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RESEARCH ARTICLE OPEN ACCESS

Solar Panel Maximum Power Point Tracker for Power Utilities

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ABSTRACT
"Solar Panel Maximum Power Point Tracker For power utilities" As the name implied, it is a photovoltaic system that uses the photovoltaic array as a source of electrical power supply and since every photovoltaic (PV) array has an optimum operating point, called the maximum power point, which varies depending on the insolation level and array voltage. A maximum power point tracker (MPPT) is needed to operate the PV array at its maximum power point. The objective of this thesis project is to build a photovoltaic (PV) array Of 121.6V DC Voltage(6 cell each 20V, 100watt) And convert the DC voltage to Single phase 120v,50Hz AC voltage by switch mode power converter's and inverter's.
Keywords **-**MPPT, Photovoltaic, Fast Changing Irradiation, Boost Converter, PWM, Inverter

I. INTRODUCTION

Energy is the most basic and essential of all resources. All the energy we use on Earth comes from fission or fusion of atomic nuclei, or from energy stored in the Earth. The problem with both fission and fusion is that they have dangerous radioactivity and side effect. Therefore, most of the generation of energy in our modern industrialized society is strongly depending on very limited nonrenewable resources, As the world's energy demands rise and resources become scarce, the search for alternative energy resources has become an important issue for our time.The most effective and harmless energy source is probably solar energy.Solar energy can be used as energy source by the use of photovoltaic (PV) array. PV array has an optimum operating point called the maximum power point (MPP), which varies depending on cell temperature and the present insolation level.When insolation level changes the tracker needs to respond within a short amount of time to the change to avoid energy loss.We use boost converter which utilize one or more switches to transform dc from one level to another.In a dc-dc converter with a given input voltage,output voltage is controlled by controlling the switch on and off durations (ton and toff) by pulse-width modulation (PWM) switching method.The output of Boost converter fed to the DC-AC inverter and by hysteresis controller which control output current we found desired level of ac output voltage.The block diagram of whole system shown below-

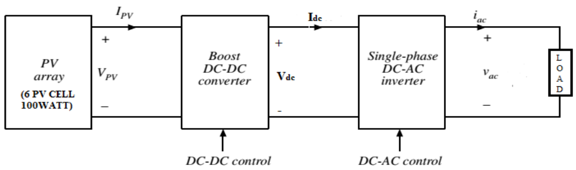


Fig. 1 BLOCK DIAGRAM OF WHOLE SYSTEM

II. PV EQUIVALENT CIRCUIT

A solar cell is any device that directly converts the energy of light into electrical energy through the process of Photovoltaic's.

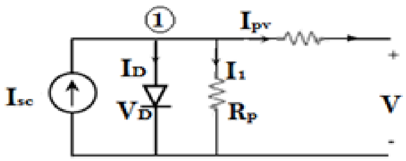


Fig. 2.1 Equivalent circuit of PV solar cell

The basic equation that describes the (I-V) characteristics of the PV model is given by the following equation:

$$I_{pv} = I_{sc} - I_o\left(e^{\frac{q(V + I_{pv}R_S)}{kT}} - 1\right) - \frac{V + I_{pv}R_s}{R_p} \qquad (1)$$

Where:
I_{pv} is the cell current (A).
I_{sc} is the light generated current (A).
I_o is the diode saturation current.
q is the charge of electron = $1.6\text{x}10^{-19}$ (coul).
K is the Boltzman constant (j/K).
T is the cell temperature (K)(**298k**)
V is the cell output voltage (V).

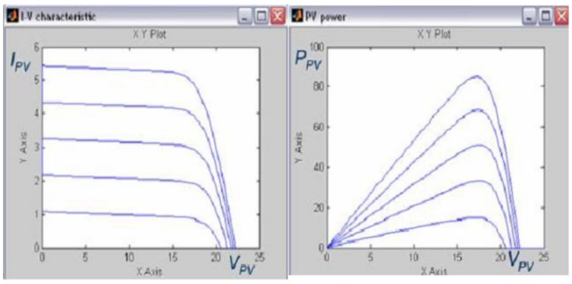


Fig.2.2 I-V & PV vs Vpv Charecteristic of Solar cell for different insolation level

III. COMMONLY USED MPPT TECHNIQUES

Photovoltaic (PV) arrays are used to provide energy for many electrical applications. To get the maximum power from the PV array, a maximum power point tracker (MPPT) is used to control the variations in the current-voltage characteristics of the solar cells.There are many algorithms that are used to control the MPPT. The algorithms that are most commonly used are the perturbation and observation method.

