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A Simple and Cost Effective Perturb and Observe Aided MPPT Algorithm for PV System Under Rapidly Varying Irradiance

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Abstract: Maximum power point tracking (MPPT) techniques are used in photovoltaic (PV) systems to extract maximum power from the PV module. There are different mppt techniques available but still most of the commercial systems utilizes the perturb& observe (P&O) technique, because of simple algorithm, low cost and ease of implementation. However, this technique is hampered when MPP under rapidly changing irradiance and there is every chance for the conventional perturb to fail. This particular paper is aimed not only to harness the advantages of Perturb & Observe but also to make it more adaptive for any sudden variation in insolation and thereby making the conventional Perturb & Observe a more versatile. The simulation and hardware results reveal that the suggested work is versatile.

Index Terms: DC-DC Converter ,MPPT, perturb & observe , Photovoltaic Cell.

1. INTRODUCTION

From the past years, the demand for electrical increased vastly,[1]Hence the requirement of new energy resources desperately needed. Photo Voltaic (PV) solar power is the one of the most potential renewable energy source, especially in mobile applications. Research in improving the performance of PV system has been carried out for the last three decades, finally paving the way for increased efficiency of PV solar cell. A new concept is the thin-film technology. In this case, the PV solar cell is made by one or more thin layers on substrate. More layers allow higher usage of the solar spectrum. Today, the highest efficiency 44.7 % of PV cell was demonstrated by Fraunhofer Institute for Solar Energy Systems.

The inherent drawback a PV system possess is its intermittent nature of power production with respect to sun's irradiation and temperature.[2],Maximum power trackers (MPT) are electronic regulators which make most of the available power in the PV panel. The power trackers adhere to algorithm called maximum power point tracking MPPT algorithm to achieve this.

There are numerous MPPT's available in the research arena where the prominent customers are P&O and incremental conductance and hill climbing etc. The perturb and obsorb algorithm known for its easy execution and reliablility. Incremental conductance on the other hand a superior to P & O in excluding the power oscillation around the MPP. But it has its own short fall of having complex in algorithm. Therefore proposing positive modifications in the available P and O technique is a rational research idea.

2. MODELING OF PV CELL

Solar energy from the sun is converted into electricity in the PV system. Generally, the PV system contains small units of PV cells. Arrangement of PV cells either in series or parallel is called PV Array, combination of PV arrays is PV system.[3]-[5] Figure 1 represents the single diode model of the PV cell where a single diode is considered in parallel with I_{ph}.

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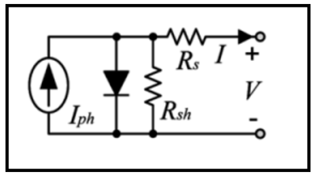


Figure 1: Equivalent circuit of a PV cell

$$I = I_{ph} - I_s \left\{ e^{\frac{V_{sh}}{n\mathrm{Vt}}} - 1 \right\} - \frac{V + IR_s}{R_{sh}} \tag{1}$$

$$I_{ph} = [I_{sc} + K_i(T - 298)] \frac{\beta}{1000} \tag{2}$$

$$I_s(T) = I_s \left(\frac{T}{T_{\mathrm{nom}}} \right)^3 \exp\left[\left(\frac{T}{T_{\mathrm{nom}}} - 1 \right) \frac{Eg}{N.Vt} \right] \tag{3}$$

In this equation, photocurrent is I_{ph}, reverse saturation current of the diode is I_s, q is the electron charge, V is the voltage across the diode, K is the Boltzmann's constant, T is the junction temperature, N is the ideality factor of the diode, and R_s and R_{sh} are the series and shunt resistors of the cell, respectively. As a result, the complete physical behavior of the PV cell is in relation with I_{ph}, I_s, R_s and R_{sh} from one hand and with two environmental parameters as the temperature and the solar radiation from the other hand.

The above equation calculates the PV cell photocurrent which depends on the radiation and the temperature where K_i = 0.0017 A/°C is the cell's short circuit current temperature coefficient and β is the solar radiation (W/m^2).

