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Effect of Perturb & Observe Algorithm and Incremental Conductance Algorithm on the Performance of Cuk Converters for Photovoltaic Application

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ABSTRACT

This study presents a new kind of maximum power point tracking algorithm based on perturb and observe algorithm and incremental conductance algorithm compare. A generalized photovoltaic array simulation model in MATLAB/Simulink environment is developed and presented. This paper presents in details comparative study between two most popular algorithms technique which is incremental conductance algorithm and perturb & observe algorithm. Considering the effect of solar irradiance and temperature changes, the output current and voltage of PV modules are simulated and optimized using this model. Cuk converter use for comparative study. Few comparisons such as efficiency, voltage, current and power output for each different combination has been recorded in this paper. Cuk converters are considered as possible dc–dc converters that can be cascaded. MATLAB simulations are used to compare the efficiency of each topology as well as evaluating the benefits of increasing cost and complexity. The cuk converters are shown to be the most efficient topologies for a given cost, with the cuk best suited for long strings. The proposed model is designed with a user-friendly icon and a dialog box like Simulink block libraries.

Key words: Maximum power point tracking (MPPT), Photovoltaic array, DC-DC converters, Perturb & observe algorithm and Incremental conductance algorithm

INTRODUCTION

The system configuration for the topic is as shown figure 1. Here the PV array is a combination of series and parallel solar cells. This array develops the power from the solar energy directly and it will be changes by depending up on the temperature and solar irradiances. So we are controlling this to maintain maximum power at output side we are boosting the voltage by controlling the current of array with the use of PI controller. By depending upon the dc-dc converters like buck, boost and cuk converters output voltage finally it connects to load for various applications [1].

PROPOSED MPPT ALGORITHM FOR PHOTOVOLTAIC APPLICATION

A. *Modeling of Solar PV Module*

In electrical terminology Modeling of Photovoltaic cell means representing with its equivalent circuit. PV cell can be represented in three equivalent circuits. A solar cell can be operated at any point along its characteristic current-voltage cure, as shown in figure 2. Two important points on this curve are the open circuit voltage (V_{oc}) and short-circuit current (Isc). The open-circuit voltage is the maximum voltage at zero current, whereas the short-circuit current is the maximum current at zero voltage. A plot of power (P) against voltage (V) for this device shows that there is a unique point on the I-V curve at which the solar cell will generate maximum power. This is known as the maximum power point (V_{mpp}, I_{mpp}) [2-3]. Because a silicon solar cells typically produce only about 0.5V. A number of cells are connected in series in a PV module. A panel is a collection of modules physically and electrically grouped together on a support structure. An array is a collection of panels.

Model I

In model I the PV cell is represented with a current source in parallel with a diode. The current source generated the photo current I_{ph}, which is directly proportional to the solar irradiance E. The p-n transition area of the solar cell is equivalent to a big diode which is also integrated in the picture [4-6].

The V-I equation of the simplified equivalent circuit could be derived from Kirchhoff's current law.

$$I = I_{ph} - I_D = I_{ph} - I_S \times \left(\exp\left(\frac{V}{m.v_T}\right) - 1\right) \quad (1)$$

Here

I_{ph}= Photo current, I_D = Diode current, I_S = diode reverse saturation current, charge of an electron e=1.6*10^{-19}C

m = Diode 'ideality factor' m=1…..5, v_T = Thermal Voltage v_T= (k.T/e)

k = constant of Boltzmann k= 1.380658*10^{-23} Jk^{-1}, T = absolute temperature, [T] =K (Kelvin)

