# A Rapid tracking Of Mppt Algorithm For Solar Pv Cell By Using Short Circuit Method And Incremental Conductance Method

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**Abstract-** This paper presents simulation of Incremental conductance (IncCond) maximum power point tracking (MPPT) used in solar array power systems with direct control method. The main difference of the proposed system to existing MPPT systems includes elimination of the proportional–integral control loop and investigation of the effect of simplifying the control circuit. Contributions are made in several aspects of the whole system, including converter design, system simulation, controller programming. The resultant system is capable of tracking MPPs accurately and rapidly without steady-state oscillation, and also, its dynamic performance is satisfactory. The Incremental conductance algorithm is used to track MPPs because it performs precise control under rapidly changing atmospheric conditions. MATLAB and Simulink were employed for simulation studied.

**Keywords-** Incremental conductance (IncCond), maximum power point tracking (MPPT), photovoltaic (PV) system.

## INTRODUCTION

Recently, energy generated from clean, efficient, and environmentally friendly sources has become one of the major challenges for engineers and scientists [1]. Among all renewable energy sources, solar power systems attract more attention because they provide excellent opportunity to generate electricity while greenhouse emissions are reduced [1]–[3]. It is also gratifying to lose reliance on conventional electricity generated by burning coal and natural gas. Regarding the endless aspect of solar energy, it is worth saying that solar energy is a unique prospective solution for energy crisis. However, despite all the aforementioned advantages of solar power systems, they do not present desirable efficiency [4], [5].

The efficiency of solar cells depends on many factors such as temperature, insolation, spectral characteristics of sunlight, dirt, shadow, and so on. Changes in insolation on panels due to fast climatic changes such as cloudy weather and increase in ambient temperature can reduce the photovoltaic (PV) array output power. In other words, each PV cell produces energy pertaining to its operational and environmental conditions [6], [7]. In addressing the poor efficiency of PV systems, some methods are proposed, among which is a new concept called "maximum power point tracking" (MPPT). All MPPT methods follow the same goal which is maximizing the PV array output power by tracking the maximum power on every operating condition.

## DIRECT CONTROL METHOD

Conventional MPPT systems have two independent control loops to control the MPPT. The first control loop contains the MPPT algorithm, and the second one is usually a proportional (P) or P–integral (PI) controller. The Incremental conductance method makes use of instantaneous and Incremental conductance to generate an error signal, which is zero at the MPP; however, it is not zero at most of the operating points. The main purpose of the second control loop is to make the error from MPPs near to zero [8]. Simplicity of operation, ease of design, inexpensive maintenance, and low cost made PI controllers very popular in most linear systems. However, the MPPT system of standalone PV is a nonlinear control problem due to the nonlinearity nature of PV and unpredictable environmental conditions, and hence, PI controllers do not generally work well. In this paper, the Incremental conductance method with direct control is selected. The PI control loop is eliminated, and the duty cycle is adjusted directly in the algorithm. The control loop is simplified, and the computational time for tuning controller gains is eliminated. To compensate the lack of PI controller in the proposed system, a small marginal error of 0.002 was allowed. The objective of this paper is to eliminate the second control loop and to show that sophisticated MPPT methods do

not necessarily obtain the best results, but employing them in a simple manner for complicated electronic subjects is considered necessary. The feasibility of the proposed system is investigated with a dc–dc converter configured as the MPPT. In [27], it was mentioned that the power extracted from PV modules with analog circuitry can only operate at the MPP in a predefined illumination level. which is specially designed for control actions. It generates pulsewidth modulation (PWM) waveform to control the duty cycle of the converter switch according to the IncCond algorithm.

