Simulation Cuk Converter Using Incremental Conductance MPPT with Direct Control Method

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ABSTRACT—This paper presents simulation and hardware implementation 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. To decrease the usage of limited Conventional energy sources and to increase the Non-Conventional energy sources like Solar energy .Because they are pollution free, fuel cost is free. Applications of P.V Array are water purification, Commercial and Industrial lighting. Compared to other Non-conventional energy sources P.V system is more efficient. The Proposed Incremental Conductance M.P.P.T method can eliminate above draw back Contributions are made in several aspects of the whole system, including converter design, system simulation, controller programming, and experimental setup. The resultant system is capable of tracking MPPs accurately and rapidly without steady-state oscillation, and also, its dynamic per-formance is satisfactory.. MATLAB and Simulink were employed for simulation studies.

Key words—Cuk converter ,incremental con-ductance (IncCond), maximum power point tracking (MPPT), photovoltaic (PV) system, Matlab/Simulink

I. INTRODUCTION

In this paper 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 gen-erated 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, theydo 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) ar-ray output power. In other words, each PV cell produces energy pertaining to its operational and environmental conditions [5], [3].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.

A. MPPT Methods:

Maximum power point tracking, frequently referred to as MPPT, is an electronic system that operates the Photovoltaic (PV) modules in a manner that allows the modules to produce all the power they capable of. MPPT is not a mechanical tracking system that physically moves the modules to make them point more directly at the sun. Since the power output of a PV array varies according to the sunlight conditions, atmospheric conditions, including cloud cover local surface reflectivity and temperature. So MPPT is necessary in order to extract the maximum power from the array at all times. MPPT is a fully electronic system that varies the electrical operating point of the modules so that the modules are able to deliver maximum available power. The MPPT varies the ratio between the voltage and current delivered to the battery, in order to deliver maximum power. If there is excess voltage available from the PV, then it converts that to additional current to the battery. Furthermore, it is like an automatic transmission. As the Vpp of the PV array varies with temperature and other conditions, it "tracks" this variance and adjusts the ratio accordingly The function of a MPPT is analogous to the transmission in a car. When the transmission is in the wrong gear, the wheels do not receive maximum power. That's because the engine is running either slower or faster than its ideal speed range

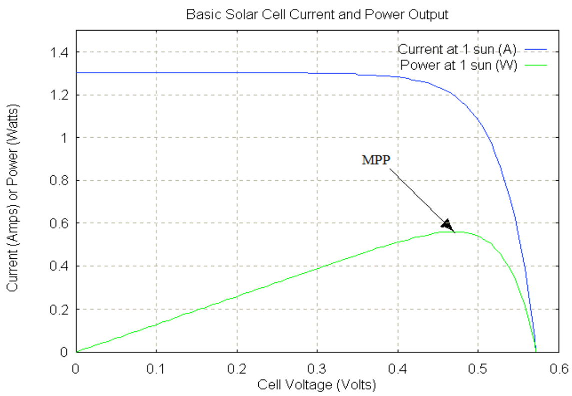

Fig 1.1 PV Module Power/Voltage/Current Characteristics

The purpose of the transmission is to couple the engine to the wheels, in a way that lets the engine run in a favorable speed range in spite of varying acceleration and terrain. Let's compare a PV module to a car engine. Its voltage is analogous to engine speed. Its ideal voltage is that at which it can put out maximum power. This is called its maximum power point. (It's also called peak power voltage, abbreviated Vpp). Vpp varies with sunlight intensity and with solar cell temperature. The voltage of the battery is analogous to the speed of the car's wheels. It varies with battery state of charge, and with the loads on the system (any appliances and lights that may be on). For a 12V system, it varies from about 11 to 14.5V.In order to charge a battery (increase its voltage), the PV module must apply a voltage that is higher than that of the battery. If the PV module's Vpp is just slightly below the battery voltage, then the current drops nearly to zero (like an engine turning slower than the wheels). So, to play it safe, typical PV modules are made with a Vpp of around 17V when measured at a cell temperature of 25°C. They do that because it will drop to around 15V on a very hot day. However, on a very cold day, it can rise to 18V!

B. System Configuration:

The system configuration for the topic is as shown. 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. The relevant circuit is as shown. After we are getting the maximum power we are applying to the utility grid.