The diode reverse saturation current varies as a cubic function of the temperature and it can be expressed as in the above equation where I_s, the diode reverse saturation current, T_{nom} is the nominal temperature, E_g is the band gap energy of the semiconductor and V_t is the thermal voltage. In general, for a given solar radiation, when the cell temperature increases, the open circuit voltage V_{oc} drops slightly, while the short circuit current increases. Voltage and current outputs of the PV modules is affected by temperature and irradiance. Power electronics components of a photovoltaic system, such as boost converters have maximum and minimum voltage inputs. During rating of power electronics equipment, these variations should be taken into account especially for the MPPT range of converters.

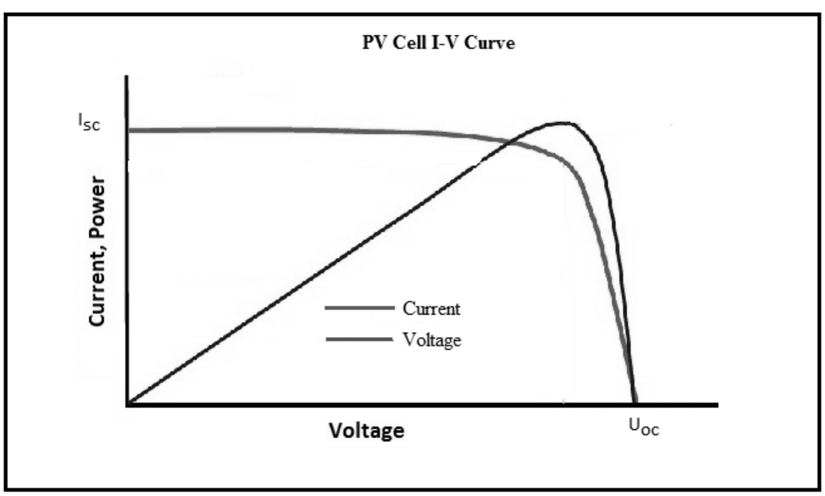


Figure 2: PV cell I-V Curve and P-V Curve

3. OPEN CIRCUIT VOLTAGE VS TEMPERATURE

A PV module's voltage output is actually a variable value that is primarily affected by temperature. The relationship between module voltage and temperature is actually an inverse one. As elaborated in Figure 3 the module's temperature increases, the voltage value decreases and vice versa. It is important to put into consideration the cold and hot temperatures during PV design. If the temperature of the module is less than the STC value of 25°C, the module's open circuited voltage, V_{oc} value will actually be greater than the value listed on the module's listing model.

PV module manufacturers will report the amount of change their modules experience in the form of temperature in terms of a percentage per degree Celsius.

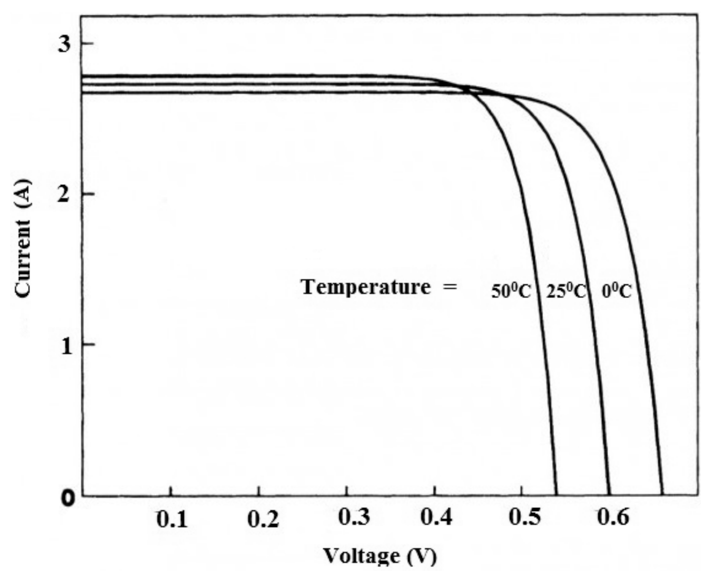


Figure 3: Current and voltage characteristics of a PV module with temperature variation

To illustrate this phenomenon, let's consider the worst case of temperatures recorded in it shows for data recorded the average maximum temperature was 14.4°C with irradiance of 123W/m^{2}h in the month of August. On the other hand the minimum average temperature was obtained in January and the data recorded was –3.4°C with irradiance of 18W/m^{2}h.

