Evaluating the radiation and temperature effect on photovoltaic systems

Sobhan Dorahaki
Young Researchers and Elite Club, Bushehr Branch, Islamic Azad University, Bushehr, Iran

Abstract

One of the best ways to identify and design a system is simulating and to achieve this goal, we use simulation software such as MATLAB Simulink. In this study, the relations ruling photovoltaic is described. Then, on the relations basis, a photovoltaic system is simulated in MATLAB software. After photovoltaic system simulation, regardless the specific geographic area, radiation and temperature effect on photovoltaic system is generally simulated. Finally, with regard to radiation and temperature values effect on P_{mp}*, it was concluded that we overlook the temperature effect than radiation effect on photovoltaic system designing. It certainly does not mean overlooking the temperature effect. It means a low-effect power changes per temperature changes against radiation.*

Keywords*: Photovoltaic, simulation, radiation, temperature, MATLAB*

1. Introduction

Photovoltaic means electricity generation from sunlight without removable tools. The performance of a photovoltaic panel generally depends on the radiant energy amount received to it. In this regard, very dry deserts with low cloud cover can provide the most suitable platform for it. Maximum sun radiation coefficient in the desert reaches above 6.55. However, in Iran this number is estimated to. The observed value is greater than global average [1]. This can improve the photovoltaic systems study in Iran.

Other effective factor on photovoltaic system is temperature factor. That due to the photovoltaic cells is made of semiconductor materials and can reduce productivity of photovoltaic panels [2, 3]. The increasing temperature in the warmer months of the year can be very disturbing.

On the other hand, it is clear that approximately in most world parts, full radiation months are warmer months of the year and therefore, it would be risky for system performance in this month. Various researches have been done for reducing panel's temperature. For example, Abdol-Zadeh, Morteza and Mehran Ameri 2007 in an article entitled "The effect of water injection on photovoltaic panel's performance" claimed that spraying water on photovoltaic panels can increases the efficiency and power factor because the temperature effect on hot summer days greatly reduces [2]. On the other hand, high construction costs and the use of cooling equipment and also thing like spraying water on the panel can be problematic in long term. Therefore, it is important to know about radiation and temperature effects within the natural climate range on panel power output power (temperature between -5 to +45 and radiation between 0.6 to1). In order to achieve this goal, one of the most powerful ways to study a system is simulating by using different simulator software. For doing so, we should analyze the relations govern the system. Photovoltaic panels are one of the essential parts of a photovoltaic system. Photovoltaic system output is largely dependent to input radiation and temperature variables [4]. On the other hand, output graphs of photovoltaic cells are largely non-linear and this in turn makes the output diagram study of these systems, difficult. Annually, researchers suggest different models closer to photovoltaic cells true model. This is done because the error between suggested model and true model should be limited.

Razhaghi and mosavi reported (2013) photovoltaic systems study and simulation by using MATLAB Simulink and radiation or temperature input reflects the enormous changes of Maximum power point [4].

Keles, C et al (2013) by studying and modeling the photovoltaic systems and using MATLAB software suggested a useful model for studies testing [5].

Received September 21, 2014; Revised December 17, 2014; Accepted January 6, 2015

T.salmi et al (2012) suggested a model that physical components such as radiation and temperature are considered by using a circuit model [6].

In continuation of previous research in this study, it is discussed the photovoltaic system analysis relations and after introduction of effective relations and simulation these relations in MATLAB software, the effectiveness amount of radiation and temperature factors on photovoltaic systems are studied.

2. Different Parts of Photovoltaic System

A photovoltaic system is composed of several sections. Each of the components have specific task. Figure 1 shows the various parts of a photovoltaic system.

