COMPUTER BASED MODELLING OF A MAXIMUM POWER POINT TRACKING CONVERTER FOR SOLAR CELL ARRAYS

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Introduction

The solar cell generated electricity is being used as a major energy source. The subject matters are on improving the efficiency of the solar cell. At a given irradiance level the maximum power is generated at the optimum operating point. Solar charge converters are for the purpose of tracking the optimum operating point of a solar cell with the changing irradiance level. The improvements in speed of convergence, accuracy, cost of implementation and reliability of the Maximum Power Point Tracking algorithms are the current discussions on this matter. The necessity of algorithm simulation arises due to tedious and expensive hardware implementation.

When designing a Maximum Power Point Tracking (MPPT) controller, it is important that the controller is made to match with the characteristics of the solar cell. The complete model of the solar cell can be described by I_{ph}, I_{S1}, I_{S2}, R_p and R_s parameter values. Since parameter values can change with the age and the climate, the actual parameter values might have deviated from the values specified by the manufacturer.

Materials Required

Platform to run Matlab R2009b/ higher with Simulink based simscape Library.

Nomenclature

V: Solar cell terminal voltage; I: Solar cell terminal current; I_{ph}: Photo generated current; I_s: Solar generated current; I_{s1}: Saturation current due to diffusion mechanism; I_{s2}: Saturation current due to recombination in space-charge layer; N, N_1, N_2: Diode quality factor; R_s: Cell series resistance; R_p: Cell parallel resistance; V_t: Bandgap voltage.

Mathematical Model of a PV Cell

The mathematical description of the current/voltage terminal characteristics of a solar cell can be illustrated by the following two equations.

i. Double exponential equation

$$I = I_{ph} - I_{s1}\left(e^{\frac{V+IR_s}{N_1V_t}} - 1\right) - I_{s2}\left(e^{\frac{V+IR_s}{N_2V_t}} - 1\right) - \frac{V+IR_s}{R_p}$$

ii. Single exponential equation

$$I = I_{ph} - I_{s1}\left(e^{\frac{V+IR_s}{N\ V}} - 1\right) - \frac{V+IR_s}{R_p}$$

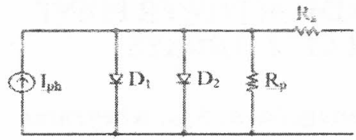

Fig. 1. Equivalent circuit model for double exponential equation

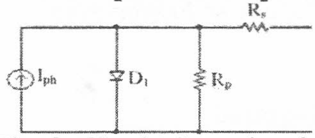

Fig. 2. Equivalent circuit model for single exponential equation

Modeling of the MPPT Converter Using MATLAB

A model for a solar cell array was constructed by combining twelve solar cell blocks available in Simscape. Parameter values for the solar cell model were evaluated assuming it to be working according to the single exponential equation and under room temperature with other temperature coefficients set at their default values.

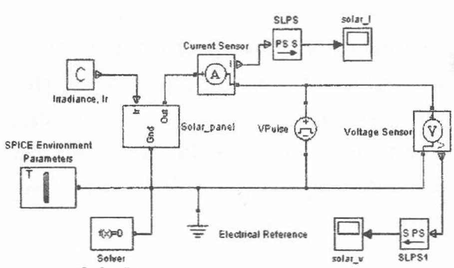

Fig.3. Circuit model to simulate the solar cell array

A circuit model was used to observe the variation of the output current with the output voltage of the solar array as in fig 4. Voltage source was used to force the desired voltage across the solar cell array. The resulting current was measured using a current sensor. In order to find the optimum parameter values for the solar cell array with the given set of data, it was required to develop a program which would simulate this circuit under different parameter values. In this program the parameter values of the simulated solar model are converged to the parameters of the actual solar cell by means of minimizing the Sum of Square error.

Several Matlab Simscape custom made components were used for the MPPT converter. A Multiplier calculates the power output of the solar cell array when the output current and the terminal voltage is given. A power tracking unit was required to drive the PWM generator according to the power output of the solar cell array. It tracks the maximum power point of the solar cell array and outputs a reference signal which the PWM generator runs on. This unit includes a differentiator circuit which calculates the change of the power output of the solar cell array with time. The power difference is then sent through a comparator which compares the power difference with a reference power level. Output of the comparator is then fed into an integrator which generates the reference signal which is used to drive the pwm generator. PWM generator is necessary to drive the switching evidence of the mppt converter.The PWM signal is generate by comparing the internal time varying sine wave with the input reference signal.

Results

The parameter values for the minimized Sum of Squared Errors were obtained as I_s = 1.01559e-006 A; I_{ph0} = 0.0535295 A; N = 1.51438; R_s = 3.32637e-006 Ω; R_p = 42.2159 Ω

The behavior of the solar cell array with the estimated parameter values

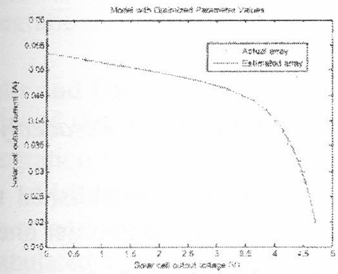

Fig. 4. Variation of I with V of the actual solar cell and the model

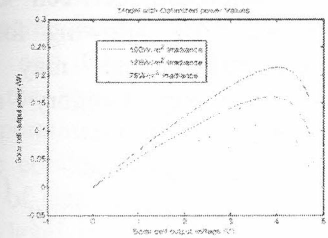

Fig. 5. Variation of output power with voltage at different irradiances

The behavior of the MPPT converter under constant irradiance

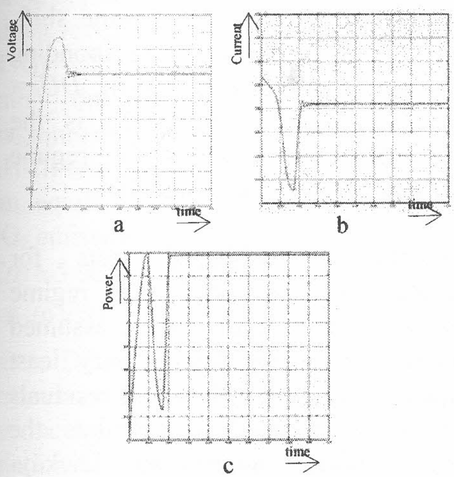

Fig. 6. Solar (a) terminal voltage (b) output current (c) output power

The behavior of the MPPT converter under varying irradiance

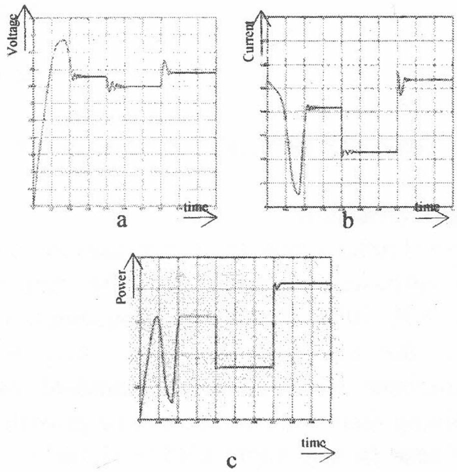

Fig. 7. Solar (a) terminal voltage (b) output current (c) output power

Conclusion

When developing a new algorithm it is important to compare its performance with existing algorithms. It would be useful if these algorithms can be simulated through computer software since fabricating the necessary hardware can be expensive and tedious. With the amenities provided with simscape one can model, test and compare different maximum power point tracking algorithms. This can be used as an effective tool for developing efficient MPPT algorithms.

References

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