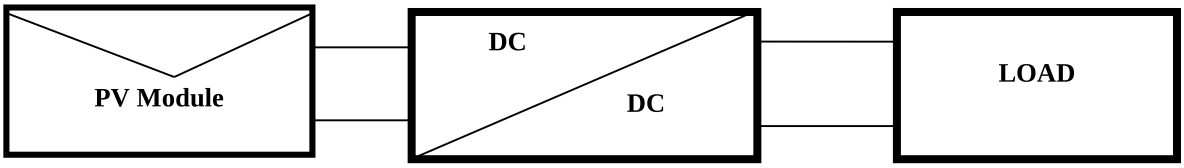

Fig. 1 Typical MPPT System Block Diagram

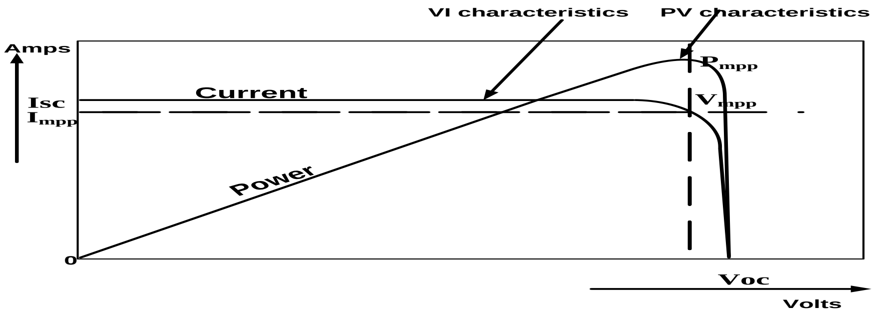

Fig. 2 Characteristics of Photovoltaic System

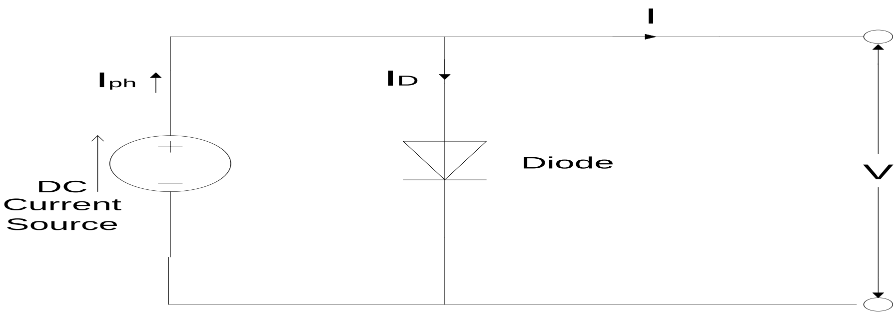

Fig. 3 Ideal PV Model

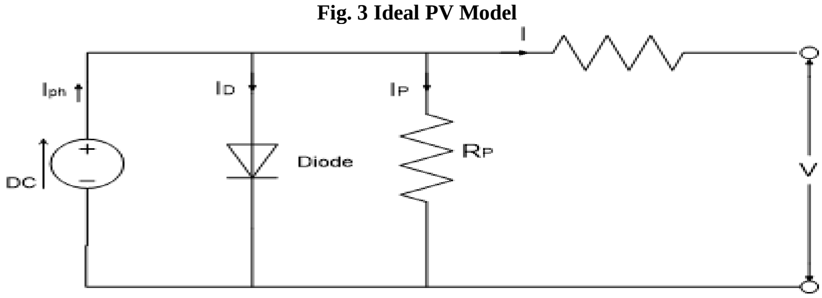

Fig. 4 Real PV Model

Model II

As mention above, the simplified equivalent circuit doesn't give an optimal representation of the electrical process at the solar cell. At real solar cells a voltage loss on the way to the external contacts could be observed. This voltage loss could be expressed by a series resistor, R_s. Furthermore, leakage currents could be observed, which could be described by a parallel resistor, R_p [7- 9].

Derived from Kirchhoff's first law the equation for the extended I-V curve is achieved.

$$0 = I_{ph} - I_D - I_P - I \quad (2)$$

With $$I_p = \frac{V_D}{R_P} = \frac{V + I \cdot R_S}{R_P} \tag{3}$$

follows

$$0 = I_{ph} - I_s \cdot \left(\exp\left(\frac{V + I \cdot R_S}{m \cdot V_T} \right) - 1 \right) - \left(\frac{V + I.R_S}{R_p} \right) - I \tag{4}$$

$$\Rightarrow I = I_{ph} - I_s \cdot \left(\exp\left(\frac{V + I \cdot R_S}{m \cdot V_T} \right) - 1 \right) - \left(\frac{V + I.R_S}{R_p} \right) \tag{5}$$

B. MPPT Algorithm Implementation

Tracking the maximum power point of a photovoltaic array is usually an essential part of a PV system. The problem considered by MPPT techniques is to automatically find the voltage V_{MPP} or current I_{MPP} at which a PV array should operate to obtain the maximum power output P_{MPP} under a given temperature and irradiance. Here we implement Perturb and observe (P&O) MPPT algorithm and Incremental conductance MPPT algorithm. In Perturb and observe (P&O) algorithm the controller adjusts the voltage by a small amount from the array and measures power; if the power increases, further adjustments in that direction are tried until power no longer increases [10-11]. It is referred to as a *hill climbing* method, because it depends on the rise of the curve of power against voltage below the maximum power point, and the fall above that point. In the incremental conductance algorithm, the controller measures incremental changes in array current and voltage to predict the effect of a voltage change. This algorithm requires more computation in the controller, but can track changing conditions more rapidly than the perturb and observe algorithm (P&O). The fig.5 and fig.6 explain the operation of Perturb and observe algorithm and incremental conductance algorithm with a flow chart [12-13].

