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IMPLEMENTATION OF MPPT ALGORITHM FOR SOLAR PHOTOVOLTAIC CELL USING INCREMENTAL CONDUCTANCE METHOD

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ABSTRACT

In this paper conventional energy is replaced with renewable energy due to its advantages over the nonconventional one. Making maximum use of the PV panel energy using Maximum Power Point tracking (MPPT) for extracting a maximum power from the PV panel due to variation in ambient temperature and irradiations. BOOST converter is used here for increasing the voltage to the desired value depends on the load. The use of MPPT techniques improves the efficiency of solar panel. Hence the usage of MPPT techniques are increasing day by day. This paper explains about the performance of popular MPPT techniques, Incremental conductance algorithms using BOOST converter .The advantage of the techniques are explained .Simulation studies of proposed system are done using PSIM software.

Keywords: Photo Voltaic (PV) energy, Maximum Power Point Tracking (MPPT) techniques, Incremental Conductance, BOOST converter.

I. INTRODUCTION

There is a increasing energy consumption needs and also environmental impacts due to non-renewable energy leads to the invention and make use of renewable energy. Among various renewable energyPhoto Voltaic energy is easy going and popular one. The easy going is nothing but environmental friendly, reliable and inexhaustible. Solar energy is the ultimate source of energy, which can be naturally replenished in short period of time. Solar power is zero greenhouse gas emission and very clean. Even though solar power has many advantages it also leads to some difficulties in implementation solar cell which is used for the power conversion has some problems which are spectrum and solar irradiation and ambient temperature. To improve the efficiency of solar cell the maximum power point tracking (MPPT) techniques are used[2].

MPPT techniques are an essential key element for PV system. There are many MPPT algorithms in use such as Fixed Duty Cycle, MPP Locus Characterization, Perturb and Observe (P&O),P&O based on PI controller ,Incremental Conductance(Inc Cond), Inc Cond based on PI controller, Fractional Open-Circuit Voltage, Fractional Short-Circuit Current, Fuzzy Logic Control, Neutral Network, Beta Method, System Oscillation Method, Ripple Correlation Control (RCC), Temperature Method, Current Sweep, DC-Link capacitor Droop control, Load Current or Load Voltage Maximization, dp/dv or dp/di Feedback Control, Array Recon-figuration, Linear Current Control, State-Based MPPT. One-Cycle Fre-quently used MPPT are Perturb & Observe (P&O) and Incremental Conductance(Inc Cond) algorithm.[5]

BOOST converter is used to increase the output voltage of PV panel to specific value depends on the load. This paper represents the performance of Incremental conductance algorithm using BOOST converter.

2. Solar cell:

2.1. Principle of Operation:

Photovoltaic (PV) cell which is used to convert the light energy into electrical energy by photo electric effect . Silicon is generally used as a photo electric cell. Electrons which are released from the electron hole and moves freely. This free movement of electron will causes the current flow.

2.2. Fundamental Parameters of solar cell:

The solar cell's characteristics are depicted by the fundamental parameters of PV cell. They are short circuit, open circuit voltage, maximum power, efficiency and fill factor.

2.2.1. Short Circuit Current (I_{sc}):

It is the current flow in the PV cell when the cell is short circuited. This occurs at zero voltage. It is depicted in the figure1.The short circuit current depends on the factors such as number of photons and spectrum of incident light , optical properties, area and probability collection of the solar cell.

2.2.2.Open Circuit Voltage(V_{oc}):

It is the maximum voltage across the solar cell at zero current. It is depicted in figure 1.This reflects the amount of forward bias as the result of the bias at the PV junction when current flows in the PV cell.

2.2.3: Maximum Power (P_{mp}):

It is the product of maximum voltage (V_{mp}) and maximum current (I_{mp}). This is shown in figure1.

