Sabir RUSTEMLI, Furkan DINCER, M. Nuri ALMALI

University of Yuzuncu Yil, Department of Electrical and Electronics Engineering, Turkey

Research on effects of environmental factors on photovoltaic panels and modeling with Matlab/Simulink

Abstract. *In the early days of photovoltaic panels, some 50 years ago, the energy required to generate a photovoltaic panel was more than the energy the panel could generate during its lifetime. As a result of many years of research and experimental studies with today this time can drop up to 3-4 years according to the incentive policies of the some countries. Only obstacle to widespread adoption of photovoltaic panels is cost of their. Therefore, even small studies on photovoltaic panel have great importance to reduce the cost of photovoltaic panel. One of the most important ones is the panel temperature and environmental effects because these factors are affected the panel temperature. In this study, environmental factors that affect to electricity generation capacity of photovoltaic panels have obtained as detailed style with modeling and simulation is designed by Matlab/Simulink programme. Also, environmental factors is added to the model and is entered the system. In addition to this situation were applied on loaded. With this modeling the effects of environmental factors for photovoltaic panels are designed and discussed as detailed by Matlab/Simulink programme.*

Streszczenie. *W artkule zaprezentowano warunki poprawy pracy paneli fotowoltaicznych. Jednym z istotniejszych parametrów jest temperatura panelu i warunki środowiskowe. Zaproponowano model matematyczny panelu uwzględniający warunki środowiskowe. (**Badania wpływu warunków środowiskowych na pracę panelu fotowoltaicznego**)*

Key Words: Photovoltaic Panel, Environmental Factors, Matlab/Simulink
Słowa kluczowe: panel fotowoltaiczny, model matematyczny

1. Introduction

The sun is regarded as a good source of energy for its consistency and cleanliness, unlike other kinds of energy such as coal, oil, and derivations of oil that pollute the atmosphere and the environment. Most scientists, because of the abundance of sunshine capable of satisfying our energy needs in the years ahead, emphasize the importance of solar energy [1]. Solar energy is obviously environmentally advantageous relative to any other renewable energy source, and the linchpin of any serious sustainable development program. It does not deplete natural resources, does not cause CO_2 or other gaseous emission into air or generates liquid or solid waste products. Concerning sustainable development, the main direct or indirectly derived advantages of solar energy are the following; no emissions of greenhouse (mainly CO_2, NO_x) or toxic gasses (SO_2, particulates), reclamation of degraded land, reduction of transmission lines from electricity grids, increase of regional/national energy independence, diversification and security of energy supply, acceleration of rural electrification in developing countries [2].

In this study, the using of electricity generation from solar energy is modeled and investigated as detailed. Photovoltaic panels that convert solar energy to electricity power generation. Solar radiation arrives along with on upper surface of photovoltaic panels with semiconductor technology take place electron exchange. Realizing of electron exchange generate electricity current. Thus, the photovoltaic panels generate the electricity. This situation can be created with the help of artificial light in a dark environment. Ends of the open circuit voltage of a photovoltaic panel can be read and if connect the ends of the load, it can be read current information.

Nowadays, using of the photovoltaic panels is fast getting. Cause of this is solar energy that is much more effective, clean and ergonomic source according to the other sources. Therefore, the researchers has been searched on photovoltaic panels long years, however, the most important problem of photovoltaic panels has not exactly feasible cost. So, small dimension application that is increasing electricity generation quantity of photovoltaic panels has been very important.

In this study, environmental factors that affect to electricity generation capacity of photovoltaic panels have obtained as detailed style with modeling and simulation is designed by Matlab/Simulink programme. Also, environmental factors is added to the model and is entered the system.

2. Detailed Modeling Method of Photovoltaic Panels

During darkness, the solar cell is not an active device; it works as a diode, i.e. it produces neither a current nor a voltage. However, if it is connected to an external supply (large voltage) it generates a current, called diode current or dark current. The diode determines the I-V characteristics of the cell. In order to increase the obtained voltage and hence power, several PV cells can be connected together in series to obtain a photovoltaic module. In addition, many modules can be connected in parallel to obtain a higher current forming what we call a photovoltaic array [3].

First of all, the photovoltaic panel should be modeled to make a photovoltaic panel simulation. Equivalent circuit of the photovoltaic panel is obtained for modeling system and the aimed modeling system should be entered to simulation program with the mathematical calculations. Also, these calculations should be designed under with load condition of the photovoltaic panel. The equivalent circuit of the photovoltaic panel is given by fig. 1.