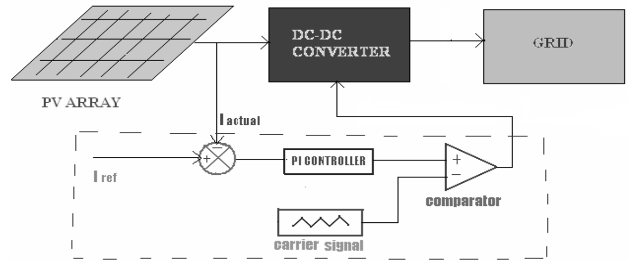

Fig 1 .2 System Configuration of PV System

C. PV Array: A photovoltaic cell is nothing but a Solar cell which consists of a p-n junction fabricated in a thin wafer or layer of semiconductor (usually silicon). In the dark, the I-V output characteristic of a solar cell has an exponential characteristic similar to that of a diode. When solar energy (photons) hits the solar cell, with energy greater than band gap energy of the semiconductor, electrons are knocked loose from the atoms in the material, creating electron-hole pairs. These carriers are swept apart under the influence of the internal electric fields of the p-n junction and create a current proportional to the incident radiation. The voltage and current relationship of the simplified solar cell based on Kirchhoff's current law

II. Maximum Power Point Tracking:

Maximum Power Point Tracker (MPPT) has been used to force the PV array to work around the maximum power point. For this reason, the MPPT is required to track the maximum power available in the PV array. The MPPT operates by periodically incrementing the terminal voltage of the PV array and continuously seek. The radiation and temperature are used to calculate the maximum PV array output power and PV array terminal voltages. The MPPT operates by periodically incrementing the terminal voltage of the PV array and continuously seek the peak power point. The control system adjusts the boost converter to seek maximum power point of PV array. A comparison between the terminal voltages (actual and optimum) will control the duty ratio of boost converter. Changing the duty ratio according to the error signal between the maximum and actual power will pass the maximum power available from PV to the electric utility. A comparison between actual and reference values for PV terminal voltage and maximum power available from PV array will control the duty ratio of boost converter. The PV simulator uses the radiation, temperature and output current from PV to determine the corresponding PV curve by using equations. The output power from PV is the result from multiplying PV terminal voltage and PV output current. Different algorithms help to track the peak power point of the solar pv module automatically. The various algorithms used are.

A. Perturb and observe.

B. Incremental Conductance.

C. Parasitic Capacitance.

D. Voltage Based Peak Power Tracking.

E. Current Based peak power Tracking.

A. Perturb and observe:

In this algorithm a slight perturbation is introduce system. Due to this perturbation the power of the module changes. If the power increases due to the perturbation then the perturbation is continued in that direction. After the peak power is reached the power at the next instant decreases and hence after that the perturbation reverses.

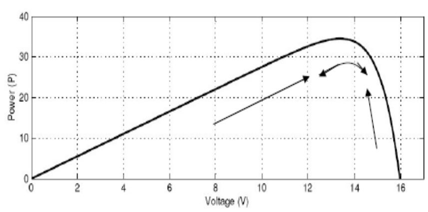

Fig 2.1 Perturb and observe Wave form

When the steady state is reached the algorithm oscillates around the peak point. In order to keep the power variation small the perturbation size is kept very small. The algorithm is developed in such a manner that it sets a reference voltage of the module corresponding to the peak voltage of the module. A PI controller then acts moving the operating point of the module to that particular voltage level. It is observed that there some power loss due to this perturbation also the fails to track the power under fast varying atmospheric conditions. But still this algorithm is very popular and simple.

B. Incremental conductance:

The disadvantage of the perturb and observe method to track the peak power under fast varying atmospheric condition is overcome by Incremental conductance method. The algorithm makes use of the equation

P=V*I-------… (1)

(Where P= module power, V=module voltage, I=module current);

Diff with respect to dV

DP/dV=I+V*dI/………… (2)

Depending on this equation the algorithm works.

At peak power point

dP/dV=0…………… (3)

dI/dV=I/V………… (4)

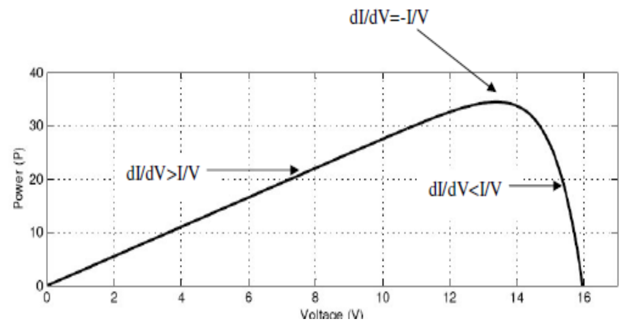

Fig 2.2 Incremental conductance method.