## PV MODULE AND MPPT

The basic structural unit of a solar module is the PV cells. A solar cell converts energy in the photons of sunlight into electricity by means of the photoelectric phenomenon found in certain types of semiconductor materials such as silicon and selenium. A single solar cell can only produce a small amount of power. To increase the output power of a system, solar cells are generally connected in series or parallel to form PV modules. Pv module characteristics are comprehensively discussed in [3], [6],and [11], which indicate an exponential and nonlinear relation between the output current and voltage of a PV module. The main equation for the output current of a module is [6]

$$I_o = n_p I_{ph} - n_p I_{rs}\left[exp\left(K_o \frac{v}{n_s}\right) - 1\right] \qquad (1)$$

where *Io* is the PV array output current, *V* is the PV output voltage, *I*ph is the cell photocurrent that is proportional to solar irradiation, *I*rs is the cell reverse saturation current that mainly depends on temperature, *Ko* is a constant, *ns* represents the number of

PV cells connected in series, and *np* represents the number of such strings connected in parallel. In (1), the cell photocurrent is calculated from

$$I_{ph} = [I_{scr} + k_i(T - T_r)]\frac{S}{100} \qquad (2)$$

where

$I_{scr}$ cell short-circuit current at reference temperature and radiation;

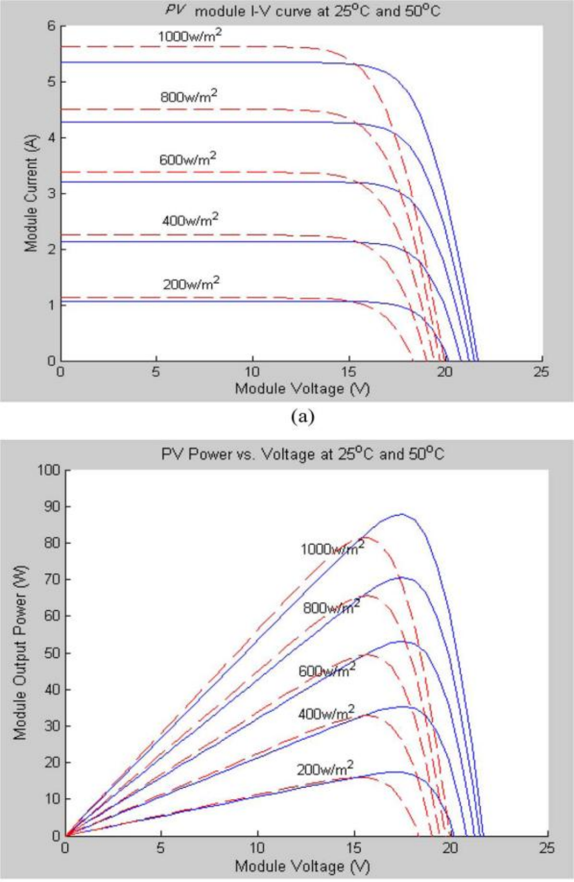
$k_i$ short-circuit current temperature coefficient;
$T_r$ cell reference temperature;
$S$ solar irradiation in milliwatts per square centimeter.
Moreover, the cell reverse saturation current is computed from

$$I_{rs} = I_{rr}\left[\frac{T}{T_r}\right]^3 exp\left(\frac{qE_G}{KA}\left[\frac{1}{T_r}-\frac{1}{T}\right]\right)$$

where
$T_r$ cell reference temperature;
$I_{rr}$ reverse saturation at $T_r$;
$E_G$ band-gap energy of the semiconductor used in the cell.
For simulations and the experimental setup also, the KC85T module was chosen. The electrical parameters are tabulated

TABLE I
ELECTRICAL PARAMETERS OF KC85T MODULE

| | |
|---|---|
| Maximum power(Pmax) | 87W |
| Voltage at MPP(Vmpp) | 17.4V |
| Current at MPP(Impp) | 5.02A |
| Open Circuit Voltage(Voc) | 21.7V |
| Short Circuit Current(Isc) | 5.34A |



(a)

(b)

Fig.1. Maximum power with varying weather conditions [−25 ◦C,−50 ◦C].
(a) *I*–*V* curves. (b) *P*–*V* curves.

in Table I, and the resultant curves are shown in Fig. 2(a) and (b). It shows the effect of varying weather conditions n MPP location at *I–V* and *P–V* curves. Fig. 2 shows the current-versus-voltage curve of a PV module. It gives an idea about the significant points on each *I–V* curve: open-circuit voltage, short-circuit current, and the operating point where the module performs the maximum power (MPP). This point is related to a voltage and a current that are Vmpp and Impp, respectively, and is highly dependent on solar irradiation and ambient temperature [7].