Photovoltaic panel terminal current and junction current of diode is given with below equations (1) and (2) according to equivalent circuit of the photovoltaic panel [4];

$$I = I_{PH} - I_D \tag{1}$$

$$I_D = I_0\left[\exp\left(\frac{q(V + IR_S)}{AkT_C}\right) - 1\right] \tag{2}$$

where: I_D - jnction current of the diode, I_o - reverse saturation current, q - Electron charge ($1.602\,x10^{-19}\,C$), k - Boltzmann constant ($1.381\,x10^{-23}\,J/K$), T_C - cell temperature, A - diode quality factor, R_s - series resistance

The diode saturation current I_o and its dependence on the temperature may be expressed by the following equation [3];

(3) $$I_0 = I_{dn}\left[\frac{T_C}{T_{STC}}\right]^3 \exp\left[\frac{qE_{qm}m}{ak_{\beta}}\left(\frac{1}{T_{STC}}-\frac{1}{T_C}\right)\right]$$

where E_q is the bandgap energy of the semiconductor = -1.12 eV. The nominal saturation current $I_{0,n}$ is obtained by evaluating with below equation [3];

(4) $$I_{0,stc} = \frac{I_{SC,stc}}{\exp\left[\frac{V_{OC,stc}}{aV_{t,stc}}\right]-1}$$

The open circuit voltage and thermal voltage equations are given to below when photovoltaic panel have unload that is ends of the circuit is open [4];

V_t - Thermal voltage

(5) $$V_t = \frac{kT_C}{q}$$

(6) $$V_{OC} = V_t \ln\left(\frac{I_L}{I_0}+1\right)$$

(7) $$V_{OC} = \frac{kT_C}{q}\ln\left(\frac{I_L}{I_0}+1\right) \approx \frac{kT_C}{q}\ln\left(\frac{I_L}{I_0}\right)$$

All of these and some equations have used for modeling of the photovoltaic panel. The aimed modeling is applied by Matlab/Simulink programme. Also, environmental factors are entered to the simulation system.

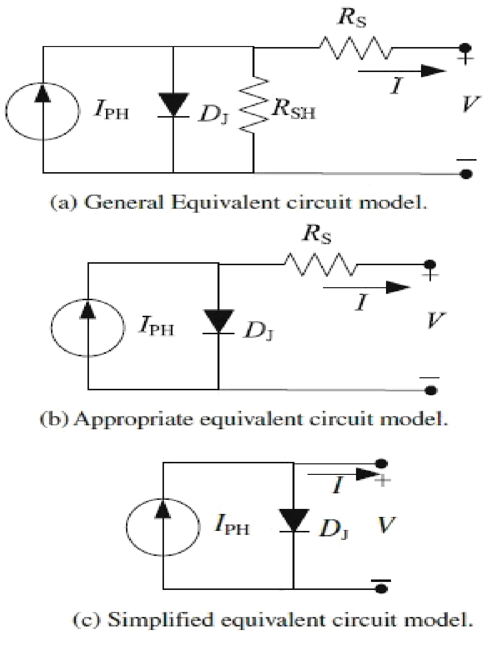


Fig. 1. Different models of PV solar cell [5].

3. Effects of Environmental Factors on Photovoltaic Panels

In order to predict the energy production of photovoltaic modules, it is necessary to predict the module temperature as a function of ambient temperature, wind speed, total irradiance. The cell temperature can be determined an equation by the following relationship [6];

(8) $$T_M\,(^0C) = 0.943\,w1 + 0.028\,w2 - 1.528\,w3 + 4.3$$

Depend on the equation (8) with coefficients are given to table 1. Given values is obtained by experimental, theory and modeling studies and lots of panel varieties are used. These data are founded as result of many studies.

Also, the short circuit current and open circuit voltage is affected separately by cell temperature. There are some equations associated with this factor. The short circuit current I_{SC} is proportional to the irradiance, at fixed temperatures, with the temperature dependence given equations. The open circuit voltage depends on the temperature changing. The temperature dependence of the parameters given by [7];