If the operating point is to the right of the Power curve then we have

dP/dV<…………... (5)

dI/dV<I/V…………. (6)

If operating point is to the left of the power curve then we have

dP/dV>0………..(7)

dI/dV>I/V… (8)

Using equations 7, 9& 10 the algorithm works. The incremental conductance can determine that the MPPT has reached the MPP and stop perturbing the operating point. If this condition is not met, the direction in which the MPPT operating point must be perturbed can be calculated using the relationship between dl/dV and –I/V This relationship is derived from the fact that dP/dV is negative when the MPPT is to the right of the MPP and positive when it is to the left of the MPP. This algorithm has advantages over perturb and observe in that it can determine when the MPPT has reached the MPP, where perturb and observe oscillates around the MPP. Also, incremental conductance can track rapidly increasing and decreasing irradiance conditions with higher accuracy than perturb and observe. One disadvantage of this algorithm is the increased complexity when compared to perturb and observe.The solar array terminal voltage can be adjusted relative to the maximum power point voltage by measuring the incremental and instantaneous array conductance (dI/dV and I/V, respectively). Although the incremental conductance method offers good performance under rapidly changing atmospheric conditions, four sensors are required to perform the computations. The drawback is that sensor devices require more conversion time thus result in a large amount of power loss. [15] views the algorithm of incremental conductance and the operation of incremental conductance algorithm is shown in Figure 2.3

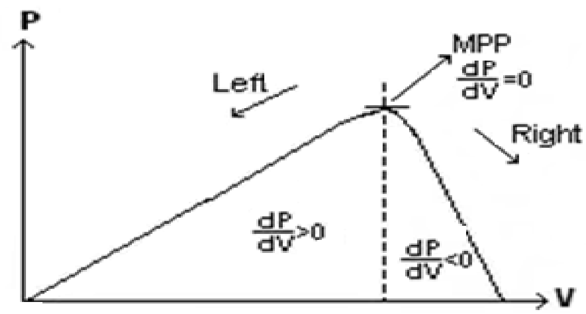

Fig 2.3 The operation of the incremental conductance method

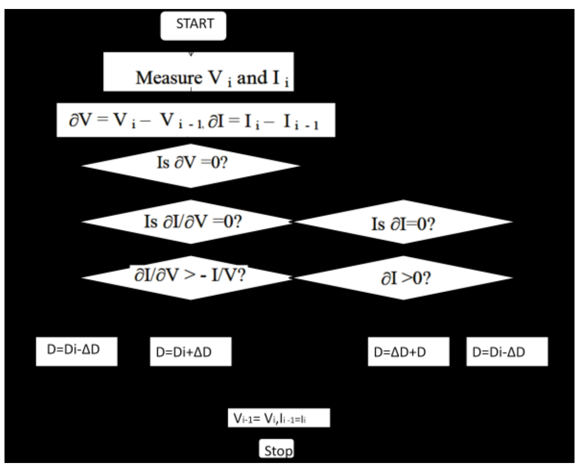

Fig 2..4 Conductance Incremental algorithm flowcharts

C. Parasitic capacitances:

The parasitic capacitance method is a refinement of the incremental conductance method that takes into account the parasitic capacitances of the solar cells in the PV array. Parasitic capacitance uses the switching ripple of the MPPT to perturb the array. To account for the parasitic capacitance, the average ripple in the array power and voltage, generated by the switching frequency, are measured using a series of filters and multipliers and then used to calculate the array conductance**.** The incremental conductance algorithm is then used to determine the direction to move the operating point of the MPPT. One disadvantage of this algorithm is that the parasitic capacitance in each module is very small, and will only come into play in large PV arrays Where several module strings are connected in parallel. Also, the DC-DC converter has a sizable input capacitor used filter out small ripple in the array power. This capacitor may mask the overall effects of the parasitic capacitance of the PV array.

D. Voltage control maximum point tracker:

It is assumed that a maximum power point of a particular solar PV module lies at about 0.75 times the open circuit voltage of the module. So by measuring the open circuit voltage a reference voltage can be generated and feed forward voltage control scheme can be implemented to bring the solar pv module voltage to the point of maximum power. One problem of this technique is the open circuit voltage of the module varies with the temperature. So as the temperature increases the module open circuit voltage changes and we have to measure the open circuit voltage of the module very often. Hence the load must be disconnected from the module to measure open circuit voltage. Due to which the power during that instant will not be utilize.