4. CURRENT VS. IRRADIANCE

In the PV module basing on the brightness of sun, current will be produced. Current is directly produced with respect to the irradiance. Higher levels of irradiance will cause more electrons to flow off the PV cells to the load attached. The effect of irradiance on voltage will be less affected compared to the effect on current. As represented in Figure 4 the PV module's voltage changes very little with varying levels of irradiance. The different irradiances presented in the below figure varies from 200W/m^2 to 1000W/m^2.

5. PROPOSED SOLAR PV MODEL

Perturb and Observe Algorithm and Simulation

In the perturb & observe algorithm [6], [7] a small perturbation is introduced to the system. The power of the modules changes slightly due to perturbation. Basing on increase in power due to perturbation, then direction of perturbation continued in same direction. Once power reaches maximum point, by the next instant power decreases, thus direction of perturbation will be reversed. The algorithm will oscillate when it reaches to the maximum point and when tries to attain steady state. In the proposed technique we will keep the perturbation to very small value. The algorithm explained with the help of a flow chart as shown in Figure 5 From the PV panel we are sensing current and voltage, from the sensed voltage and current we are going to calculate power. The values of voltage and power at k^{th} instant are stored.

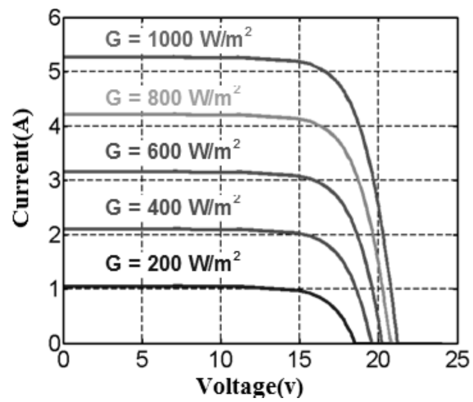


Figure 4: Current and Voltage characteristics of a PV module with irradiance variation

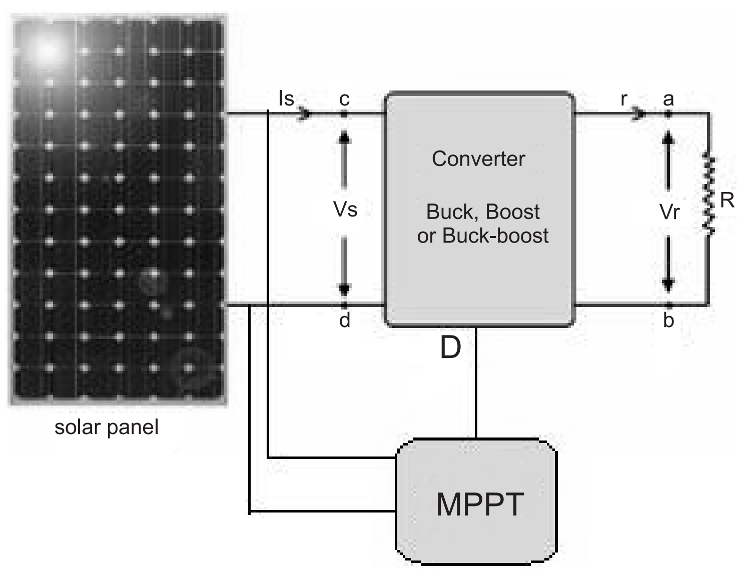


Figure 5: Solar panel model

$$P(k) = V(k) \times I(k) \tag{4}$$

Then for the next instant we are measuring the voltage and current, power is calculated from the measured values and stored. It is compared with the stored value and updated. The power and voltage at $(k-1)^{th}$ instant are subtracted with the values from k^{th} instant and the same process is continued.

