A MODEL OF PHOTOVOLTAIC SYSTEM WITH MAXIMUM POWER POINT TRACKING CONTROL AND THE OBSERVATION OF THE EFFECTS OF ENVIRONMENTAL PARAMETERS WITH THE APPLICATION AT BATMAN CITY IN TURKEY

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Abstract

The electrical behavior of the Photovoltaic module with the change of environmental parameters such as temperature and solar irradiance is presented in this paper. An observation of photovoltaic system with maximum power point tracking control using the Perturb-Observe algorithm and the effect of variable solar irradiance over this system has also been taken place. It is very essential to develop a simulation model of the PV panel for simulation studies. Also, it is crucial to operate the PV energy conversion systems near the Maximum Power Point to increase the efficiency of the photovoltaic system. The maximum power operating point varies with solar irradiance level and temperature. For a successful photovoltaic system the tracking control of the maximum power point is a most important issue.

1. Introduction

The energy demand is increasing day by day; therefore, the need for renewable sources those will not harm the environment are prime importance. Yet majority of the energy requirements is satisfied by fossil fuels but the use of photovoltaic systems could help in supplying the energy demands for the betterment of environment. This study focuses on the modeling and the maximum power point tracking algorithm [1] of a PV system using MATLAB/Simulink [2] and observation of the performance of the modeled system with the change of solar irradiance.

2. Equivalent circuit of PV module

The electrical behavior of PV module can be observed using its equivalent circuit. The equivalent circuit of a PV module is as follows [3].

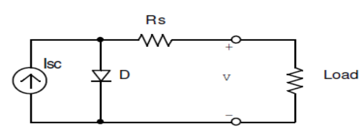

Figure 2.1. Equivalent circuit of PV Module

The mathematical approach of the above equivalent circuit is below:

$$I = I_{sc} - I_o \left[\exp \left(q \frac{V + IR_s}{nkT} \right) - 1 \right] \tag{2.1}$$

This mathematical approach has been implemented in MATLAB. For MATLAB Simulation Model BP Solar BP SX 150S PV module has been chosen. Module is made of 72 multi- crystalline silicon solar cells in series and 150w of maximum nominal power. The current-voltage (I-V) curve is based on the module being under standard conditions of sunlight (1000w/m^2) and module temperature (25°C). It assumes there is no shading on the module. Two main factors affect the performance of solar cells. These are temperature and solar irradiance.

2.1. Impact of solar radiation on V-I characteristic of PV Module and Maximum PPT

Standard sunlight conditions on a clear day are assumed to be 1000 watts of solar energy per square meter (1000 W/m2). This is sometimes called "one sun" or a "peak sun." Less than one sun will reduce the output current of the module by a proportional amount (figure 2.2) [4].

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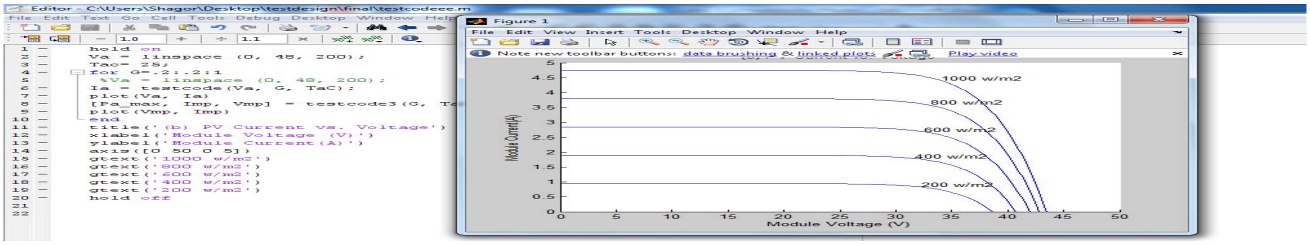

Figure 2.2. The I-V curve of the selected graph at different irradiance (T=25°C).

2.2. Impact of temperature on V-I characteristic curve of Photovoltaic Module

Module temperature affects the output voltage inversely. Higher module temperatures will reduce the voltage by 0.04 to 0.1 volts for every one Celsius degree rise in temperature. In Fahrenheit degrees, the voltage loss is from 0.022 to 0.056 volts per degree of temperature rise.