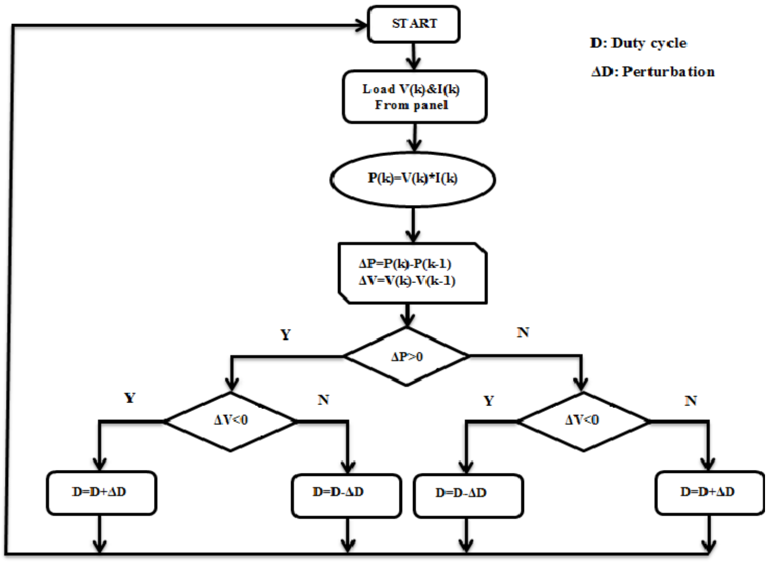

Fig. 5 Perturb and Observe Algorithm

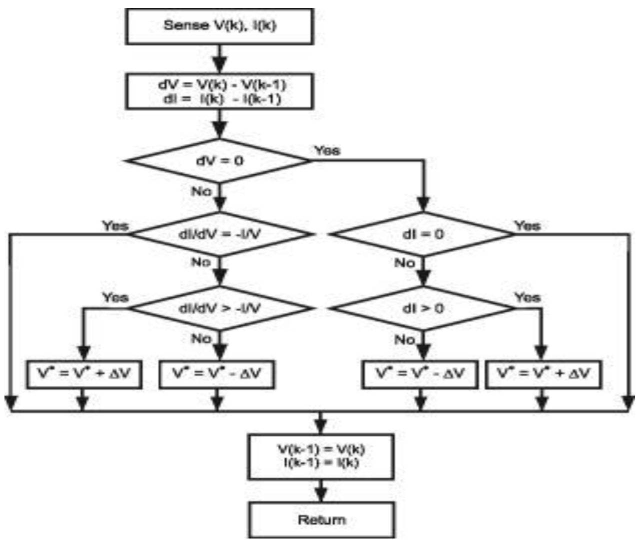

Fig. 6 Incremental Conductance Algorithm

CUK CONVERTER

There is three basic type of DC-DC converter for to track the maximum power from solar PV system to the load. A dc/dc converter froms an integral part of any MPPT system. Without dc/dc converter no MPPT system are designed. There are variations on the basic Cuk converter. For example, the coils may share single magnetic core, which drops the output ripple, and adds efficiency. Because the power transfer flows continuously via the capacitor, this type of switcher has minimized EMI radiation. [14] The Cuk converter enables the energy flow bidirectional, by adding a diode and a switch. The basic circuit of a Cuk converter is shown in Fig.7 and as you can see it has an additional inductor and capacitor. The circuit configuration is in some ways like a combination of the buck and boost converters, although like the buck-boost circuit. It delivers an inverted output. Note that virtually all of the output current must pass through C_1, and as ripple current. So C_1 is usually a large electrolytic with a high ripple current rating and low ESR (equivalent series resistance), to minimize losses. When switch is turned on, current flows from the input source through L_1 and MOSFET, storing energy in L_1. Magnetic field. Then when MOSFET is turned off, the voltage across L_1 reverses to maintain current flow. As in the boost converter current then flows from the input source, through L_1 and diode, charging up C_1 to a voltage somewhat higher than V_{in} and transferring to it some of the energy that was stored in L_1. Then when MOSFET is turned on again, C_1 discharges through via L_2 into the load, with L_2 and C_2 acting as a smoothing filter [15-17].

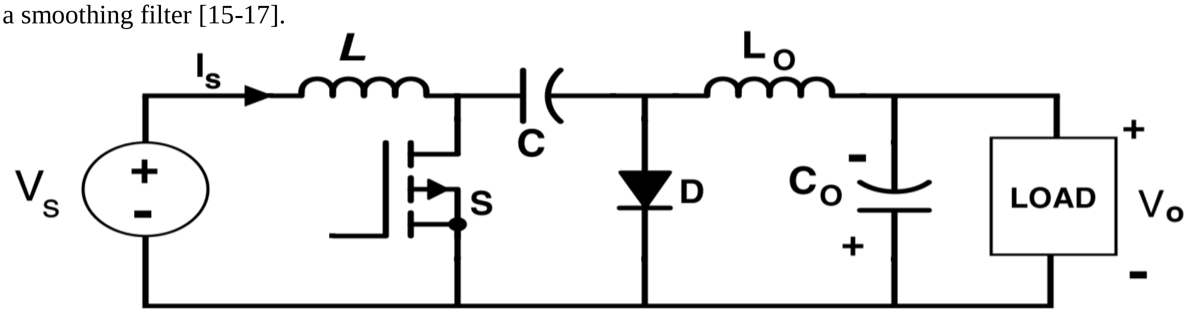

Fig. 7 Circuit Diagram of Cuk Converter

SIMULATION RESULTS

The simulation of solar PV module characteristics is done on the MATLAB/Simulink.