$$P(k-1) = V(k-1) \times I(k-1) \tag{5}$$

$$\Delta P = P(k) - P(k-1) \tag{6}$$

$$\Delta V = V(k) - V(k-1) \tag{7}$$

The power-voltage curve of the solar *pv* cell having positive slope ($\Delta P/\Delta V > 0$) when the power is increasing. The slope will becomes negative ($\Delta P/\Delta V < 0$) after reaching the maximum point. The duty cycle is decreased in case of positive slope and increased if the slope becomes negative. Thus, depending on the sign of $\Delta P(P(k+1) - P(k))$ and $\Delta V(V(k+1) - V(k))$ the algorithm decides whether to increase the duty cycle or to reduce it even for smaller perturbation.

$$D = D \pm \Delta D \tag{8}$$

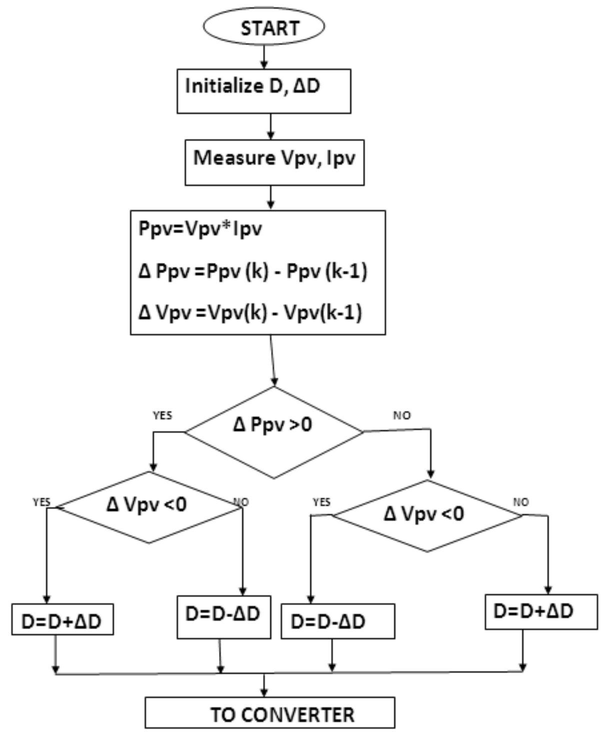


Figure 5: Flow chart of perturb & observe algorithm

6. DC-DC CONVERTER

A boost converter is a DC-to-DC power converter, [17], [18] input voltage will be stepped up, so the output voltage greater than its input voltage. It is a class of switched-mode power supply (SMPS) contains at least two semiconductors (a diode and a transistor) and at least one energy storage element, a capacitor, inductor, or the two in combination. Output voltage ripples are reduced by the use of filters which are made of capacitors, someimes in combination with inductors. The key principle that drives the boost converter is the tendency of an inductor to resist changes in current by creating and destroying a magnetic field. In Figure 6.

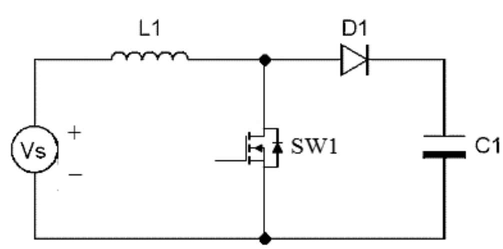


Figure 6: Boost converter

7. HARD WARE MODEL

The hardware set up and simulation results are shown in Figure 7,8 and 9 respectively.