2.2.4. Efficiency:

It is the ratio of output power from the PV panel to input power from the photons of the incident light. It depends on temperature, spectrum and intensity of incident light.

$$\eta = (V_{oc}I_{sc}FF)/P_{in} \quad (1)$$

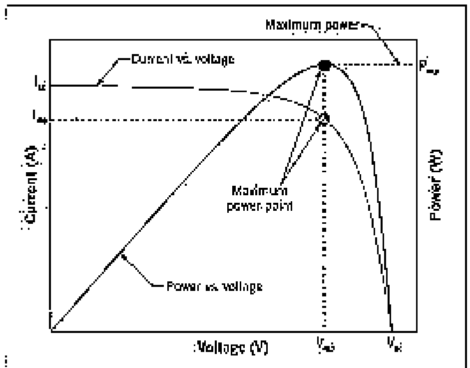

Figure 1: I-V and P-V curve of the solar cell

2.2.5. Fill Factor:

It is the ratio of maximum power to the product of V_{oc}andI_{sc} . It generally measures the quality of the particular solar cell used.

$$FF= (V_{mp}I_{mp})/(V_{oc}I_{sc}) \quad (2)$$

Generally the fill factor range would be from 0.5 to 0.82 based on the parameters of the panel. Fill Factor is inversely proportional to temperature.

2.3. Photo Voltaic Modeling:

The most common method of representing the PV cell is as Single-Diode Model (SDM). PV cell can also be represented as Double Diode Model (DDM) it takes into consideration, recombination loss at the space depletion region of solar CELLS. PV cell can be Three Diode Model (TDM) this includes the consideration of the influence of grain boundaries in multi crystalline PV cells and leakage current through the peripheries of the solar cell. The consideration of all the above factors in the DDM and TDM makes the analysis of PV cell complex hence SDM is usually preferred due to its simplicity. The equivalent circuit of PV cell is shown in figure 2.

2.3.1: Basic Equations of a PV Cell:

The light generated current depends basically on two parameters namely, solar insulation and ambient temperature. In this SDM, PV output current is I and PV output voltage is V. Basic equations are obtained from the theory of semiconductor physics and PV mathematical model [4,6].

2.3.2. Thermal voltage: Thermal voltage, (V_t), is given by,

$$V_t= (T_{op}\,k)/ q \quad (3)$$

Where T is operating temperature in (K), q is the electron charge ($1.6*10^{-19}$c), K is the Boltzmann constant ($1.3806*10^{-23}$J/K).

2.3.3. Reserve saturation current:

Reserve saturation current, (I_{rs}),is given by,

$$I_{rs}=I_{sc}/(_{exp}(V_{oc}*q/k*c*t_{op}*n) \quad (4)$$

Where I_{sc} is Short Circuit current(A), V_{oc} is Open Circuit voltage (V), n is ideality factor(1.3) which depends upon the material used as the PV cell, C is the number of cells.

2.3.4. Saturation current:

Saturation current (Is), is given by,

$$I_s=I_{rs}(T_{op}/T_{ref})\hat{}3\exp\{q^2*E_g/k*(1/T_{op})-(1/T_{ref})n\} \quad (5)$$

Where T_{ref} is reference temperature ((25+273K)), E_g is band gap energy(1.1eV).

2.3.5. Diode Current:

Diode current, (I_d), is given by,

$$I_d=I_s*N_p*\{exp((v/N_s)+(I*R_s/N_s)/(n*Vt*C))-1\} \quad (6)$$

Where R_s is series resistance (Ω), N_s is the number of cells in series, N_p is the cells in parallel.

2.3.6. Shunt Current:

Shunt current(Ish), is given by,

$$I_{sh}= [(V+ (I*R_s)/R_p)] \quad (7)$$

Where

R_p-parallel resistance (Ω)

2.3.7 PV Output Current:

Output current (I) is given by,

$$I= \{[I_{ph}* N_p]-I_{sh}-I_d \quad (8)$$

Where

$$I_{ph}=\{(|(T_{op}-T_{ref)}*K_i]+I_{se})*I_{rr}\} \quad (9)$$

Where K_i is current temperature coefficient (A/K)

K_v is voltage temperature co efficient (V/K)

I_{ph} is phase current

Table 1 Panel specification Electrical

Electrical Parameter	Value
Maximum power (Pmp)	30 W
Voltage at Pmp(Vmp)	18.35 V
Current at Pmp(Imp)	1.674 A
Open circuit voltage(Voc)	22.2 V
Short circuit current(Isc)	1.73 A

3. Maximum Power Point Tracking (MPPT):

It is known as MPPT is used in almost all PV system to improve efficiency of the PV panel used. It is an algorithm with electronic device which is capable of producing maximum power at all varying conditions.