Parameters of Solar PV module

Output voltage, current and power curve of Solar PV model is shown in the figure 9.

Open circuit voltage (V_{oc}) = 22.22V
Short circuit current (Isc) = 5.45 A
Current at Pmax = 4.95A
Voltage at Pmax=17.2 V
Diode 'ideality factor' m=2
Thermal Voltage = v_T= (k.T/e)
Charge of an electron e=1.6021733*10^{-19} as
Constant of Boltzmann k= 1.380658*10^{-23} Jk^{-1}
Insolation= 800W/M^2

Effect of Maximum Power Point TrackerTechniques on the performance of cuk converters for PV Systems

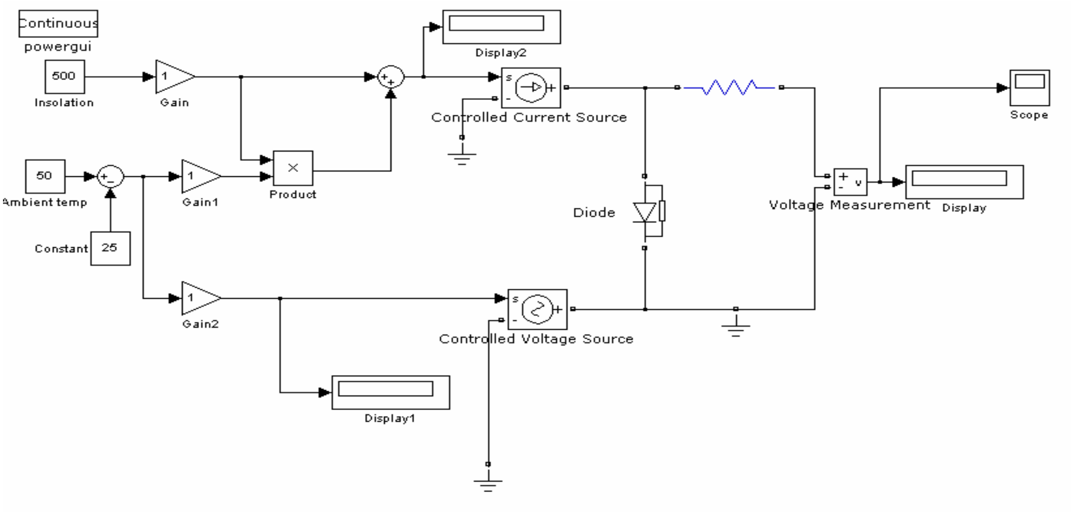

Fig. 8 Solar PV Module Simulink Model

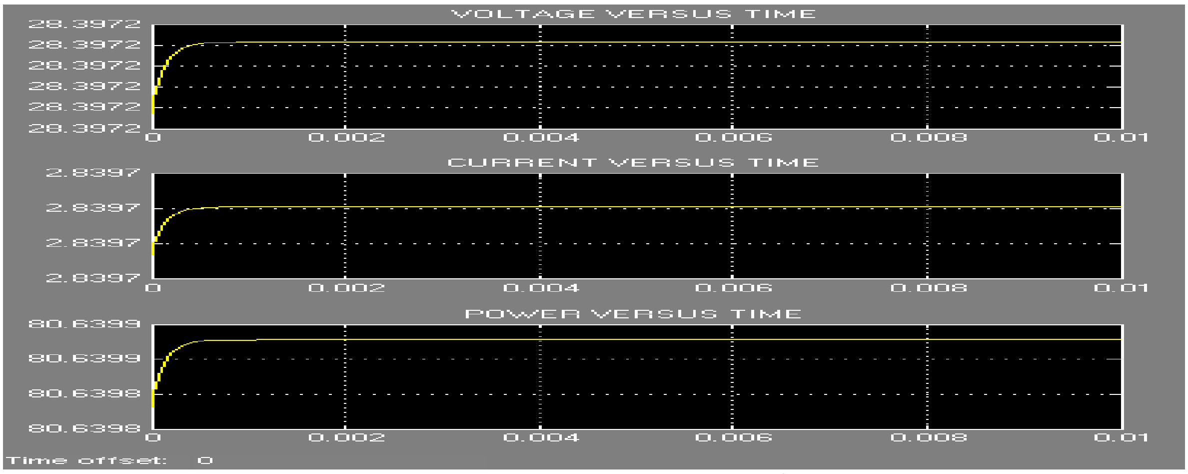

Fig. 9 Output Voltage, Current and Power Curve of PV Panel

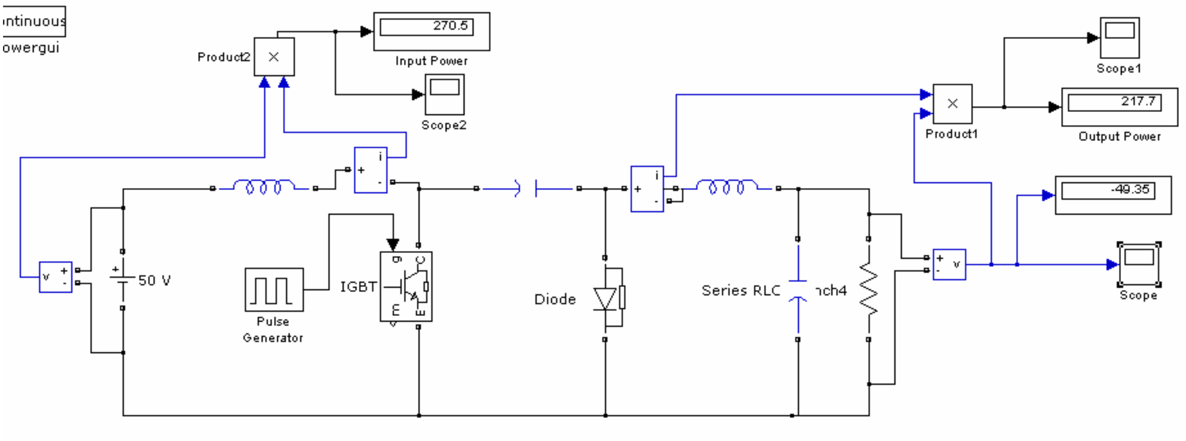

Fig.10 Cuk Converter Simulink Model

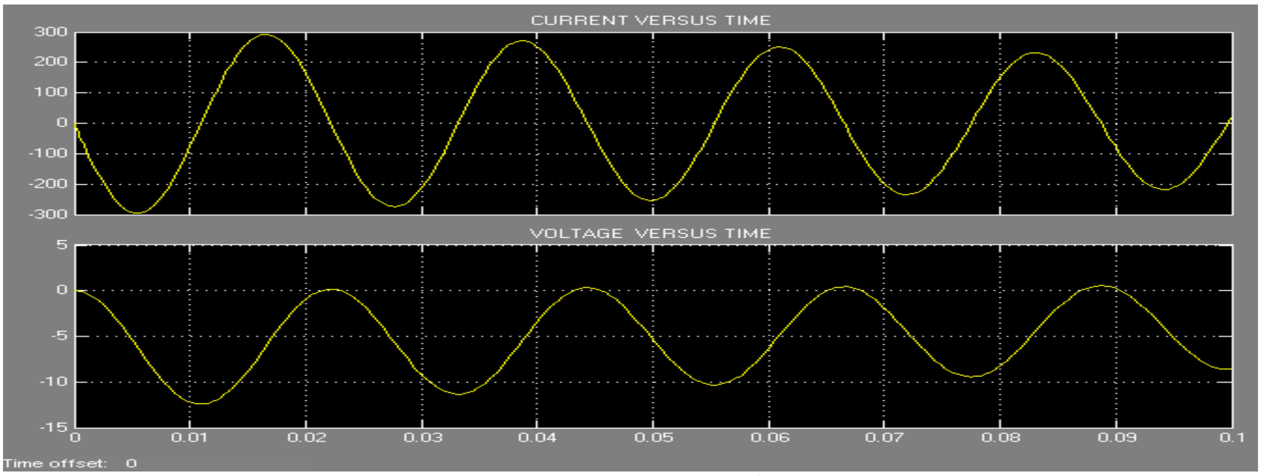

Fig.11 Output Current and Voltage Curve of Cuk Converter

Table -1 Output Value for PV Panel

Output Voltage	Output Current	Output Power
28.3 V	2.84 V	80.64 W

Table -2 Theoretical Value and Simulation Value of Cuk Converter

Converter	Analysis	TheoreticalValue	SimulationValue	PercentageDifference
Cuk	V_{in}	18 V	18 V	0 %
	V_{out}	-14 V	- 10.595 V	28 %

Table -3Comparison Output Value Between Perturb & Observe and Incremental Conductance in CUK Converter

Algorithm	V_{in} (V)	I_{in} (A)	V_{out} (V)	I_{out} (A)
P&O	5.772	2800	2.372	27
IC	5.832	2800	-0.27	-0.015

Calculated theoretical result and simulation result can be observed that the28% difference between theoretical value and experimental value, it can be also seen from the simulation output. All three simulations give difference type of curve. Theoretical value calculated from the basic equation of converters. This involved the calculation when selection of component. Meanwhile the experimental value is from the simulation result using MATLAB/simulink environment. In this comparison show that buck converter will give the best simulation result, follow by boost converter and last is cuk converter. All of this converter will be used in comparing two basic algorithms in MPPT.