E. Current control maximum power point tracker:

The peak power of the module lies at the point which is at about 0.9 times the short circuit current of the Module. In order to measure this point the module or array is short-circuited. And then by using the current mode control the module current is adjusted to the value which is approx 0.9 times the short circuit current.The problem with this method is that a high power resistor is required which can sustain the short-circuit current. The module has to be short circuited to measure the short circuit current as it goes on varying with the changes in insulation level. This method exploits the assumption of linear relationship between the "cell current corresponding to The maximum power (I_{MP})" and the cell-short circuit current (I_{SC}). This relationship can be expressed as

$$I_{MP} = K.\, I_{SC}$$

Where K is called the current factor Peak Power of the module lies at about 90% of its short circuit current. Measuring the short circuit current Isc and adjusting the operating the converter at 90% of Isc the module can be made to operate at Peak power The Flowchart of Short-circuit current MPPT is shown below

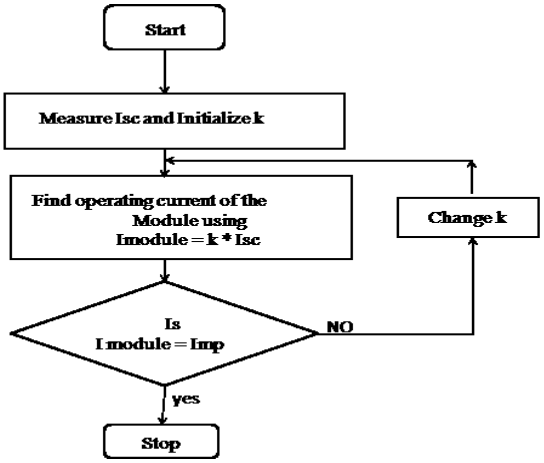

Fig 2.5Flow Chart For the Short-Circuit Method

III .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 non isolated 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. 3.1 and 3.2 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

$$VL1=Vg \qquad (9)$$
$$Vl2=-V1-V2 \qquad (10)$$
$$Ic1=i2 \qquad (11)$$
$$Ic2=i2-(V2/R) \qquad (12)$$

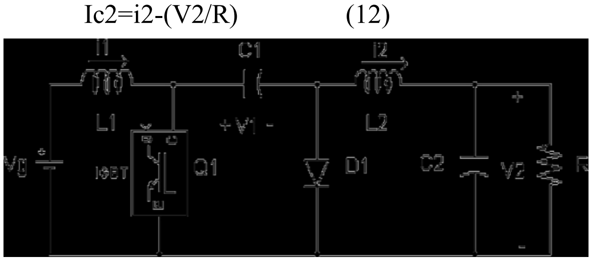

Fig. 3.1. Electrical circuit of the Cuk converter used as the PV power-stage interface

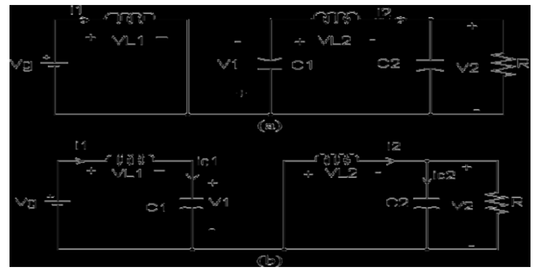

Fig. 3.2. Cuk converter with (a) switch ON and (b) switch OFF

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:

The relations between output and input currents and voltages are given in the following:

$$VL1=Vg-V1 \qquad (13)$$

$$VL2=-V2 \qquad (14)$$

$$Ic1=i1 \qquad (15)$$

$$Ic2=i2-V2/R \qquad (16)$$

Some analyses of Cuk converter specifications are provided in [7], and a comparative study on different schemes of switching converters is presented in the literature [8].

$$Vo/Vin=-(D/1-D) \qquad (17)$$

$$Iin/Io=-(D/1-D) \qquad (18)$$

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

IV.SIMULATION RESULTS

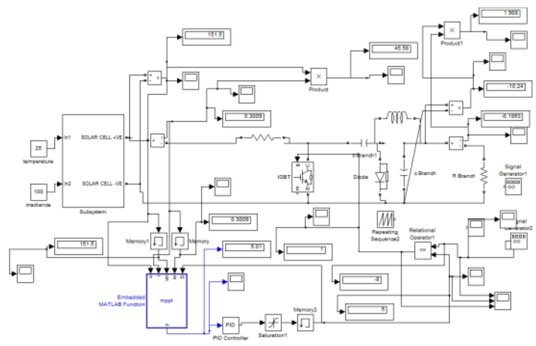

Fig4.1 Simulation Implementation of Incremental Conductance MPPT With Direct Control Method Using Cuk Converter