1. Different MPPT Techniques:

There are numerous algorithms that are capable of tracking maximum power. The selection of a particular MPPT depends on various factors such as implementtation, complexity, sensors required, cost, and ability to detect multiple local maxima, application and response time.

Perturb and Observe (P&O method) also known as perturbation. This concept is based on the principle that is to modify the operating voltage of the solar panel until maximum power is obtained.

Incremental conductance tracks the variation in the direction of the voltage it is more advantageous when compared that of P& O. Fuzzy logic controllers are used due to its advantages such as working with imprecise inputs, ability to handle non linearity and can work withinaccurate mathematical model.[1]

2. PERTURB AND OBSERVE (P&O):

It is the most frequently used MPPT techniques as it is simple and implemental cost is less. The implemental cost is as it requires only one sensor namely voltage sensor. The principle in which it operates as, the voltage of the load connected to the PV panel is perturbed or varied to obtain maximum power from the panel output. Thus the load voltage is perturbed and the output of the PV panel is observed to track the maximum power hence the name perturb and observe. This method faces disadvantage such as its inability to track the maximum power at rapidly varying weather condition and when the operating point reaches the maximum power point (MPP) it does not stops rather it perturbs even after reaching the MPP. The flow chart is shown in the figure 2[6]

3. INCREMENTAL CONDUCTANCE:

It works under the principle that the slope in the PV curve is zero at MPPT. The PV module voltage is varied until the slope dp /dv=0, thus in this techniques the direction of variation of the module voltage is determined. This is achieved by comparing the incremental and instantaneous conductance. The incremental conduc -tance di /dv and instantaneous conductance is –I/V.

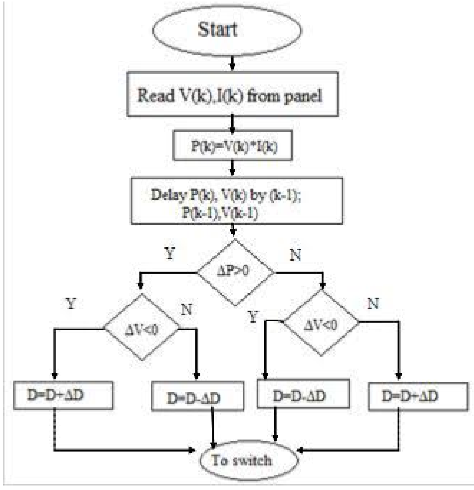

Figure 2:Flowchart for Perturb and Observe Algorithm

when the operating point is on the positive slope of the PV curve the module voltage is increased and if it is on the negative slope module voltage is decreased. Thus the tracking of MPP is achieved.

At MPP, dp/dv=0

dp/dv=d(VI)/dv=I+V dI/dv

dI/dv= -I/V

This methodis advantageous over P and O method as it avoids oscillation at MPP, it can track MPP even during rapidly varying weather conditions and the tracking accuracy is also high.The flow chart is shown in the Figure 3 [4].

Form (ECF) Figure 5 illustrates the circuit action during the initial high period of the high frequency square wave applied to the MOSFET gate at start up. During this time MOSFET conducts, placing a short circuit from the right hand side of L1 to the negative input supply terminal. Therefore a current flows between the positive and negative supply terminals through L1, which stores energy in its magnetic field. There is virtually no current flowing in the remainder of the circuit as the combination of D1, C1 and the load represent a much higher impedance than the path directly through the heavily conducting MOSFET.