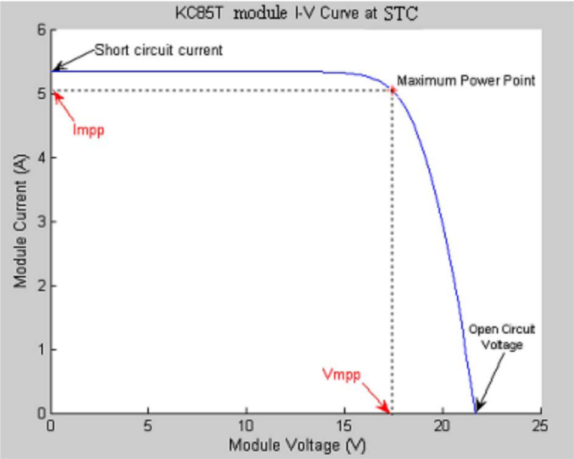


Fig. 2. Current-versus-voltage curve of a PV module.

In Fig. 1, it is clear that the MPP is located at the knee of the *I–V* curve, where the resistance is equal to the negative of differential resistance [25], [30]

$$\frac{V}{I} = -\frac{V}{I} \qquad (3)$$

This is following the general rule used in the P&O method, in which the slope of the PV curve at the MPP is equal to zero

$$\frac{dP}{dV} = 0 \qquad (4)$$

Equation (8) can be rewritten as follows:

$$\frac{dP}{dV} = I.\frac{dV}{dV} + V.\frac{dI}{dV} \qquad (5)$$

$$\frac{dP}{dV} = I + V.\frac{dI}{dV} \qquad (6)$$

and hence

$$I. + V.\frac{dI}{dV} = 0 \qquad (7)$$

which is the basic idea of the Incremental conductance algorithm.

One noteworthy point to mention is that (3) or (4) rarely occurs in practical implementation, and a small error is usually

permitted . The size of this permissible error (*e*) determines the sensitivity of the system. This error is selected with respect to the swap between steady-state oscillations and risk of fluctuating at a similar operating point.

It is suggested to choose a small and positive digit. Thus, (6) can be rewritten as

$I. + V.\frac{dI}{dV}$ =e

In this paper, the value of "*e*" was chosen as 0.002 on the basis of the trial-and-error procedure. The flowchart of the Incremental conductance algorithm within the direct control method is shown in Fig. 3. According to the MPPT algorithm, the duty cycle (*D*) is calculated. This is the desired duty cycle that the PV module must operate on the next step. Setting a new duty cycle in the system is repeated according to the sampling time.

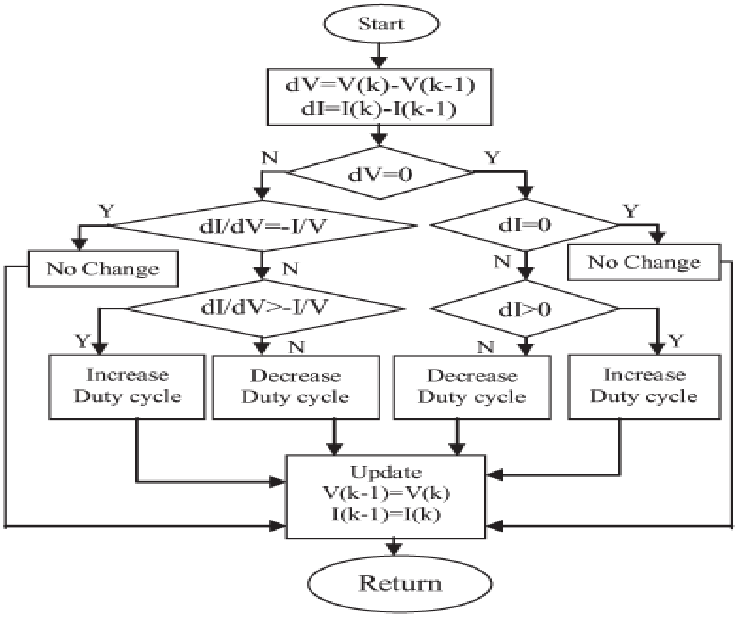


Fig. 3. Flowchart of the Incremental conductance method with direct control.