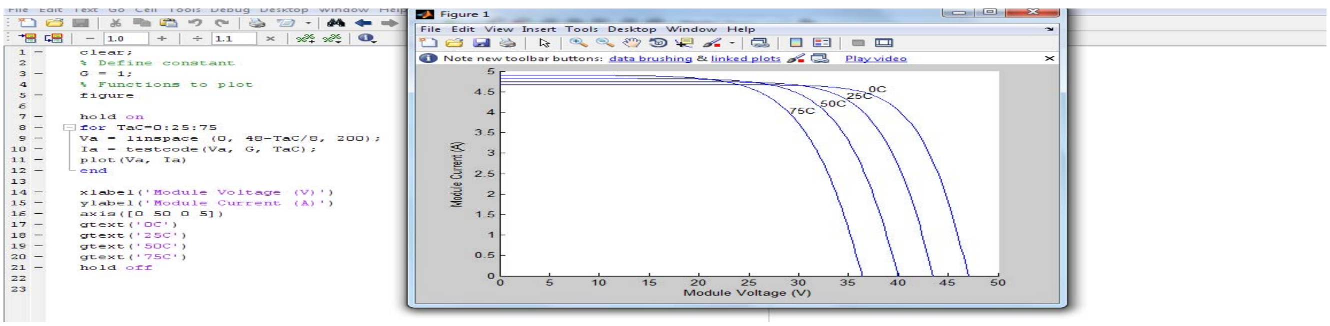

Figure 2.3. The I-V curve of the selected graph at different temperature T= 0°, 25°, 50°, and 75°C (G= 1000w/m2)

2.3. Calculation of the Irradiation on an Inclined Surface

The solar radiation data are generally given in the form of global radiation on a horizontal surface. Global daily irradiation is denoted by G. If the PV panels are positioned with an angle on a horizontal surface the total global irradiation received by the PV will change. Using MATLAB the irradiation (Ho) received over days on a unit horizontal surface area outside the earth atmosphere of the city Batman of Turkey has observed. The Latitude of this city is L=37.93°N.

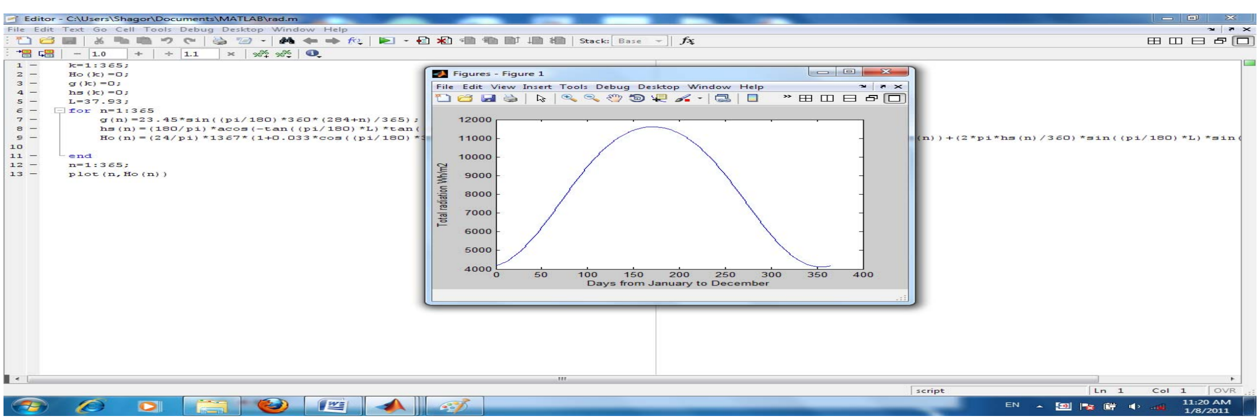

Figure 2.4. Values of the irradiation received over a year by a unit horizontal surface area outside the earth atmosphere at Batman.

In the table 2.1, the average irradiation over a PV Panel on Earth at different tilt angle in Batman city, Turkey for each month [5]-[6] is given. In the table the tilt angle of the PV panel is changing from 0 degree to 90 degree. It is shown that the maximum irradiation as a total of twelve months is at 24 degree of inclination angle and the value is 4702W/m2. If the angle of inclination can be changed every month of the year there will be very substantial increase of irradiation on PVs.