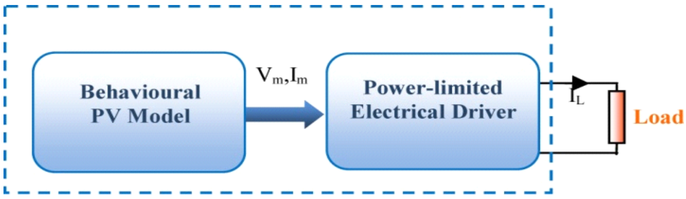

Figure 1. The different parts view of a photovoltaic system

In figure 1, first block diagram represents physical behavior of a photovoltaic panel that normally its output is nominal voltage and current values. Due to non-linearity voltage-current curve, this system current is a limitation that keeps the voltage and current output in a certain range. The second block diagram represents current and voltage regulators (limiter) to achieve value. This limiter role is locking output on peak of the curve. In this section, usually an additive or decrescent DC / DC converter is used [7]. In the last section, consumer is located. Due to its amount, limiter should put operating point on maximum power. However, it seems obvious that photovoltaic system depending on network connection or disconnected from the network or other arrangements, it can also include other devices [8]. For example, to convert the panel DC voltage to AC voltage, we usually use inverters that are classified into several categories due to their performance.

Usually, constituent unit of a photovoltaic system are follows:

A) Panel: Panel structure quality have a dramatic effect on sunlight absorbance, temperature rejection and increasing the solar panel efficiency.

B) Energy Storage

C) Inverters

D) MPPT Controllers (Maximum power point tracker): Various types of controllers are used and they have a significant role in output power level. This section task is keeping the point on maximum power point in P_V curve [9, 10].

3. Photovoltaic Systems Simulation Based on Physical Behavior

The physical behavior of a photovoltaic cell is very similar to a diode with a P-N link. By irradiating to a link, some energy penetrate into the link and reaches to its P-N link. This causes the current creation in the semiconductor. In ideal cells, the wasted current amount is zero. But in reality, some amount of generated current is wasting. Usually the wasted current with a parallel resistance (are placed in connection with ground. This resistor value is usually a large number. Because in usual, the wasted amount is much lower than the output value. By applying the above contents, figure 2 circuit is resulted.

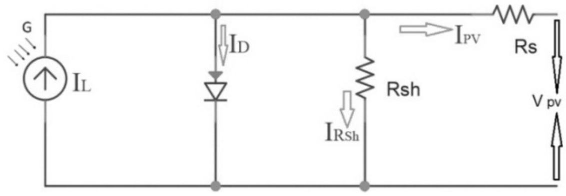

Figure 2. Circuit model of a photovoltaic system [11]

Current source shown in figure 2 is a modeling of a produced current that its amount is based on temperature and environment radiation values [4]. Equation (1) shows its value.

$$I_l = \frac{G}{G_n}(I_{scn} + K_i(T - T_n)) \tag{1}$$

In above equation, G is actual radiation, is reference radiation, T is reference temperature,I_{scn} is short circuit current in T_n condition, K_i and is current increasing coefficient for the variations per each Celsius degree.
Equation (1) simulation in MATLAB Simulink software is shown in figure 3.

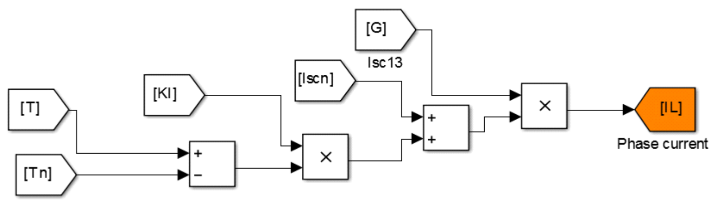

Figure 3. The block diagram of equation (1) simulation

As described above, R_{sh} that shown in Figure 2 represents a path for leakage current to ground. The current amount is obtained through the equation (2):

$$I_{Rsh} = \frac{V_{pv}+R_s I_{Pv}}{R_{sh}} \tag{2}$$

In above equation, I_{pv} panel output current and V_{pv} is output voltage. The current and voltage output amount are largely dependent on load resistance value. The equation simulation in MATLAB software is shown in Figure (4):