## SELECTING PROPER CONVERTER

When proposing an MPP tracker, the major job is to choose and design a highly efficient converter, which is supposed to operate as the main part of the MPPT. The efficiency of switch-mode dc–dc converters is widely discussed in [1]. Most switching-mode power supplies are well designed to function

with high efficiency. Among all the topologies available, both Cuk and buck–boost converters provide the opportunity to have either higher or lower output voltage compared with the input voltage. Although the buck–boost configuration is cheaper than the Cuk one, some disadvantages, such as discontinuous input current, high peak currents in power components, and poor transient response, make it less efficient. On the other hand, the Cuk converter has low switching losses and the highest efficiency among nonisolated dc–dc converters. It can also provide a better output-current characteristic due to the inductor on the output stage. Thus, the Cuk configuration is a proper converter to be employed in designing the MPPT. Figs. 4 and 5 show a Cuk converter and its operating modes, which is used as the power stage interface between the PV module and the load. The Cuk converter has two modes of operation. The first mode of operation is when the switch is closed (ON), and it is conducting as a short circuit. In this mode, the capacitor releases energy to the output. The equations for the switch conduction mode are as follows:

$$v_{L1} = V_g$$
$$v_{L2} = -V_1 - V_2$$
$$i_{c1} = i_2$$
$$i_{c2} = i_2 - V_2/R$$

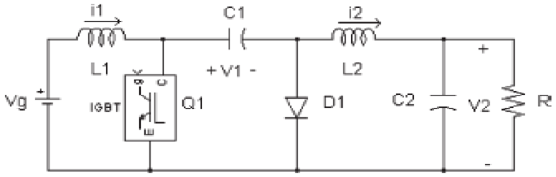


Fig. 4. Electrical circuit of the Cuk converter used as the PV power-stage interface.

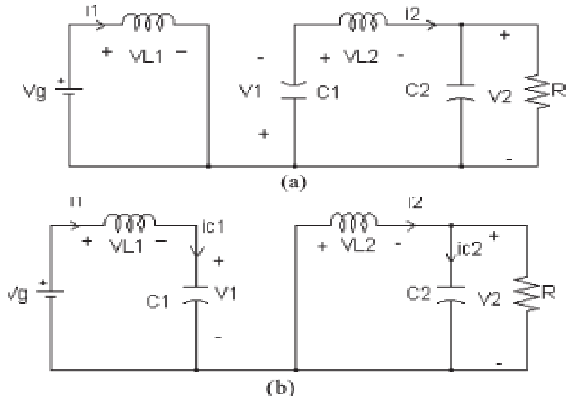


Fig. 5. Cuk converter with (a) switch ON and (b) switch OFF.

On the second operating mode when the switch is open (OFF), the diode is forward-biased and conducting energy to the output. Capacitor C1 is charging from the input. The equations for this mode of operation are as follows:

$$v_{L1} = V_g - v_1$$
$$v_{L2} = -V_2$$
$$i_{c1} = i_1$$
$$i_{c2} = i_2 - V_2$$

The principles of Cuk converter operating conditions state that the average values of the periodic inductor voltage and capacitor current waveforms are zero when the converter operates in steady state. The relations between output and input currents and voltages are given in the following:

Some analyses of Cuk converter specifications are provided in, and a comparative study on different schemes of switching converters is presented in the literature. The components for the Cuk converter used in simulation and
the hardware setup were selected as follows:

1) input inductor L1 = 5 mH;
2) capacitor C1 (PV side) = 47 $\mu$f;
3) filter inductor L2 = 5 mH;
4) switch: insulated-gate bipolar transistor [(IGBT)—
IRG4PH50U];
5) freewheeling diode: RHRG30120;
6) capacitor C2 (filter side) = 1 $\mu$F;
7) resistive load = 10 Ω;
8) switching frequency = 10 kHz;

9) controller: TMS320F2812 DSP.