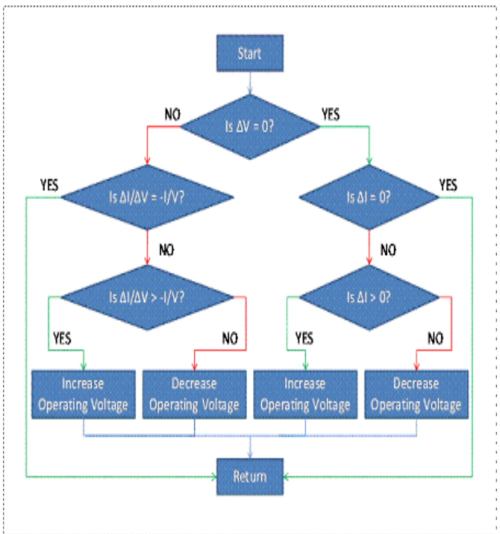

Figure 3: Flowchart for Incremental Conductance Algorithm.

4. BOOST converter Operation

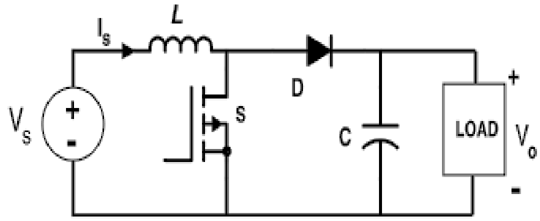

Figure. 4Circuit diagram of BOOST conveter

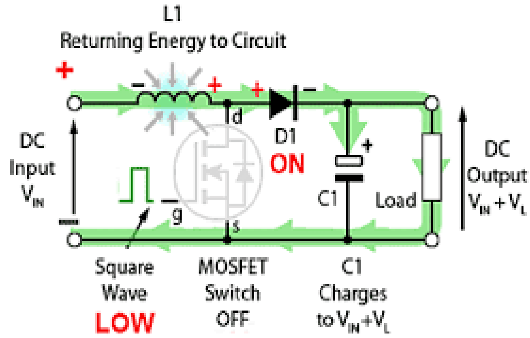

Figure. 5 Current Path with MOSFET OFF

Figure 5 shows the current path during the low period of the switching square wave cycle. As the MOSFET is rapidly turned off,then the sudden drop in current causes L1 to produce a back e.m.f. in the opposite polarity to the voltage across L1 during the on period, to keep current flowing. This results in two voltages, the supply voltage V_{IN} and the back e.m.f(V_L) across L1 in series with each other.

This higher voltage (V_{IN} +V_L), now that there is no current path through the MOSFET, forward biases D1. The resulting current through D1 charges up C1 to V_{IN} +V_L minus the small forward voltage drop across D1, and also supplies the load.

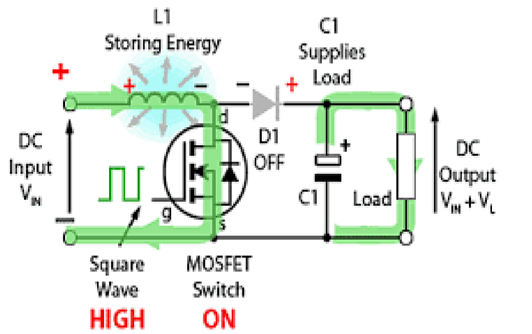

Figure 6 Current Path with MOSFET ON

Figure 6 shows the circuit action during MOSFET on periods after the initial start up. Each time the MOSFET conducts, the cathode of D1 is more positive than its anode, due to the charge on C1. D1 is therefore turned off so the output of the circuit is isolated from the input, however the load continues to be supplied with V_{IN} +V_L from the charge on C1. Although the charge C1 drains away through the load during this period, C1 is recharged each time the MOSFET switches off, so maintaining an almost steady output voltage across the load [3].

The theoretical DC output voltage is determined by the input voltage (V_{IN}) divided by 1 minus the duty cycle (D) of the switching waveform, which will be some figure between 0 and 1 (corresponding to 0 to 100%).