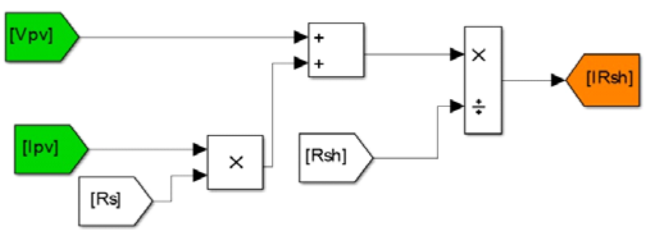

Figure 4. The block diagram of equation (2) simulation

The output voltage is largely a non-linear component which this reason should search in diode non-linear (exponential) functions. The current value can be obtained from equation (3): [11, 12]

$$I_D = I_s\left(e^{\frac{V_{pv}+R_S\times I_{pv}}{nKT/q}} - 1\right) \quad (3)$$

The simulation of equation (3) in MATLAB software is shown in Figure 5:

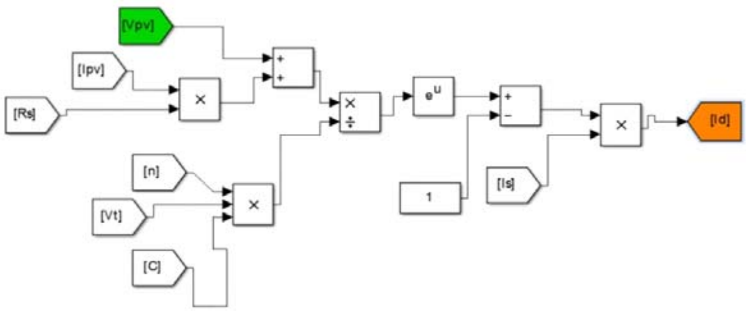

Figure 5. The block diagram of equation (3) simulation

Also we can apply KCL rule at the top node, output current relation obtained in the following way:

$$I_{pv} = I_l - I_D - I_{Rsh} \quad (4)$$

The equation (4) simulation in MATLAB software is shown in figure 6:

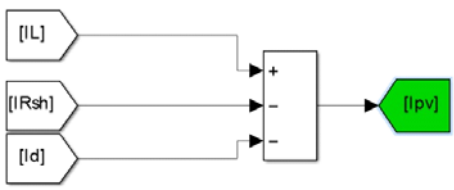

Figure 6. The block diagram of equation (4) simulation

4. Simulation Output

As can be seen in Figures 1 to 6, simulation inputs are temperature and radiation values that will vary by P_{mp} value changes. Figure 7 shows I-V diagram for radiation values changes (25 ° C).

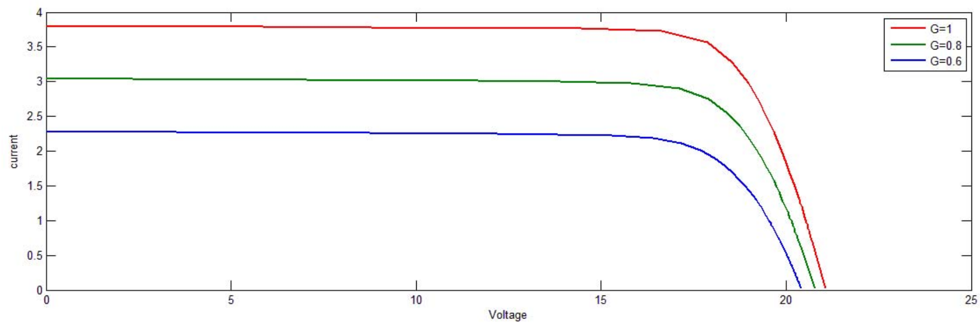

Figure 7. I-V diagram for radiation changes in 25 ° C

This diagram shows that with radiation value increasing, short-circuit current increases. Also the increase of radiation effect decreases the voltage. P-V diagram in figure 8 shows the radiation changes in constant temperature:

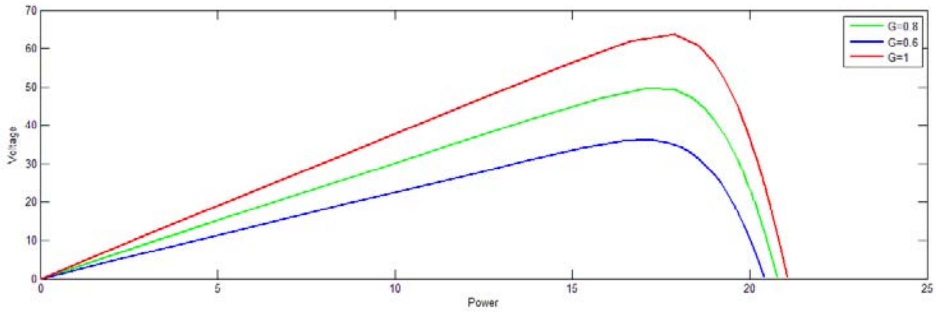

Figure 8.P-V diagram for radiation changes in 25 ° C constant temperature.

In figure 8, it can be seen that P_{mp}value increases with radiation increasing. This variation range is approximately within 32 to 60 watt. Also by considering temperature as a variable and radiation as a constant, figure 9 is obtained.

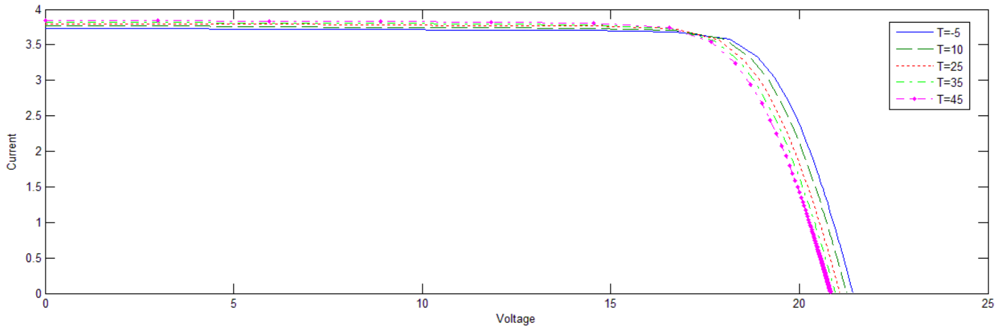

Figure 9. I_V diagram for temperature changes in constant radiation

It can be seen that with ambient temperature increasing, short circuit current increase is negligible. Also, temperature increasing causes a dramatic reduction in open circuit voltage which in turn reduces the system power. Figure 10 shows the P_V diagram for constant values of radiation and temperature.

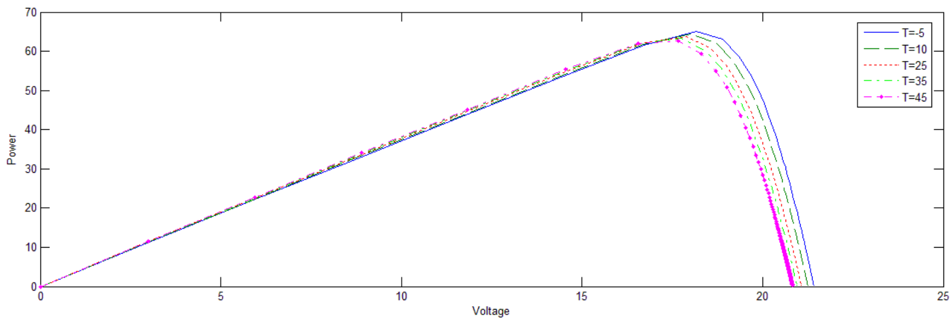

Figure 10. P_V diagram for temperature changes in constant radiation

Figure 10 shows that with temperature changes in constant radiation, P_{mp} has a negligible change which indicating very low temperature effect on photovoltaic system. However, due to the large number of panels in the power plant, this effect should be considered and we should consider a solution for it. But according to the diagram in figure 10 we can say the magnitude of this effect in small dimensions can be ignored due to radiation effects. \