The components for the measurement circuit are as follows:

1) voltage transducer: LV25-P;

2) current transducer: LA25-NP.

The power circuit of the proposed system consists of a Cuk converter and a gate drive, and the control of the switching is done using the control circuit. The control tasks involve measuring the analog voltage and current of the PV module using current and voltage sensors, convert them to digital using an ADC, process the obtained information in a microcontroller, then them compare to the predefined values to determine the next step, revert the PWM to the gate drive, and hence control the switching of IGBTs. The control loop frequently happens with respect to the sampling time, and the main program continues to track the MPPs.

## SIMULATION RESULTS

The diagram of the closed-loop system designed in MATLAB and Simulink , which includes the PV module electrical circuit, the Cuk converter, and the MPPT algorithm. The converter components are chosen according to the values presented in above. The PV module is modeled using electrical characteristics to provide the output current and voltage of the PV module. The provided current and voltage are fed to the converter and the controller simultaneously. The PI control loop is eliminated, and the duty cycle is adjusted directly in the algorithm. To compensate the lack of PI controller in the proposed system, a small marginal error of 0.002 is allowed. To test the system operation, the condition of changing irradiation was modeled. The temperature is constant at 25 ◦C, and the illumination level is varying between two levels. The first illumination level is 1000 W/m2; at *t* = 0.4 s, the illumination level suddenly changes to 400 W/m2 and then back to 1000 W/m2 at *t* = 0.8 s. An illustration of the relationship between the duty cycle and PV output power to demonstrate the effectiveness of the algorithm mentioned in the flowchart. the change in duty cycle adjusted by the MPPT to extract the maximum power from the module. The results in Fig. 5(b) show that the output power at *G* = 1000 and 400 W/m2 are 87 and 35 W, respectively, which are absolutely the desired output power . It also shows that the system provides the best desirable tradeoff between the two irradiation levels.