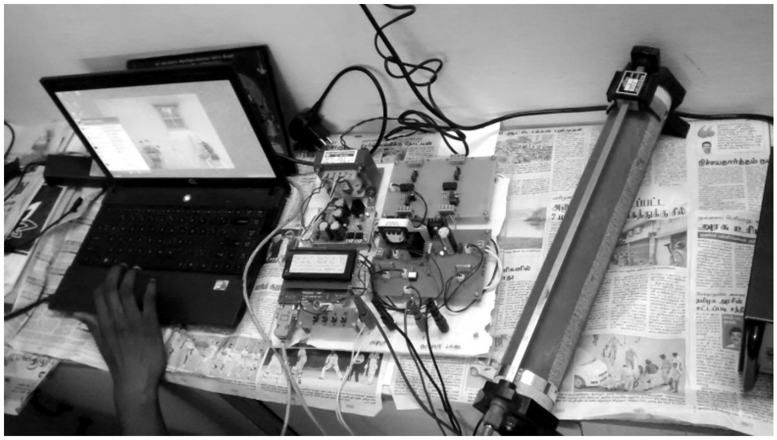
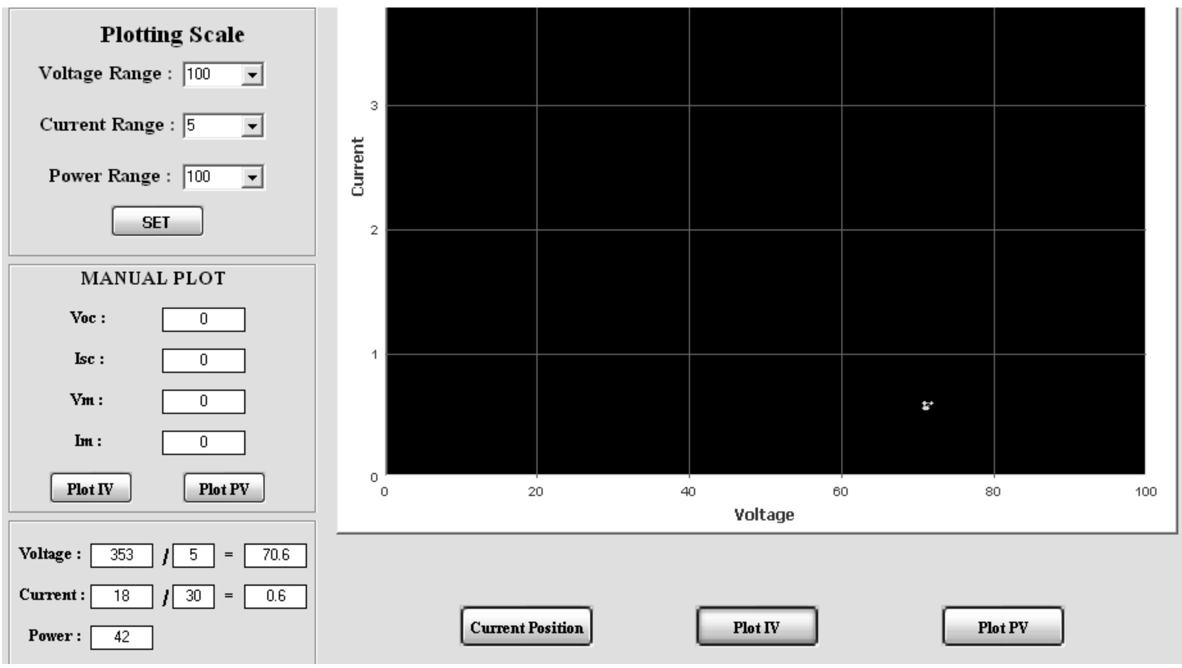
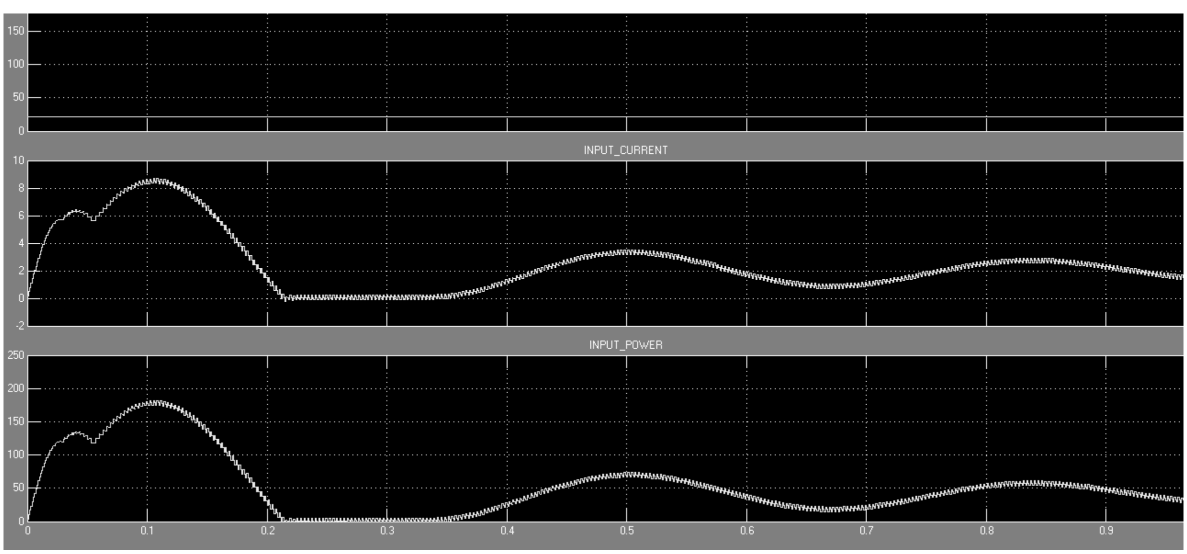


