

Simulation and Prototyping of Microcontroller Based Maximum Power Point Tracking of PV Array

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Abstract— As an important means of expanding renewable energy resources, the use of solar energy rapidly increase. To make solar energy more viable, the efficiency of solar array systems must be maximized. Photovoltaic generation has now-a-days proved to be a cost-effective method for renewable environment impact. The sun tracking is feasible approach for maximizing the efficiency of solar array systems. The simulation for the Maximum Power Point Tracking (MPPT) system is developed and validated. The design and construction of a proto type for solar tracking system with two degrees of freedom, which detects the sunlight using photocells & having microcontroller based controlling is developed. This paper reports on the electrical output of solar panel be plotted on a graph of voltage vs. current curve. The resulting line on the graph shows the current output of the panel for each voltage at a specific light level and temperature. The design offers a reliable and affordable method of aligning a solar module with the sun in order to maximize its energy output.

Keywords—Photovoltaic (PV), Microcontroller (MCU), Maximum power point tracking (MPPT), solar panel, Photovoltaic array (PVA), Light Dependent Resistor (LDR).

I. INTRODUCTION

Photovoltaic (PV) power generation has seen significant penetration into different applications ranging from space systems to residential and commercial installations. With this increase, high reliability and the availability of PV systems are essential. The photovoltaic resource among all the renewable is considered to be increasingly important for power generation in last few decades [1]. Recently an analytical approach to determine the PV cell parameters, i.e. resistances by adjustment of I-V equation with experimental characteristics was suggested [2]. The purpose of maximum power point tracking is to move the solar panel to the maximum power point when atmospheric changing happens in order to draw the maximum power from the array. In order to collect energy from the sun it is essential that the sun's location in relation to the solar panel could be predicted [3]. This paper discusses modelling of Maximum Power Point Tracking (MPPT) system, which automatically provides best alignment of solar panel with the sun, to get maximum output.

To meet the requirements of home or business, the power that one module can produce is not sufficient. Most PV arrays use an inverter to convert the DC power into alternating current that can power the motors, loads, lights etc. The modules in a PV array are generally connected in series and parallel to obtain the desired voltages & to produce more

current respectively. The PV array system which is made by parallel connected modules is as shown Fig.1.

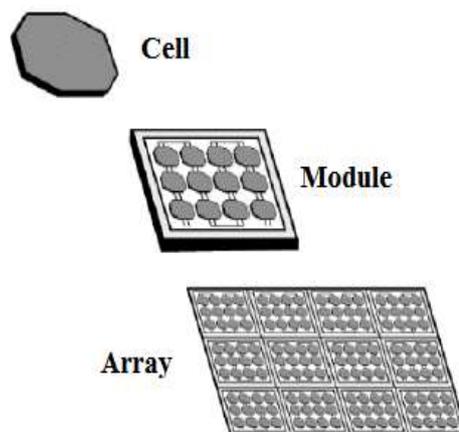


Fig. 1 Photovoltaic System

The block diagram for the MPPT of PV array is as shown in Fig.2

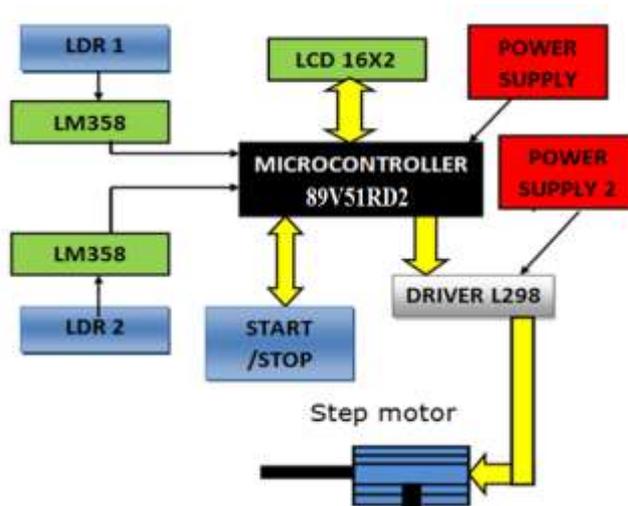


Fig. 2 Block Diagram of Microcontroller based MPPT of PV Array

Light Dependent Resistor (LDR) is used for the detecting the solar radiation and output of LDR-1 & LDR-2 are given to the controller. The PV module is rotate at where the intensity of the solar radiation is higher. Intensity of the solar radiation is sensed by the output value of the LDRs which is given to the microcontroller. Stepper motor is used for the two degree

rotation of the PV module on the parallel axis of the motor shaft.