Table 2.1. Average irradiation on a PV Panel on Earth at different tilt angle at Batman in Turkey for each month

Inclination Angle	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Ave. year wh/m2
0 □	1900	2690	4070	5050	6240	**7040**	**6840**	6040	5270	3730	2410	1800	4233
6 □	2054	2863	4258	5164	**6261**	6973	6809	6137	5510	3992	2616	1965	4550
12 □	2194	3016	4414	5237	6231	6851	6721	**6180**	5699	4221	2803	2117	4640
18 □	2318	3146	4533	**5266**	6150	6671	6574	6166	5835	4414	2968	2252	4691
24 □	2425	3253	4616	5252	6016	6433	6368	6095	5915	4570	3110	2371	4702
30 □	2513	3334	4661	5194	5830	6137	6104	5967	**5940**	4686	3226	2472	4672
36 □	2582	3390	**4667**	5093	5595	5787	5784	5784	5910	4760	3316	2553	4602
42 □	2631	**3419**	4636	4951	5312	5387	5411	5546	5823	**4794**	3379	2613	4492
54 □	**2666**	3396	4459	4546	4618	4451	4526	4922	5487	4734	**3420**	**2671**	4158
60 □	2653	3344	4316	4288	4214	3928	4024	4542	5241	4641	3398	2667	3938
72 □	2563	3164	3929	3678	3320	2807	2935	3671	4608	4337	3270	2595	3406
84 □	2393	2887	3421	2965	2356	1653	1795	2689	3810	3885	3035	2440	2778
90 □	2281	2716	3129	2582	1870	1099	1237	2175	3361	3609	2880	2333	2439

2.4. Maximum power point tracking control

As shown in Figure 2.5, this control method is simpler and uses only one control loop, and it performs the adjustment of duty cycle within the MPP tracking algorithm.

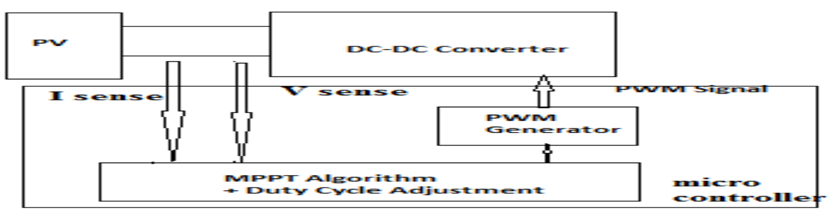

Figure 2.5. MPPT control loop.

The main unit of maximum power point control is the DC-DC converter. The following figure is the MATLAB implementation of converter with the selected module. Simulation has been made under nominal condition. G=1000w/m2, T = 25°C. The figures tells that the output of the PV module is 33.4 V and the output power of the module is 149.5 W which is the maximum according to the Data sheet. Boost coverter steps up the voltage two times higher which ripples between 65 to 70V.

To track the Maximum output Power point of PV module the P&O algorithm has been used and using boot converter the voltage has been steped up the two times higher than the PV output voltage .The value of Duty cycle of Pulse generator has increased and be remained constant at 0.5 to fix up the range of converter output voltage within 40-70 V for different solar irradiance This is the Maximum output voltage range for the selected PV module for different solar irradiance.

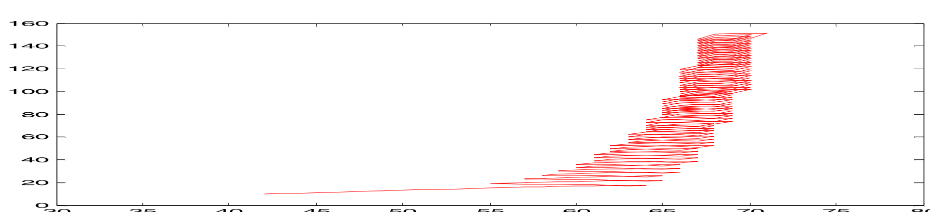

Figure 2.8. Output Voltage vs Power curve of MPP controled DC-DC boost converter.