(9) $$I_{SC}(T) = I_{SC,STC}[1+\alpha(T_M - T_{STC})]\frac{G}{G_{STC}}$$

(10) $$V_{OC}(T) = V_{OC,STC}[1+\beta(T_M - T_{STC})]$$

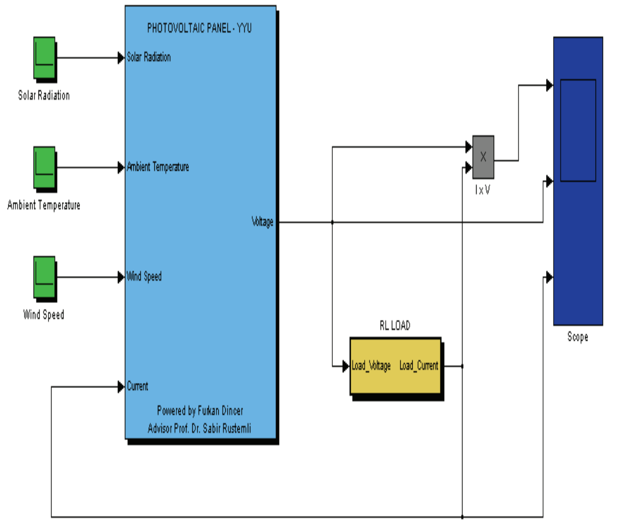
where: α- temperature coefficient for the short circuit current, β - temperature coefficient for the open circuit voltage, G - irradiation (W/m^2), T_M - module temperature (°C))

Table 1. Coefficients for the environmental parameters model [6].

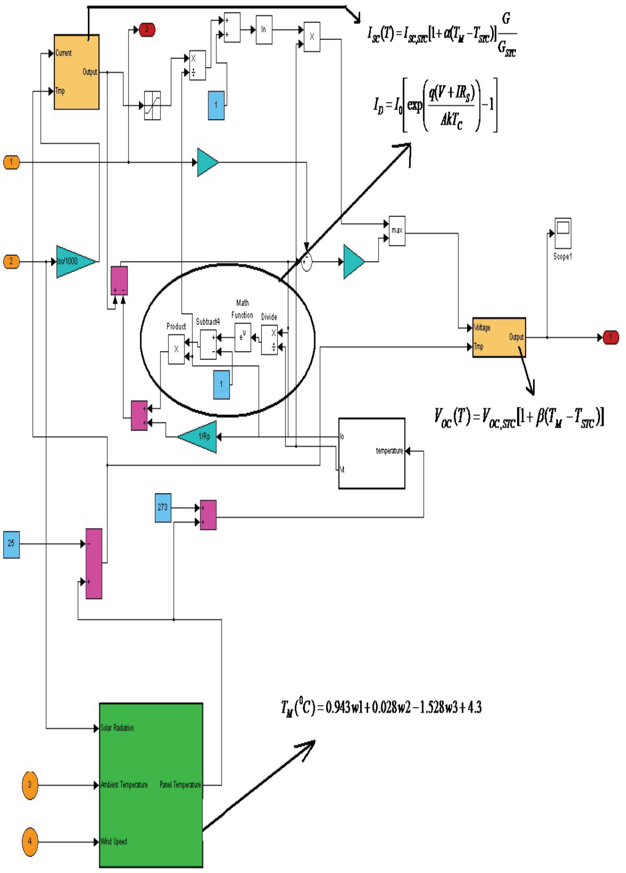
Technology		Tamb	Irra-diance	Wind speed	const
	Module	W1	W2 °C(W/m²)	W3 °C(m/s)	°C
Amorphous Si	1PTL	0.930	0.025	-1.321	2.7
	2PTL	0.937	0.025	-1.373	2.7
	3PTL	0.947	0.027	-1.610	4.1
	4PTL	0.943	0.027	-1.605	4.2
	5NREL	0.958	0.023	-1.353	4.4
	6NREL	0.952	0.029	-1.604	5.4
	7NREL	0.930	0.026	-1.288	5.5
	Average	0.943	0.026	-1.450	4.1
Monocrystalline Si	1PTL	0.935	0.029	-1.562	3.5
	2PTL	0.930	0.031	-1.542	3.6
	3NREL	0.961	0.025	-1.425	4.5
	Average	0.942	0.028	-1.509	3.9
Copper indium diselenide	1PTL	0.944	0.030	-1.644	3.8
	2PTL	0.959	0.027	-1.406	3.4
	3NREL	0.979	0.029	-1.472	4.7
	Average	0.960	0.029	-1.507	4.0
EFG-Polycrystalline Si	1PTL	0.920	0.028	-1.548	4.0
	2PTL	0.922	0.029	-1.529	4.0
	3NREL	0.962	0.022	-1.326	4.9
	Average	0.935	0.026	-1.468	4.3
Polycrystalline Si	1PTL	0.914	0.031	-1.701	4.7
	2PTL	0.917	0.030	-1.747	4.8
	3NREL	0.948	0.028	-1.550	5.6
	Average	0.926	0.030	-1.666	5.1
Cadmium telluride	1PTL	0.952	0.033	-1.770	4.5
	2PTL	0.975	0.032	-1.689	3.9
	3NREL	0.933	0.027	-1.544	6.1
	Average	0.953	0.031	-1.667	4.8
	Overall average	0.943	0.028	-1.528	4.3