5. Discussion and Conclusions

In this study, the relations of photovoltaic system are described and also desired relations steps simulated in MATLAB Simulink. Finally, regardless of geography, I_V and P_V diagrams of photovoltaic system in 25°C constant temperature and amounts of radiation variable for 1, 0.8 and 0.6 simulated and it was resulted that for mentioned variables,P_{mp} amount was varied of 32 to 60 watt. This digit shows the research value and full radiation month selecting to reach maximum productivity. Also, investigating the temperature effects on 5, 10.25, 34 and 45 ° C (almost it can be said that naturally, it covers maximum range of temperature variations in geographic area) showed that greatest P_{mp} changes are about 4 watt. According to the obtained results in this study, it can be said that considering the radiation dramatic effects in design of a photovoltaic system, we can overlook the temperature effect, which has a very little effect on output. Of course, it is obvious that in powerhouse dimensions with 250 or 300 panels or more, a few watts drop can be problematic but in small dimension, we can overlook this effect versus radiation effect. In future research, creation of micro-networks in residential buildings with regard to obtained data from this study will be studied.

References

[1] Bahrami E, Abbaspoursani K. Determining the optimal gradient angle of the solar array in Karaj's climatic conditions. *Iranian Journal of energy*. 2012; 15(2): 37-44.

[2] Abdul Zadeh M, Amerim. *The effect of water spraying on photovoltaic panels performance*. Sixteenth Annual Conference on Mechanical Engineering, Kerman, Martyr Bahonar engineering university of kerman. 2008.

[3] Chihchiang Hua, Jongrong Lin. A modified tracking algorithm for maximum power tracking of solsr array. *ELSEVIER Energy conversion and Management*. 2004: 911-925.

[4] Razzaghi Majid, Seyyed Mahdi Moosavi. *Analysis of solar cells performance based on temperature and radiation changes*. Renewable and Clean Energy Congress, Hamedan. 2013.

[5] Keles C, Malatya, Turkey; Alagoz BB; Akcin M; Kaygusuz A. *A Photovoltaic system Model for Matlab/Simulink simulation*. Fourth International Conference on Power Engineering, Energy and Electrical Drives (POWERENG). 2013: 1643-1647.

[6] T Salmi, M Bouzguenda, A Gastli and A Masmoudi. Matlab/Simulink based modeling of solar photovoltaic cell. *Renewable Energy Research*. 2012; 2(2): 213-218.

[7] Q Zeng, P Song, L Chang. *A photovoltaic simulator based on DC chopper*. IEEE Canadian Conference on Electrical and Computer Engineering. 2002; 1: 257-261.

[8] A Karabiber, C Keles, A Kaygusuz, and BB Alagoz. An approach for the integration of renewable distributed generation in hybrid DC/AC microgrids. *Renewable Energy*. 2013; 52: 251–259.

[9] E Koutroulis, K Kalaitzakis, and NC Voulgaris. Development of a microcontroller-based photovoltaic maximum power point tracking con-trol system. *IEEE Trans. Power Electron*. 2001; 16(1): 46–54.

[10] Kim I, Kim M & Youn M. New maximum power point tracker using sliding-mode observer for estimation of solar array current in the grid-connected photovoltaic system. *IEEE Transactions on Industrial Electronics.* 2006; 53: 1027–1035.

[11] H Patel and V Agarval. Matlab based Modeling to Study the Effects of Partial Shading on P_V Array Characteristics. *IEEE Trans. on Energy Conversion*. 2008; 23(1): 302-310.

[12] E Skoplaki, JA Palyvos. On the temperature dependence of photovoltaic module electrical performance: A review of efficiency/power correlations. *Solar Energy*. 2009; 83: 614–624