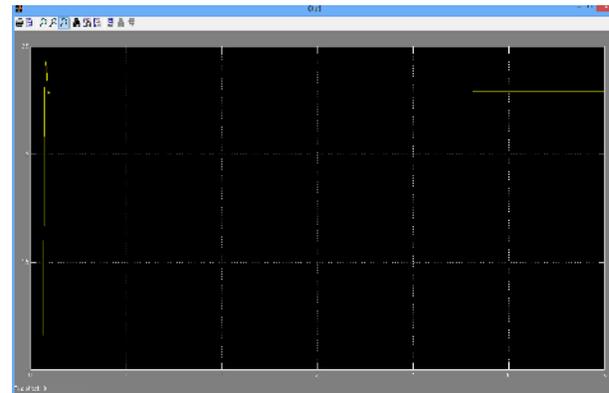


Fig. 5. PV characteristic of solar panel.

The interfacing of the PV array with the buck converter has been achieved using a constant voltage source.

IV. CONCLUSION

A generalized PV module has been developed and verified with available module. The proposed model takes solar radiation intensity and cell temperature as input and outputs the I-V and P-V characteristics under various conditions. This model can be used for the analysis in the field of solar photovoltaic conversion system and MPPT technologies. The formula's developed for parameter extraction of photovoltaic module is useful as some of parameters may get change due to use in field because of dust, humidity, temperature and aging.

REFERENCES

- [1]. John A. Duffie & William A. Beckman, "Solar Engineering of Thermal Process", 3rd ed., John Wiley & Sons, pp. 747-773, (2006).
- [2]. Tsai, H.L., Tu, C.S., Su, Y.J., "Development of Generalized Photovoltaic Model Using matlab/simulink", *Proceedings of the World Congress on Engineering and Computer Science, 2008*, pp. 978-988.
- [3]. Yu, T.C., Chien, T.S., "Analysis and Simulation of Characteristics and Maximum Power Point Tracking for Photovoltaic Systems", *PEDS, 2009*, pp. 1339-1344.
- [4]. Nema, S., Nema, R.K., Agnihotri, G., "Matlab/simulink based study of photovoltaic cells/modules/array and their experimental verification", *International Journal of Energy and Environment*, Vol. 1(3), 2010, pp.487-500.
- [5]. Durgadevi, A., Arulselvi, S., Natarajan, S.P., "Study and Implementation of Maximum Power Point Tracking (MPPT) Algorithm for Photovoltaic Systems", *International Conference on Electrical Energy Systems*, 2011, pp. 240-245
- [6]. Chaudhari, V., A., "Automatic peak power tracker for solar pv modules using dspacer software," Maulana Azad National Institute of Technology, Deemed University, Bhopal, India, 2005.
- [7]. M.H. Rashid, *Power Electronics Circuits: Devices and Applications*, 3rd edition, Upper Saddle River, NJ: Prentice-Hall, 2004.