4. Modeling of Photovoltaic Panels Using with Matlab/Simulink Programme

In this study, equipments that should be used and modeling style are explained as detailed according to the aimed system for mathematical modeling and simulation. Operating system of simulation, integration of blocks to main system and applied method for simulation are explained for applied mathematical modeling and obtained block diagrams. With this applied how the characteristics of photovoltaic panel change under different cell temperatures, causes of the changes, effects of changes on photovoltaic panel are examined as detailed. Also, the radiation amounts that affect to temperature of photovoltaic panel, ambient temperature and such wind speed parameters were analyzed in detail. Simulation results are presented under loaded condition.



a) Main system and series connected RL load



b) The sub-function block depend on the main system

Fig.2. Photovoltaic panel main system and the sub-function block system

First of all, the main system of photovoltaic panel and contain of the system was created as shown in fig. 2. The function block systems of photovoltaic panel consist of some necessary blocks. The blocks are designed for simulation system according to the inputs and outputs of photovoltaic panel. Connected to the system established by the main blocks in the system changes to be made any time, system is designed from scratch instead of using a solar panel system; the main system can change very quickly and easily.

The main system of photovoltaic panels, with obtained mathematical model of photovoltaic panel is established. Blocks were placed in the system. Created in this study by Matlab/Simulink, also contains a feature very different than normal because desired data are close to ideal under with load condition.

4.1. Load with Photovoltaic Panel Modeling

Ends of the equivalent circuit is connect to the load and current, voltage, power curves and associated with parameters are measurement under same way conditions. Given formulations under non-load conditions are similar to this system. Indicated formulations should be added load series resistive-coil and system should be designed all over. This situation is entered to model. Fig. 3. shows that parameters and their changing under fixed wind speed and different ambient temperature.

When the indicated conditions are applied to the system, first of all, wind speed is fixed as 0 m/s and the ambient temperature is increased 15 ºC, 30 ºC and 45 ºC as stepped. When the wind speed is 0 m/s and the ambient temperature is 15 ºC, obtained data from this system are approximately current of 4.28, watt of 73.50, voltage of 17.15. When the wind speed is 0 m/s and the ambient temperature is 30 ºC, obtained data from this system are approximately current of 4.02, watt of 65.80, voltage of 16.10. When the wind speed is 0 m/s and the ambient temperature is 30 ºC, obtained data from this system are approximately current of 3.85, watt of 58.25, voltage of 15.07.

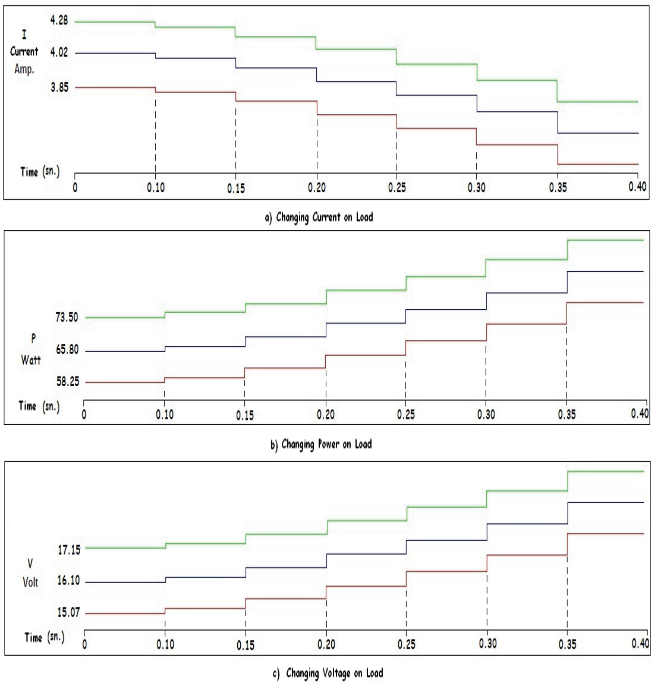


Fig. 3. $G = 1000$ W/m², $T_a = 15-30-45$ ºC, w = 0 m/s parameters and changing of current, voltage, power on load

How photovoltaic panel electricity generation capacity is changing under different conditions is presented as shown in fig. 3. When panel temperature is increasing, photovoltaic panel electricity generation capacity is decreased. This situation is understandable from fig. 3. The most important natural factor of decreasing panel temperature is wind speed because if wind speed is increasing, panel temperature is decreased. Therefore, photovoltaic panel electricity generation capacity is increased. For the detection of this condition should be fixed solar radiation and increased wind speed. Indicated simulation conditions and data that ends of the circuit are shown in fig. 4.