II. MATHEMATICAL MODELLING OF PV ARRAY

The PV arrays are built up with combined series/parallel combinations of PV solar cells, which are usually represented by a simplified equivalent circuit model such as given in below Fig. 3

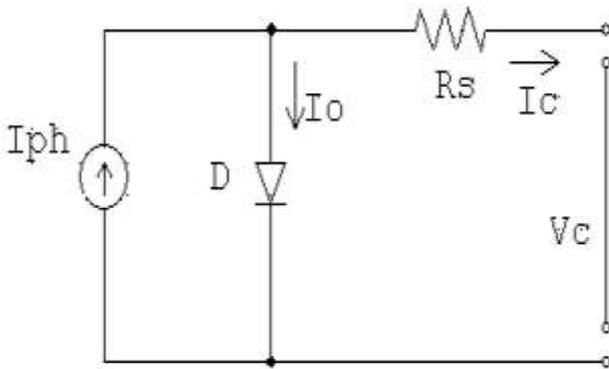


Fig. 3 Equivalent Circuit of PV cell

The PV cell output voltage is a function of the photocurrent that mainly determined by load current depending on the solar irradiation level during the operation.

$$V_c = \frac{AkT_c}{e} \ln \left(\frac{I_{ph} + I_o - I_c}{I_o} \right) - R_s I_c \quad (1)$$

Where, the symbols are defined as follows:

- V_c = Cell output voltage
- e = Electron charge ($1.602 \times 10^{-19} \text{ } ^\circ\text{C}$)
- k = Boltzmann constant ($1.38 \times 10^{-23} \text{ J/K}$)
- I_c = Cell output current
- I_{ph} = Photocurrent
- I_o = Reverse saturation current of diode (0.0002 A)
- R_s = Series resistance of cell (0.001 Ω)
- T_c = Cell operating temperature (25 $^\circ\text{C}$)

The voltage of a single solar cell which is then multiplied by the number of the cells connected in series to calculate the full array voltage is given by eq.1. The curve fitting factor A is used to adjust the I-V characteristics of the cell obtained from eq.1 to the actual characteristics obtained by testing. Since the array current is the sum of the currents flowing through the cells in parallel branches, the cell current I_c is obtained by dividing the array current by the number of the cells connected in parallel before being used in eq.1, which is only valid for a certain cell operating temperature T_c with its corresponding solar irradiation level S_c .

The effect of the changes in temperature and solar irradiation levels should also be included in the final PV array model because PV array will follow this change. When the ambient temperature and irradiation levels change, the cell operating temperature also changes, resulting in a new output

voltage and a new photocurrent value temperature, this in turn affects the cell output voltage. These effects are represented in the model by the temperature coefficients C_{TV} and C_{TI} for cell output voltage and cell photocurrent respectively:

$$C_{TV} = 1 + \beta_T (T_a - T_x) \quad (2)$$

$$C_{TI} = 1 + \frac{\gamma_T}{S_c} (T_a - T_x) \quad (3)$$

Where, $\beta_T=0.004$ and $\gamma_T=0.06$ for the cell used and $T_a=25^\circ\text{C}$ is the ambient temperature during the cell testing. This is used to obtain the modified model of the cell for another ambient temperature T_x . If the solar irradiation level increases from S_{X1} to S_{X2} , the cell operating temperature and the photocurrent will also increase from T_{X1} to T_{X2} and from I_{ph} to I_{ph2} , respectively. Thus, the change in the operating temperature and in the photocurrent due to variation in the solar irradiation level can be expressed via two constants, C_{SV} and C_{SI} , which are the correction factors for changes in cell output voltage V_c and photocurrent I_{ph} , respectively:

$$C_{SV} = 1 + \beta_T \alpha_S (S_X - S_C) \quad (4)$$

$$C_{SI} = 1 + \frac{1}{S_c} (S_X - S_C) \quad (5)$$

Where, S_c is the benchmark reference solar irradiation level during the cell testing to obtain the modified cell model. S_x is the new level of the solar irradiation. The temperature change, ΔT_c , due to the change in the solar irradiation level is obtained using,

$$\Delta T_c = \alpha_S (S_X - S_C) \quad (6)$$

The constant α_s represents the slope of the change in the cell operating temperature due to a change in the solar irradiation level and is equal to 0.2 for the solar cells used. Using correction factors C_{TV} , C_{TI} , C_{SV} and C_{SI} , the new values of the cell output voltage V_{cx} and photocurrent I_{phx} are obtained for the new temperature T_x and solar irradiation S_x as follows:

$$V_{CX} = C_{TV} C_{SV} V_c \quad (7)$$

Where, V_c = Benchmark reference cell output voltage

I_{ph} = Reference cell photocurrent

III. SIMULINK MODEL OF PV ARRAY

A general block diagram of the photovoltaic array model for GUI environment of Simulink in Matlab is as shown in Fig. 4 along with filter and load models. The block called PVA model for GUI is the last stage of the model. This block contains the sub models that are connected to build the final model. A diode and filter are connected to prevent the reverse current flow and to maintain a stable voltage respectively. The PV array consists of PV cells all connected in series to have a desired voltage output. Depending on the load power required, the number of parallel branches can be increased to 2 or more.

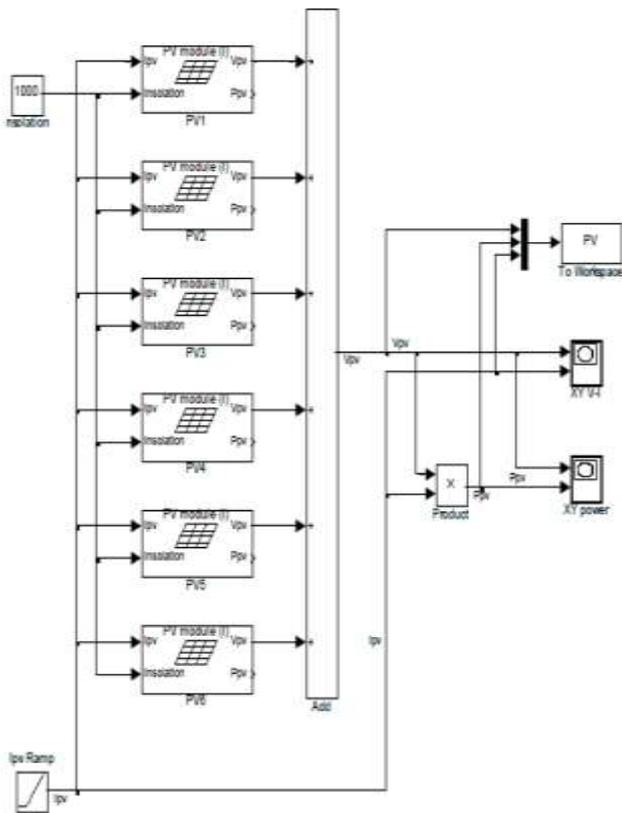


Fig. 4 Simulink Model of PV Array

IV. SIMULATION RESULTS AND DISCUSSION

The effect of variation in solar radiation and cell temperature are important to estimate the performance under different weather conditions. The photo-current is directly proportional to solar radiation. In fact, PV cell performance does not degrade significantly from full sun shine to partial cloud conditions.