Table-3 shows the comparison between Perturb and observe algorithm and Incremental Conductance algorithm. From the simulation the input voltage from PV panel to the algorithm and the converter give almost the same value. The input current for this circuit give big value of current, 2800 A and this value is same for both algorithms. Incremental conductance algorithm will give the negative value of current and voltage and this will cause the positive power output.

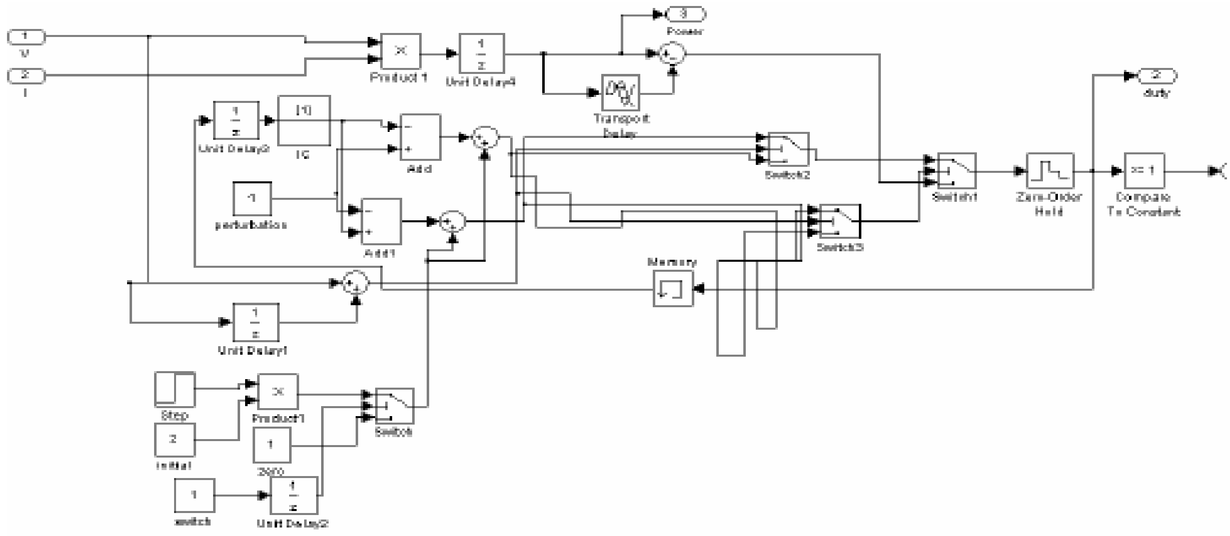