Figure 7: Hardware setup

8. SIMULATION RESULTS





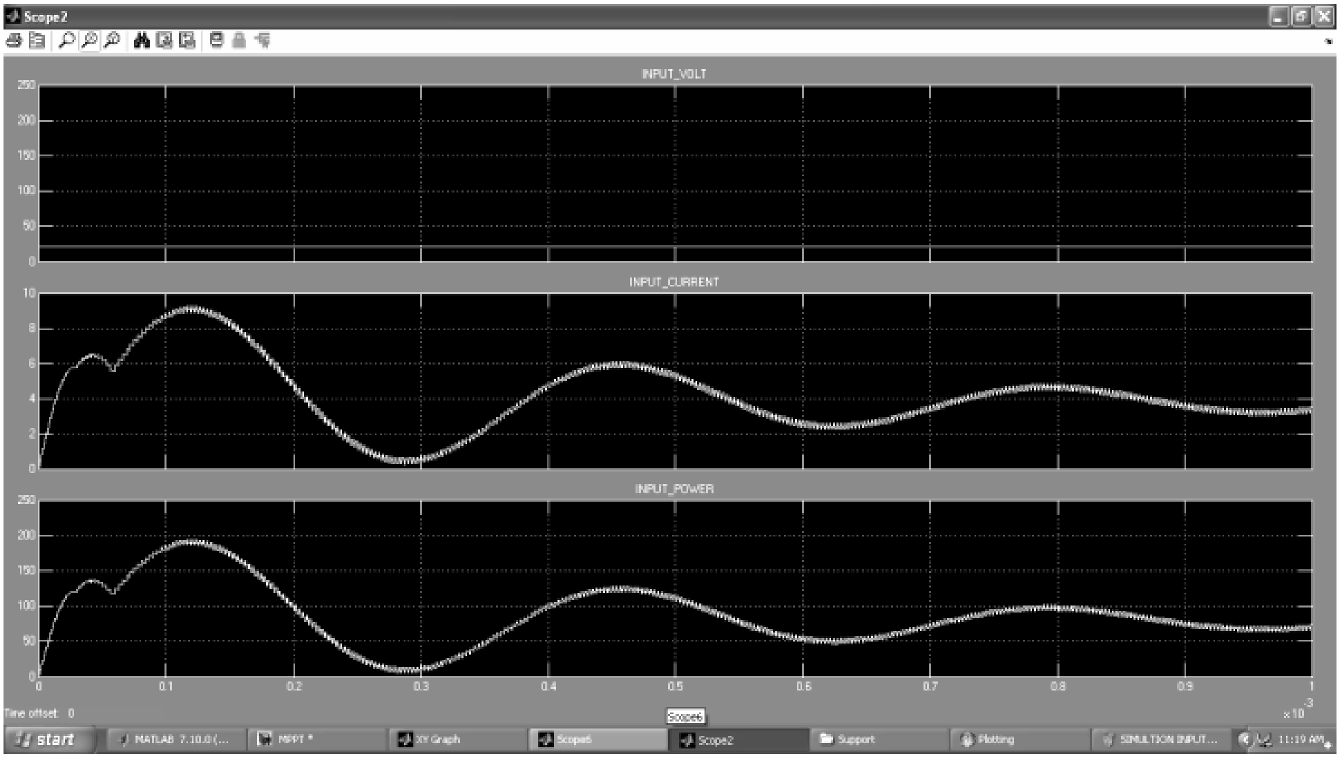
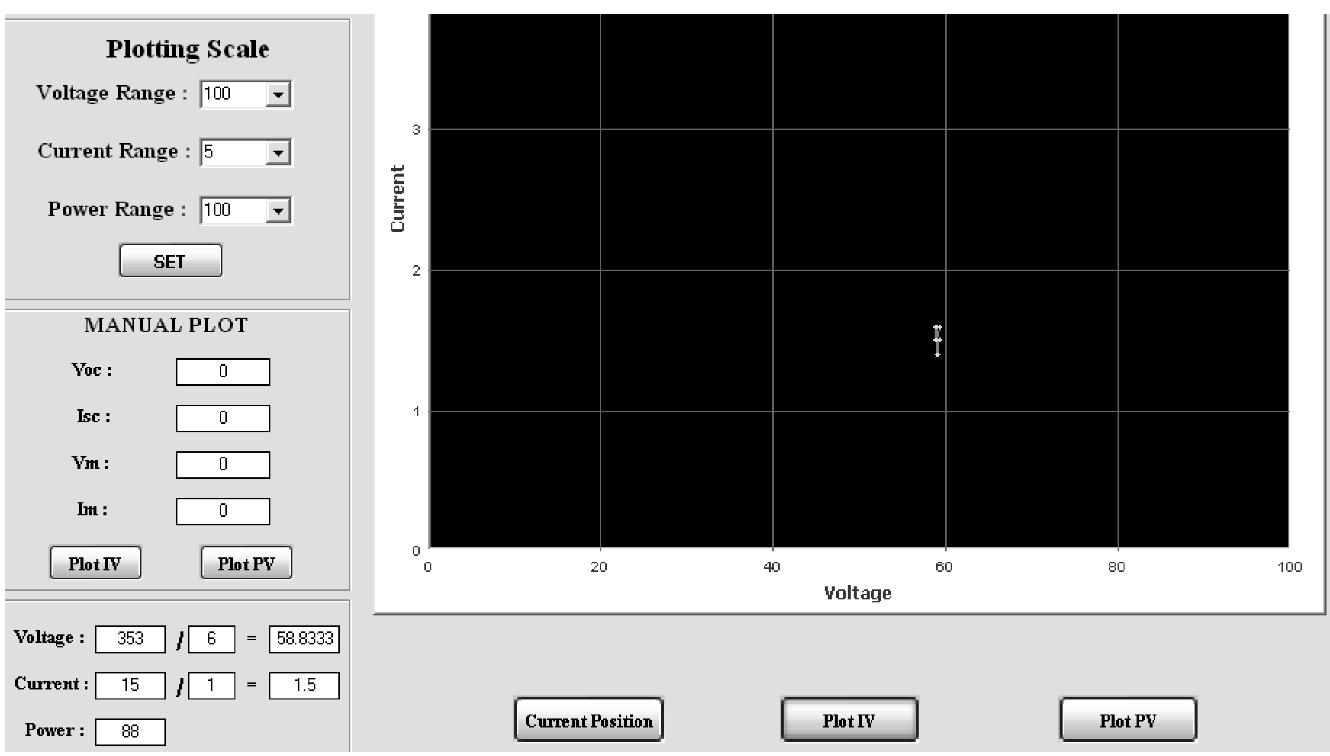


Figure 8: Simulation results

9. CONCLUSION

This paper modeling a standalone PV system based on modified Perturb and observe algorithm for maximum power point tracking. Simulation results are verified with the hardware results for various irradiations. The system operates in the maximum power point for the same irradiances value.