RESULTS AND DISCUSSION:

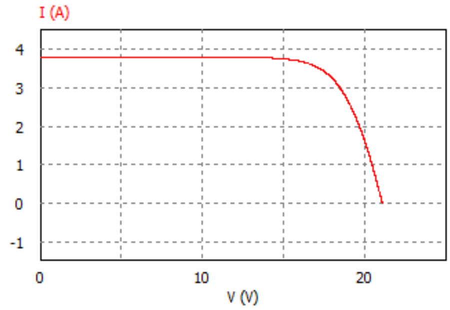

Figure 7: VI Characteristics of PV panel

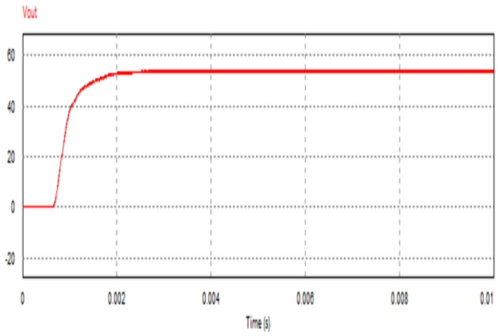

Figure 8a: Output V from the Boost Converter using MPPT

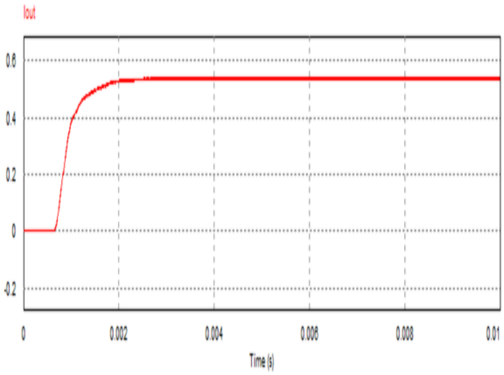

Figure 8b: Output current from the Boost Converter using MPPT

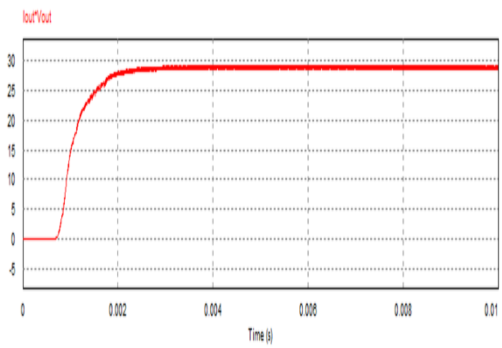

Figure 8c: Output Power from the Boost Converter using MPPT.