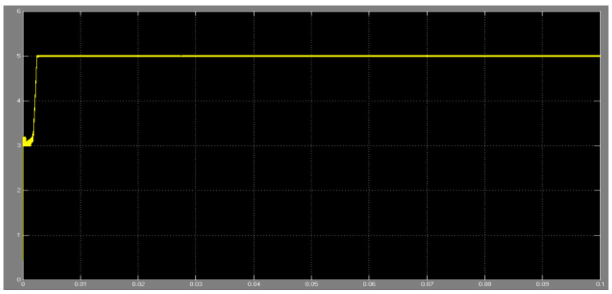

Fig 4.2 PV Module current waveforms for IncCond without MPPT technique

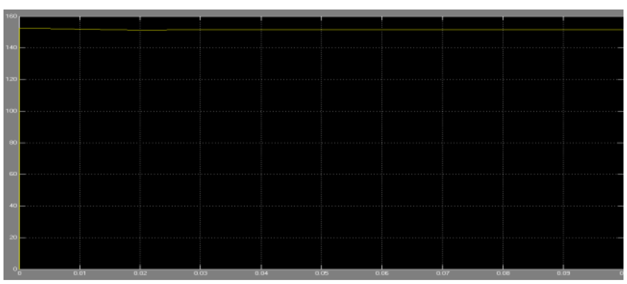

Fig 4.3 PV Module voltage waveforms for IncCond without MPPT technique

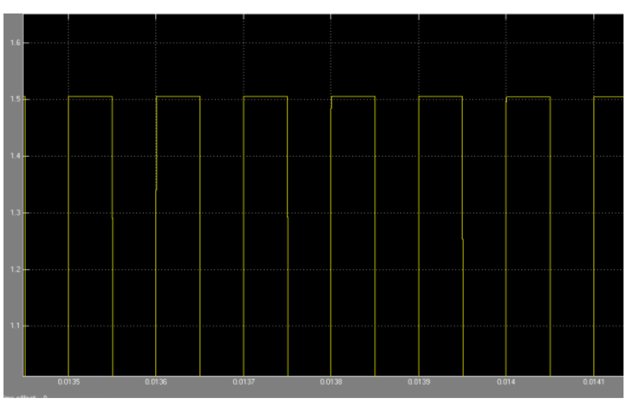

Fig 4.4PV Module Current waveforms for IncCond with MPPT technique

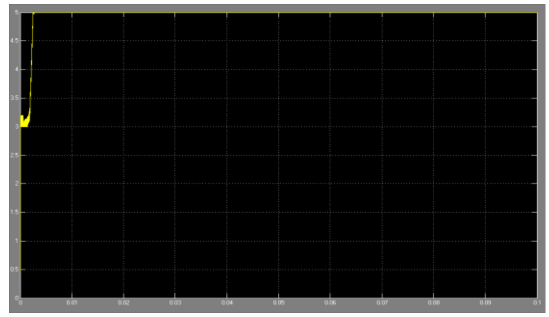

Fig 4.5 PV Module voltage waveforms for IncCond with MPPT technique

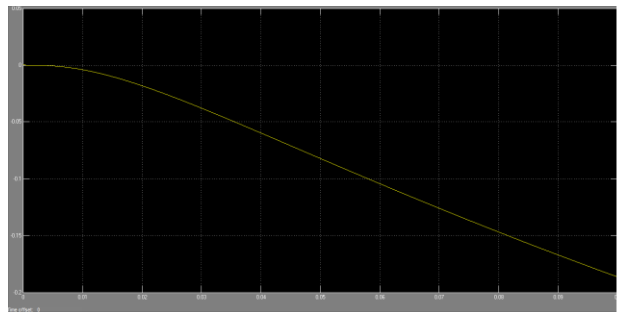

Fig 4.6 PV Module Power waveforms for IncCond without MPPT technique

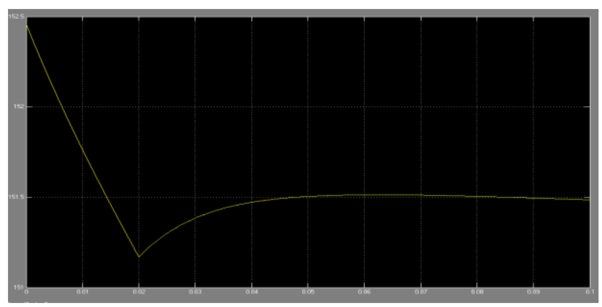

Fig 4.7 PV Module Power waveforms for IncCond Without MPPT techniques

V. CONCLUSION

In this paper, a fixed-step-size IncCond MPPT with direct control method was employed, and the necessity of another control loop was eliminated. The proposed system was simulated and constructed, and the functionality of the suggested control concept was proven 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 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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