(I) Short circuit method

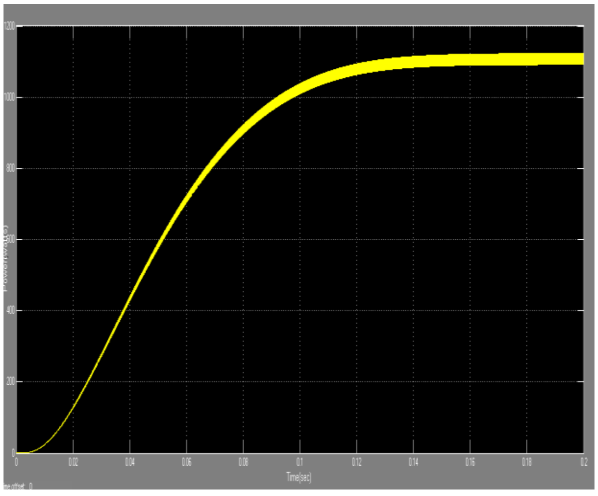


Fig (a) PV module output current

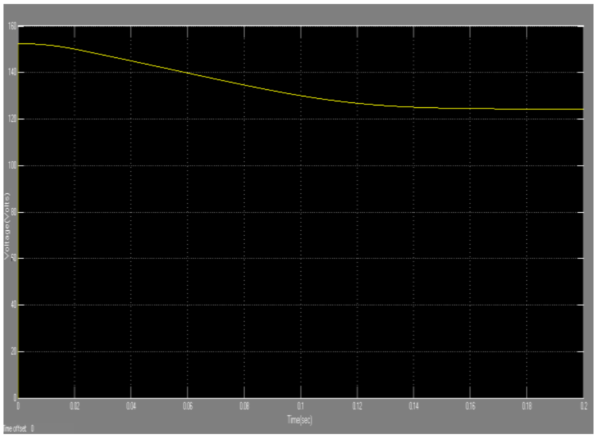


Fig (b) PV module output voltage

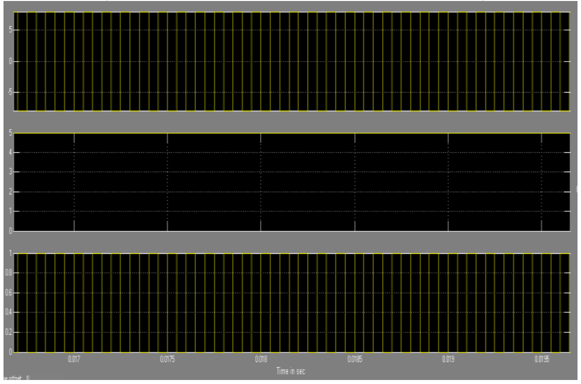


Fig (c) Duty cycle

(II) Incremental Conductance Method

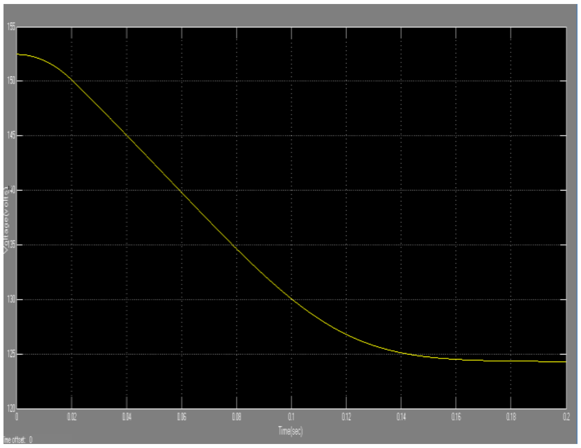


Fig (d) PV module output Voltage

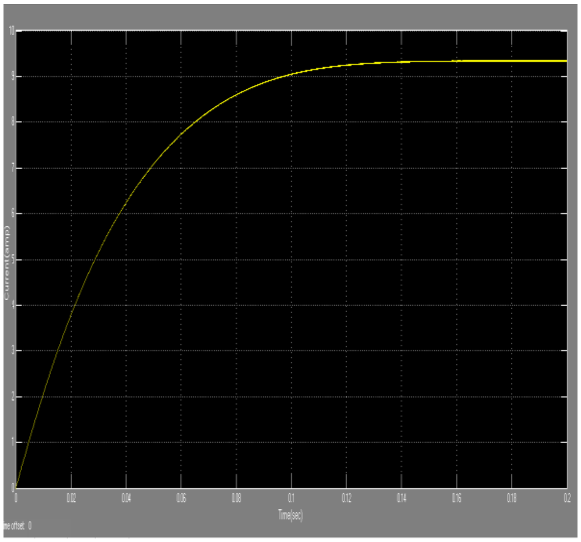


Fig (e) PV module output Current

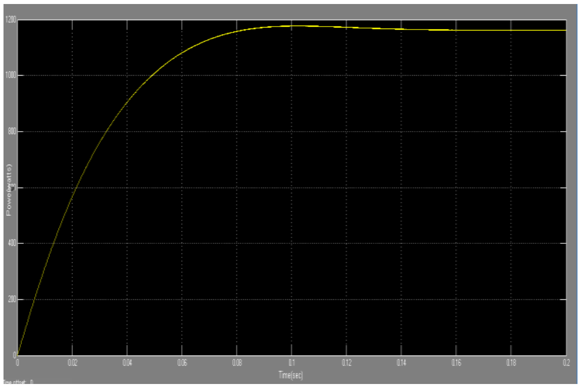


Fig (f) PV module output Power

## CONCLUSION

In this paper, a fixed-step-size Incremental conductance MPPT with direct control method was employed, and the necessity of another control loop was eliminated. The proposed system was simulated, and the functionality of the suggested control concept was proven. From the results acquired during the simulations, it was confirmed that, with a well-designed system including a proper converter and selecting an efficient and proven algorithm, the implementation of MPPT is simple and can be easily constructed to achieve an acceptable efficiency level of the PV modules. The results also indicate that the proposed control system is capable of tracking the PV array maximum power and thus improves the efficiency of the PV system and reduces low power loss and system cost.

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