MPPT CONTROL OF BOOST CONVERTER USING HILL CLIMBING ALGORITHM FOR PV SYSTEM

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Abstract: In this paper utilization of a boost converter for control of photovoltaic power using Maximum Power Point Tracking (MPPT) control mechanism is presented. First the photovoltaic module is analyzed manually. For the main aim of the project the boost converter is to be used along with a Maximum Power Point Tracking control mechanism. The MPPT is responsible for extracting the maximum possible power from the photovoltaic and feed it to the load via the boost converter which steps up the voltage to required magnitude. The main aim will be to track the maximum power point of the photovoltaic module so that the maximum possible power can be extracted from the photovoltaic. The algorithms utilized for MPPT are generalized algorithms and are easy to model or use as a code. The algorithms are written in Arduino 1.6.7 software and utilized in simulation. Both the boost converter and the solar cell are modeled using Power SIM Systems blocks.

Keywords: Photo Voltaic (PV) energy, Maximum Power Point Tracking (MPPT) techniques,Hill climbing algorithm, DC-DC converter.

1. Introducton:

There isa increasing energy consumption needs and also environmental impacts due to non-renewable energy and it make use of renewable energy. Among various renewable energyPhotoVoltaic energy is a popular one.. Solar energy is the ultimate source of energy, which can be naturally replenished in short period of time. Solar power is zero green house 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.

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 Reconfiguration, Linear Current Control, State-Based MPPT. One-Cycle Frequently used MPPT are Perturb & Observe(P&O) and Incremental Conductance(Inc Cond) algorithm.

DC-DC converter is used to increase the output voltage of PV panel to specific value depends on the load. This paper represents the performance of hill climbing algorithm using DC-DC 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.

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

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.

$FF=(V_{mp}I_{mp})/(V_{oc}I_{sc})$ (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.

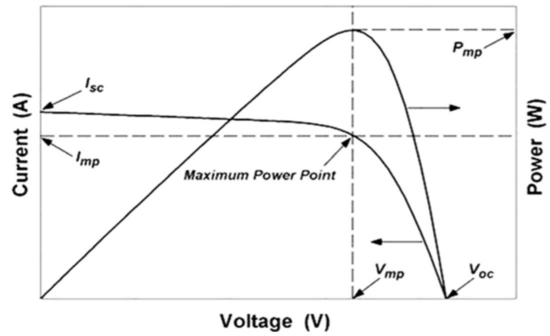

Figure 1:I-V and P-V curve of the solar cell

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,

$$V_t = \frac{(T_{op}\,\mathrm{K})}{q} \quad (3)$$

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. Reservesaturation current:

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

$I_{rs}=I_{sc}/(_{exp}(V_{oc}*q/k*c*t_{op}*n))-1$ (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,

$Is=I_{rs}(T_{op}/\ \ T_{ref})^\wedge\ \ 3exp\{q^2*E_g/k*(1/T_{op})-(1/T_{ref})n\}$ (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,

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

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

Where

R_p-parallel resistance (Ω)

2.3.7 PV Output Current:

Output current (I) is given by,

$I= \{[I_{ph}*N_p]-I_{sh}-I_d$

Where

$I_{ph}=\{(|(T_{op}-T_{ref)}*K_i]+I_{se})*I_{rr}\}$ (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)	30w
Voltage at Pmp(Vmp)	17.7
Current at Pmp(Imp)	1.7
Open circuit voltage(Voc)	21.40
Short circuit current(Isc)	2

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 implementation, 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.

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

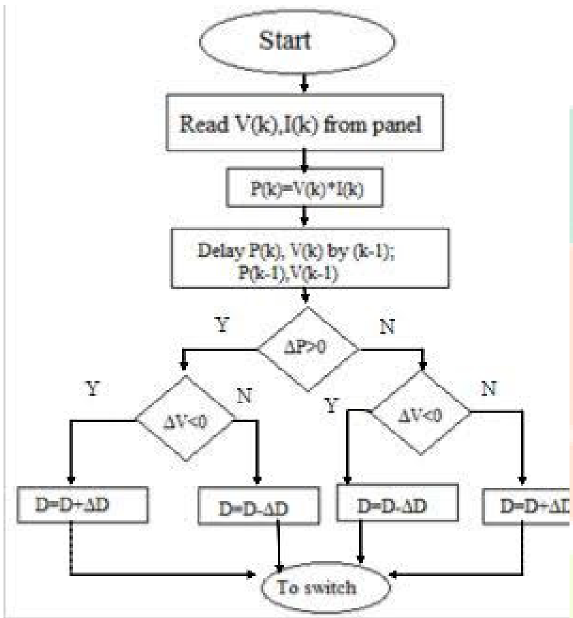

Figure 2:Flowchart for Perturb and Observe Algorithm

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 conductance di /dv and instantaneous conductance is –I/V. 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

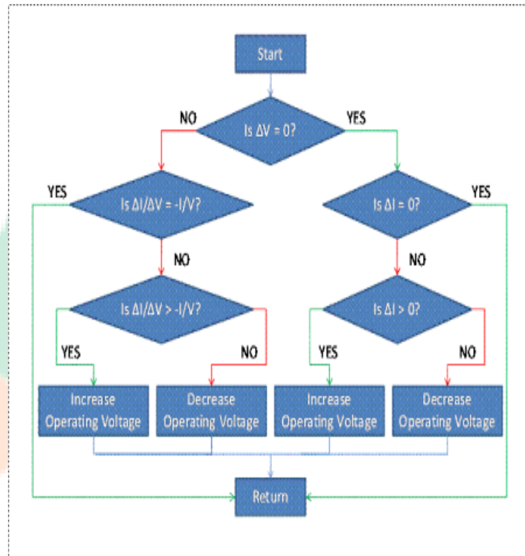

Figure 3: Flowchart for Incremental Conductance Algorithm.