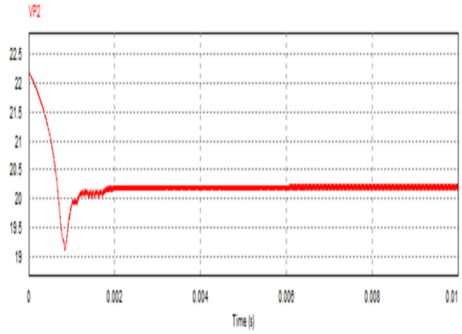

Figure 9a: Output Voltage from the PV panel

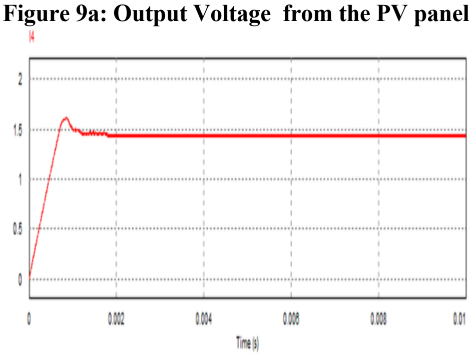

Figure 9b: Output I from the PV panel

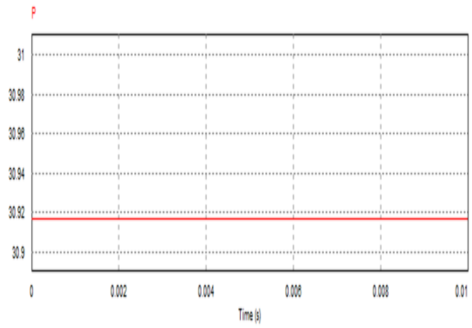

Figure 9c: Output power from the pv panel

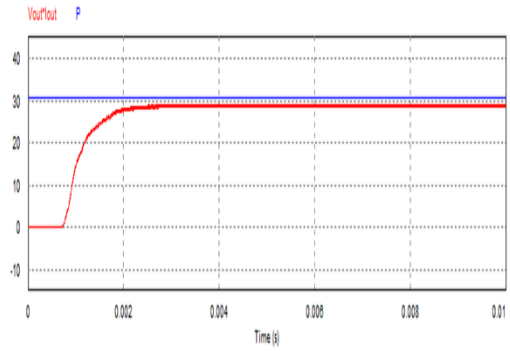

Figure 10a: Tracking of input power and output power

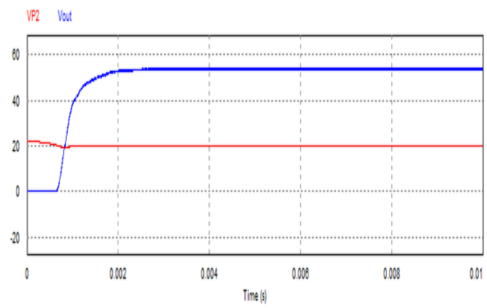

Figure 10b: Tracking of input voltage and output voltage

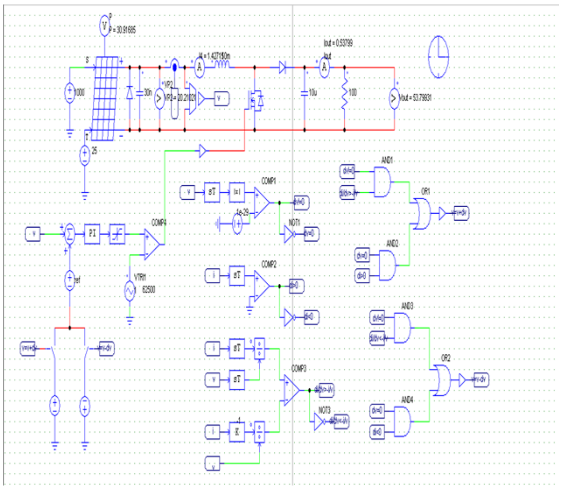

Figure 11: Overall Simulation in Psim

Figure 7 shows the VI characteristics of PV panel. The curve is drawn between open circuit voltage and short circuit current.

Figure 8a, 8b, 8c shows the Output V, I, P from the BOOST converter. The inductor, capacitor, load values are given as 10mH, 10uF, 100ohm.The supply voltage is given from PV panel. From this we can get voltage, current and power from boost converter.

Figure 9a, 9b, 9c shows the Output I, V, P from the PV panel. The temperature is given as 25° and irradiation value is 1000°. The number of cell, maximum power, voltage, current, open circuit voltage, short circuit current is given as per data sheet. By giving these values we can get voltage, current and power from PV panel.

Figure 10a shows the tracking of input and output power. The power (Pin) from the panel is measured as 30.91W and power consumed by the load is measured as 29.05W. It is inferred that Pin and Pout is almost equal. So that it is said to be tracking.

Figure 10b shows the tracking of input and output voltage. The voltage from the panel is found to be 20.21V and voltage across the load is found to be 53.79. Since we are using boost converter it is clear that Vout is greater than Vin.

Figure 11 shows the overall block diagram represents that PV panel gives voltage to the boost converter. The voltage from the panel is less. Boost converter gives maximum voltage as per our requirements. Incremental conductance method gives constant power throughout the experiment.

The expected output using PV panel and boost converter is 54W. The output we get is 53.79. By using incremental conductance method we get constant voltage irrespective of irradiation, temperature. This proves robustness of our technique.

CONCLUSION:

In this paper, the Incremental conductance technique and its performance is analyzed with BOOST converter. This system's performance and functionality is discussed and studied using PSIM. From the results it is inferred that the Incremental conductance provides stable output for irradiation and Temperature changes. This technique tracks the power more effectively than other methods.

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