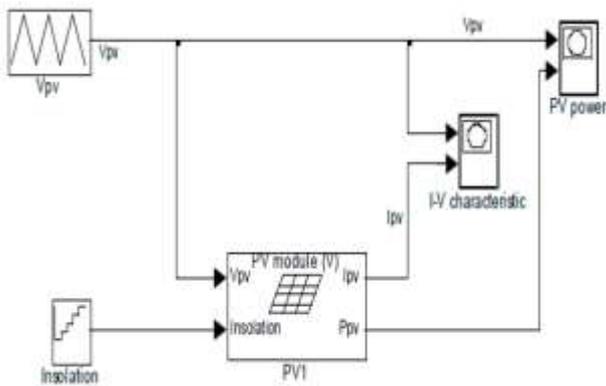


Fig. 5 PV Array Module for Simulink

The P-V characteristic of P_{PV} as a function of V_{PV} is as shown in Fig.6.

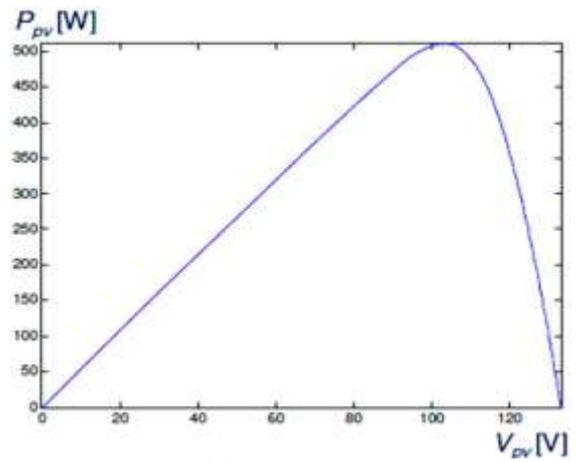


Fig. 6 P_{PV} as a function of V_{pv}

Fig.7 shows P-I characteristic in which the P_{PV} is shown as a function of I_{PV} which is equal to I_{ref}

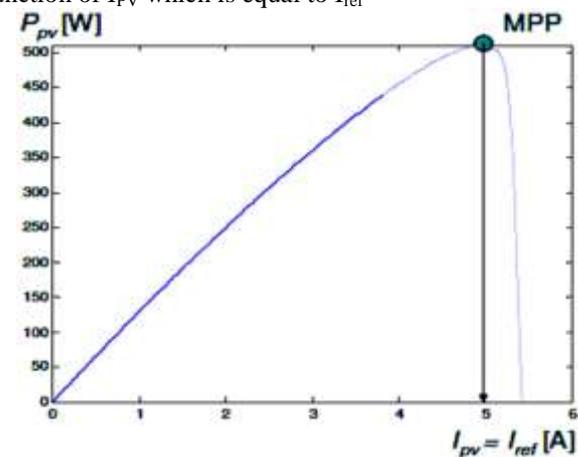


Fig. 7 P_{pv} as a function of I_{pv} = I_{ref}

The effect of variation in solar radiation on I-V and P-V characteristics is shown in Fig.8 and Fig.9 respectively.

P-V Characteristics

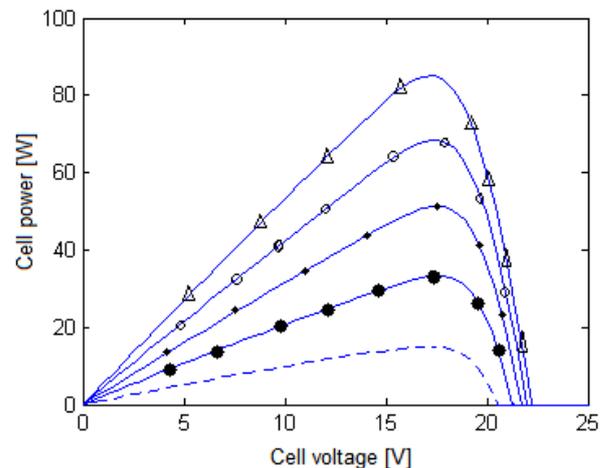


Fig. 8 P-V characteristics of the PV Module

In case of low solar radiation, there is slight decrease in open circuit voltage with respect to reduction in value of short circuit current.