Fig. 12 Perturb and Observe Algorithm Simulink Model

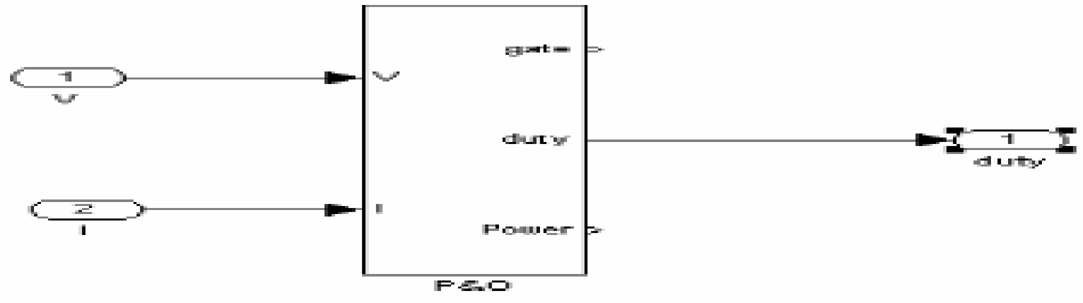

Fig. 13 Perturb and Observe Algorithm Simulink Model for Subsystem

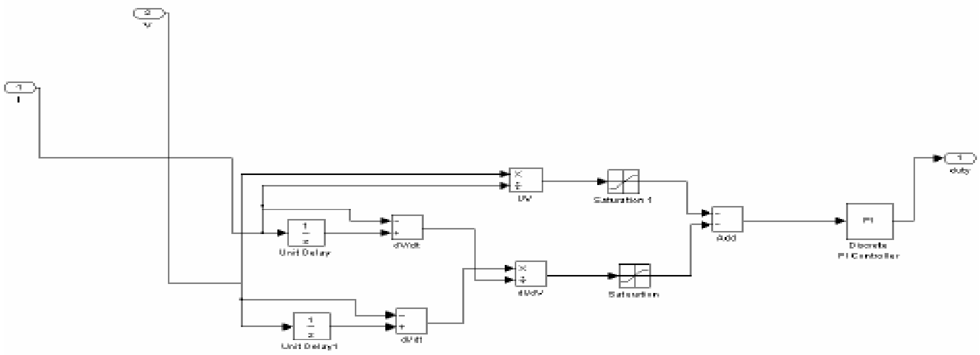

Fig. 14Incremental Conductance Algorithm Simulink Model

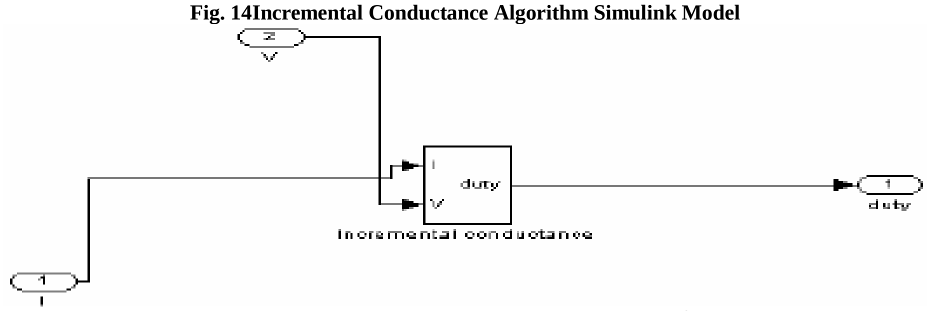

Fig. 15 Incremental Conductance Algorithm Simulink Model for Subsystem

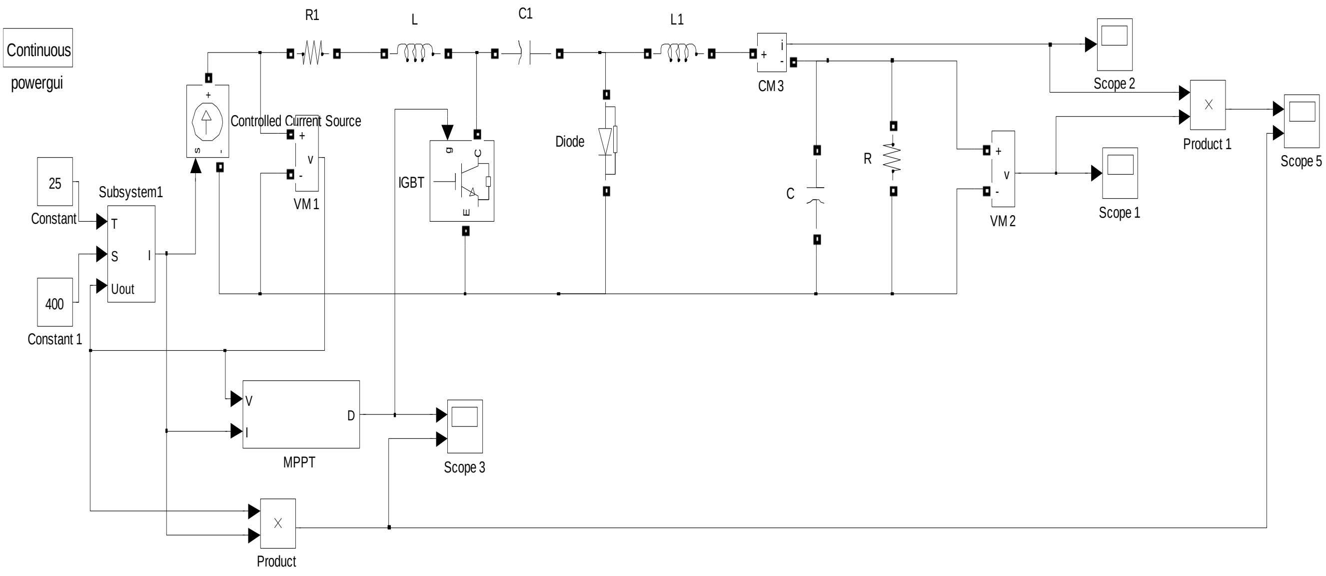

Fig. 17 Cuk Converter Simulation with Perturb & Observe Algorithm and Incremental Conductance Algorithm