The above model (figure2.5) has been implemented in MATLAB/Simulink. The effect of variable irradiance data with the variation of time on three series photovoltaic module has been observed Here Maximum Power Point Tracking algorithm has been used to keep the DC output of DC/DC converter at 200 V. For this reason the duty cycle of the DC/DC converter has been changed with the change of PV output voltage. Here P&O algorithm (figure2.8) is used for Maximum Power Tracking. We can also observe from the following figures that the total output power has changed with irradiation level.

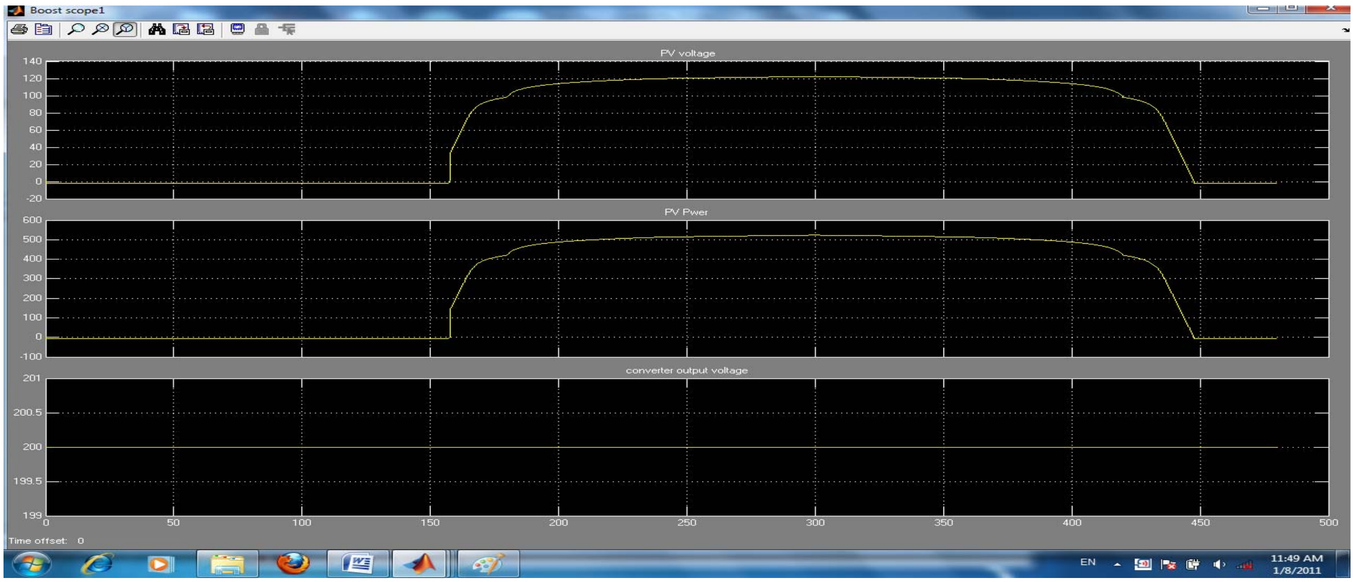

Figure 2.9. Graph of PV voltage, PV Power and Converter output voltage at [0 400 850 1950 4251 1950 850 400 0] W/m2-day.

3. Conclusion

This paper is the first step to develop a complete solar photovoltaic power electronic conversion system in simulation and the observation of the effect of variable solar irradiance over this system. The application with the irradiation values at city Batman in Turkey is given.

4. References

1. J. L. Dos Santos, F. L.M. Antunes, and A. Chehab, *A maximum power point tracker for PV systems using a high performance boost converter*, Eusebio Brasil, 2004, pp. 2-4.

2. H. Tsai, C. Tu, and Y. Su, "Development of Generalized Photovoltaic Model Using MATLAB/Simulink," *Proceedings of the World Congress on Engineering and Computer Science,* San Francisco, USA, 2008, pp. 22 – 24.

3. R. A. Messenger and J. Ventre, *Photovoltaic Systems Engineering*, CRC Press, New York 2004, pp. 47-52.

4. S. Shahidul and T. Sengor, "Photovoltaic System with Maximum Power Point Tracking Control and a Generalized Model Of Grid Connected Pv System," *10th International Conference on Sustainable Energy Technologies, 4th - 7th September.* Kumburgaz, Istanbul, Turkey, 2011 (accepted).

5. www.eie.gov.tr.

6. www.epdk.gov.tr.