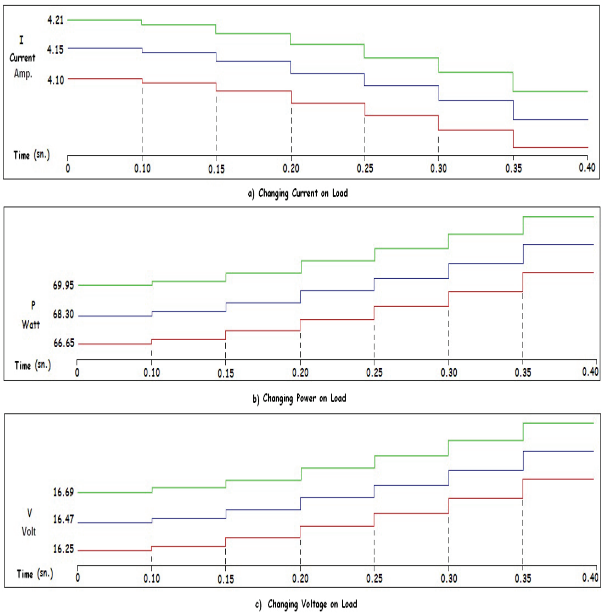


Fig. 4. $G = 1000$ W/m², $T_a = 30$ ºC, w = 1 – 3 – 5 m/s parameters and changing of current, voltage, power on load

When the indicated conditions are applied to the system, first of all, the ambient temperature is fixed as 30 ºC and the wind speed is increased 1 m/s, 3 m/s and 5 m/s as stepped. When the ambient temperature is 30 ºC and the wind speed is 1 m/s, obtained data from this system are approximately current of 4.10, watt of 66.65, voltage of 16.25. When the ambient temperature is 30 ºC and the wind speed is 3 m/s, obtained data from this system are approximately current of 4.15, watt of 68.30, voltage of 16.47. When the ambient temperature is 30 ºC and the wind speed is 5 m/s, obtained data from this system are approximately current of 4.21, watt of 69.95, voltage of 16.69.

5. Conclusion

To common the use of photovoltaic panels, researchers have tried various lots of methods to increase the electricity generation capacity. Because the existing photovoltaic panel, to increase the benefit of various methods of electricity energy generation capacity that is cost-effective investment, is able to become more economical. Therefore, even if very little increase in electricity generation capacity of photovoltaic panel, that have great importance.

In this study, panel temperature that affects electricity generation capacity of photovoltaic panel is examined. How the panel temperature is affected to electricity generation capacity of photovoltaic panel and caused of this effect is investigated and variety lots of findings are obtained. As a result of these findings, it understood that the increasing of panel temperature is affected electricity generation capacity of photovoltaic panel and as the panel temperature is increasing, current is very little increased but voltage is decreased. So, power of photovoltaic panel is decreased. These findings have very important in terms of economical perspective. These theoretical and experimental studies are applied and obtained by Matlab/Simulink program that have common and professional for engineering applications.

Results obtained in the panel temperature of the factors affecting the exchange are handled separately. As ambient temperature is increasing, panel temperature is increased and as wind speed is increasing, panel temperature is decreased. Result of this situation, it understood that wind speed is a natural cooling system for photovoltaic panel. Thus, the electricity generation capacity of photovoltaic panel is increased according to the normal conditions and the findings may be more easily understood from figures.

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Authors: *Prof. Dr. Sabir Rustemli, Department of Electrical and Electronics Engineering, Yuzuncu Yil University, 65080, Van/Turkey, E-mail: sabirrustemli@yyu.edu.tr; Furkan Dincer, Department of Electrical and Electronics Engineering, Yuzuncu Yil University, 65080, Van/Turkey, furkandincer@yyu.edu.tr, M. Nuri Almali, Department of Electrical and Electronics Engineering, Yuzuncu Yil University, 65080, Van/Turkey, mna1@yyu.edu.tr.*