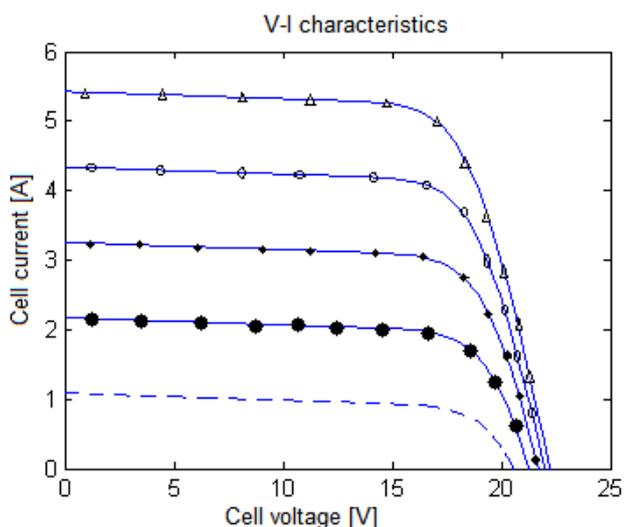


Fig. 9 V-I characteristics of the PV Module

V. SIMULATION RESULTS AND DISCUSSION

Prototype is designed for detailed analysis as well as for the real time application is developed. Hardware setup of the microcontroller based Maximum Power Point Tracking (MPPT) of Photovoltaic array is as shown in Fig.10. PV module is connected with the shaft of the stepper motor. The maximum power point tracking is achieved by the stepper motor operation by the variation of solar radiation. Philips 89V51RD2 microcontroller is used for the motion controlling of the PV module which is connected to the shaft of the stepper motor as shown Fig.10.



Fig. 10 Shaft connection of Stepper motor

89V51RD2 Controller is having the program loaded for the operation of the stepper motor to achieve the position where the maximum power can achieve.

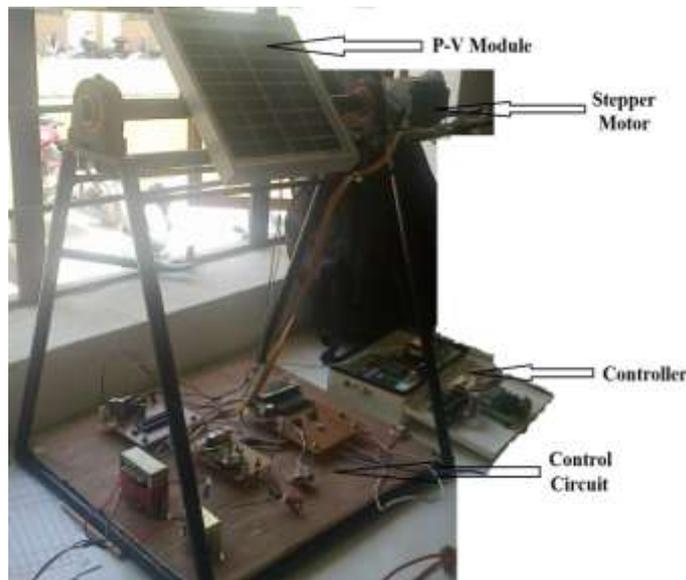


Fig. 11 Hardware of the PV Module

VI. CONCLUSION

This paper presents the development of MPPT system which comparatively better and accurate. The change in the temperature and maximum power point tracking for the maximum utilization of the solar radiation can be achieved by this topology. The open circuit P-V, P-I, V-I curves obtained from the simulation of the PV array designed hardware module. It is dependence on the solar radiation levels and temperature. Detailed study of the various values of the voltage and current obtained and plotted in the open circuit V-I curve of the PV array. The prototype is developed for the practical analysis. The voltage and current values lies on the curve showing that the hardware design of developed prototype is proper. However the performance of the photovoltaic device depends on the spectral distribution of the solar radiation.

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