4. DC-DC converter Operation

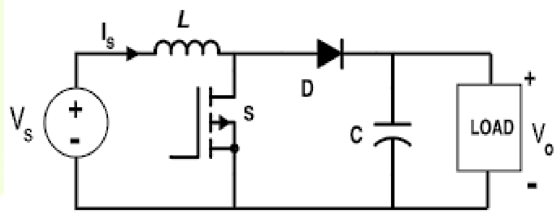

Figure. 4Circuit diagram of DC-DC conveter

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.

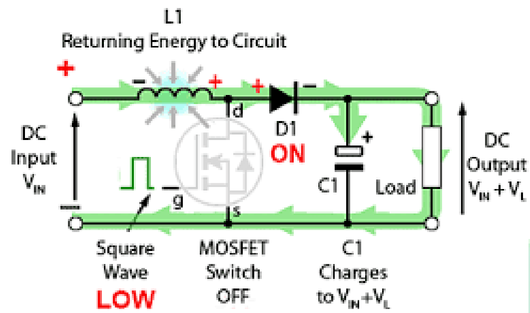

Figure. 5 Current Path with MOSFET Off

Figure. 5shows the current path during the low period of the switching square wave cycle. As the MOSFET is rapidly turned off 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.

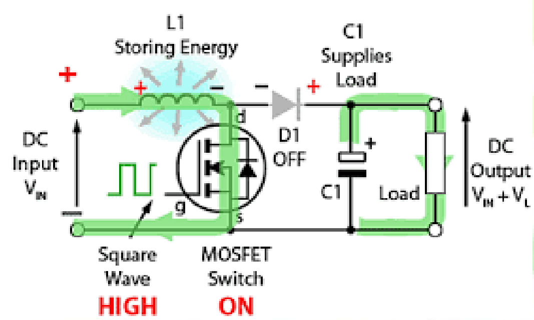

Figure. 6 Current Path with MOSFET On

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.

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%).

SIMULATION:

Modeling and simulation of PV module, DC-DC converter and both the MPPT algorithms are done in Simulink.The system is always simulated at Standard Test Condition (STC) that is at 25 C temperature and 1KW/m^2 irradiance. Figure shows the Simulink modeling of PV module, DC-DC converter and Hill climbing MPPT Algorithm. The inputs of the PV module are solar insulation and ambient temperature. The output obtained from the module is current which acts as a curret

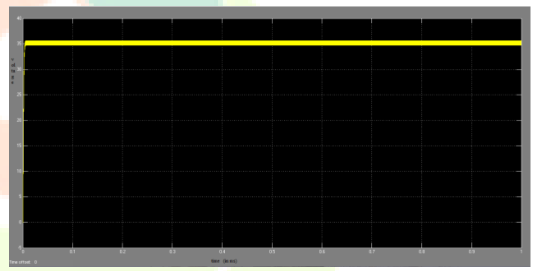

Figure 7:Output Voltage from the DC-DC Converter using MPPT

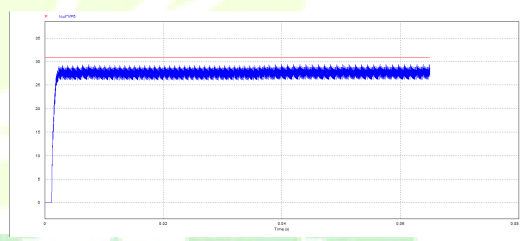

Figure **8: Tracking of Input power and Output power**

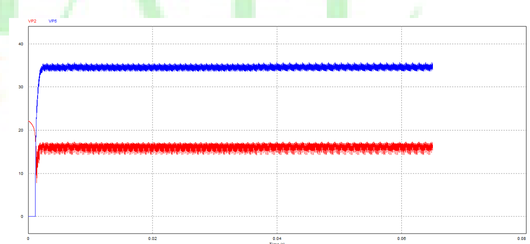

Figure 9: Tracking of Input Voltage and Output Voltage

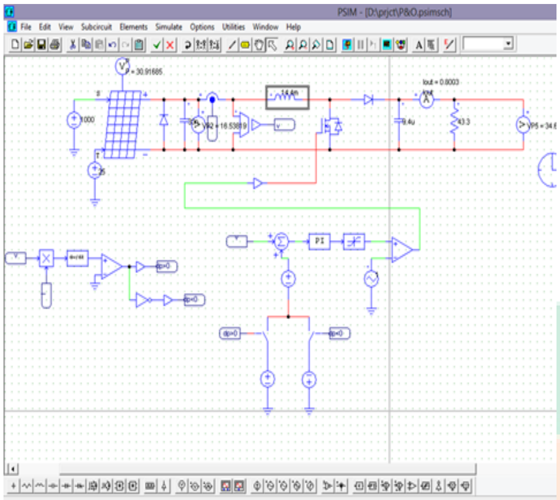

Figure 10: Overall Simulation Using PSIM

Figure 7 shows the output voltage from DC-DC converter. Figure 8 shows the power waveforms from pv panel. Figure 9 shows tracking of input and output voltage. Figure 10 shows the overall simulation using psim. These values and waveforms obtained from psim for irradiance value 1000 and temperature value 25° C.

CONCLUSION:

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

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