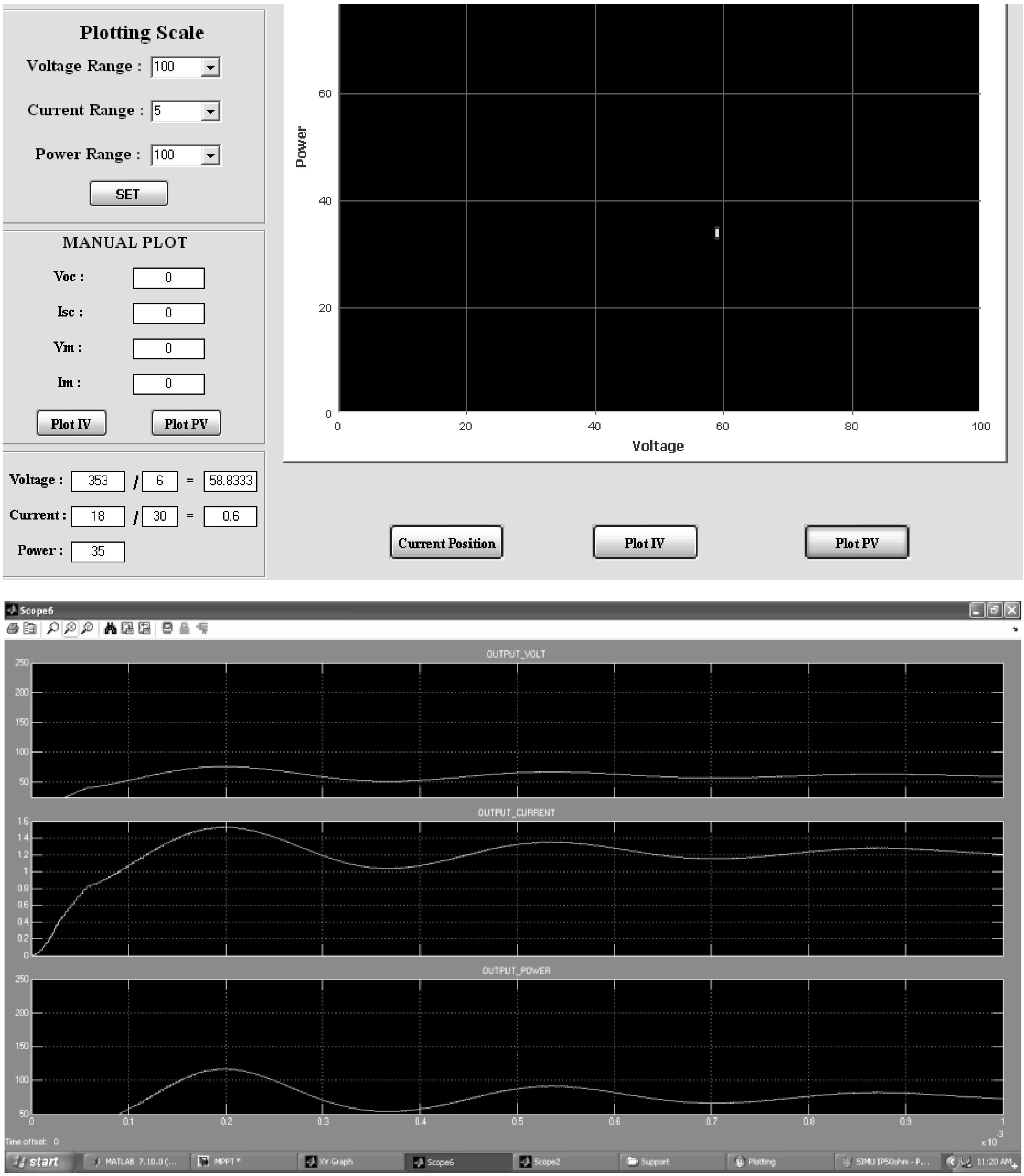


Figure 9: Simulation results

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