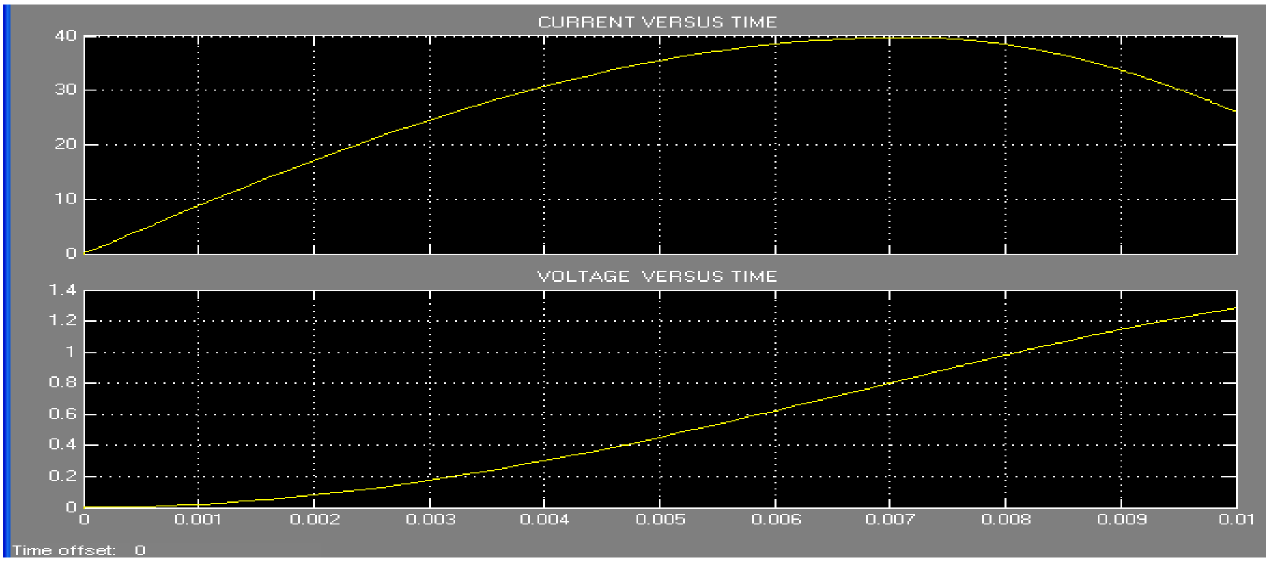

Fig. 18Output Current and Voltage Curve of Cuk Converter with Perturb and ObserveAlgorithm

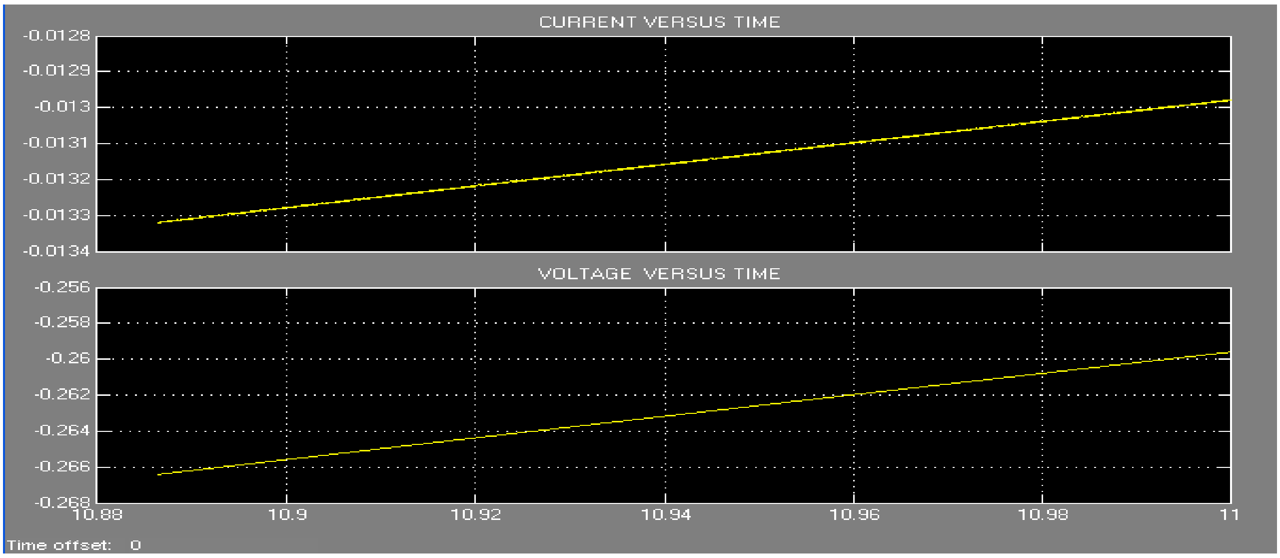

Fig. 19 Output Current and Voltage Curve of Cuk Converter with Incremental Conductance Algorithm

CONCLUSIONS

The proposed work has presented a comparison of two most popular MPPT algorithms, Perturb and Observe algorithm with Incremental Conductance algorithm. One simple solar panel that has standard value of insolation and temperature has been included in the simulation circuit. From all the cases, the best algorithm for MPPT is incremental conductance algorithm. This algorithm gives a better output value for cuk converter. Hence this algorithm will give different kind of curves for the entire converter. Considering the effect of solar irradiance and temperature changes, the output current and voltage of PV modules are simulated and optimized using this model. A perturb and observe algorithm and incremental conductance algorithm based maximum power point tracker is also developed using the presented model in Matlab/Simulink. It can successfully track the maximum power point more accurately and quicker than other conventional method based controller in these situations.

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