3.1)Perturbation and Observation Method :

Perturbation and Observation Method (P&O)Method has a simple feedback structure and fewer measured parameters.It operated periodically perturbing (i.e. incrementing or decreasing)) the array terminal voltage and comparing the PV output power with that of the previous perturbation cycle. If the perturbation leads to an increase (decrease) in array power, the subsequent perturbation is made in the same (opposite) direction. In this manner, the peak power tracker continuously seeks the peak power condition.

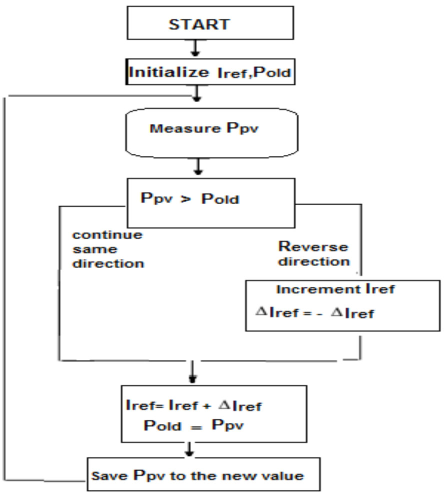


Fig.3 Flow chart of (P&O)Method

IV. BOOST CONVERTER

The boost converter as shown in fig. also known as the Step-up converter.As the name implies its typical application is to convert low input voltage to high output voltage.

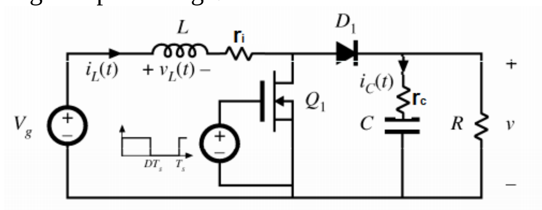


Fig.4.1 BOOST CONVERTER

In a DC-DC boost converter with a given input voltage,output voltage is controlled to desired level by controlling the switch ON and OFF durations (ton and toff).

CIRCUIT OPERATION: The circuit operation can divided into two modes.MODE1: Mode 1 begins when switch Q1 switched on at t=0.The input current, which rises, flows through inductor L and swichQ1.

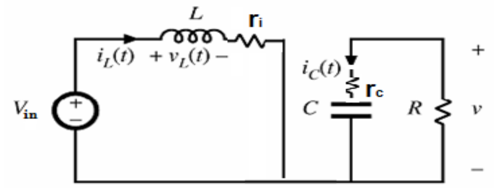


Fig. 4.2 BOOST CONVERTER during 'ON' mode

In a Boost converter, during 'on' mode:

From KVL $v_{in} - Ir_i - L\frac{di_L}{dt} = 0$

From KCL $\frac{v_C}{r_c+R} + C\frac{dv_C}{dt} = 0$

In State Space from,

$$\begin{bmatrix} \frac{di_L}{dt} \\ \frac{dv_C}{dt} \end{bmatrix} = \begin{bmatrix} \frac{-r_i}{L} & 0 \\ 0 & \frac{-1}{C(r_c+R)} \end{bmatrix} \begin{bmatrix} i_L \\ v_C \end{bmatrix} + \begin{bmatrix} \frac{1}{L} \\ 0 \end{bmatrix} v_{in}$$

MODE2: Mode 2 begins when switch Q1 switched off at t=t1.The current that flowing through the switch would now flow through L,C,load,and diode Dm.The inductor current falls untill switch is turned on again in the next cycle.The energy stored in in ductor L is transferred to the load.

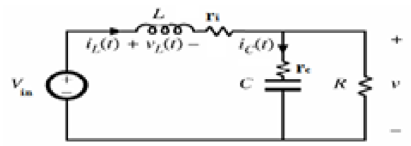


Fig. 4.3 BOOST CONVERTER during'OFF' mode

From KVL $\frac{di_L}{dt} = \frac{v_{in}}{L} - \frac{i_L}{L}\left(r_i + \frac{R r_c}{R+r_c}\right)$

From KCL $\frac{dv_C}{dt} = \frac{1}{C(R+r_c)}(R_i - V_c)$

In State Space Form:

$$\begin{bmatrix} \frac{di_L}{dt} \\ \frac{dv_C}{dt} \end{bmatrix} = \begin{bmatrix} -\left(r_i + \frac{R r_c}{R+r_c}\right) & \frac{-R}{L(R+r_c)} \\ \frac{R}{C(R+r_c)} & \frac{-1}{C(R+r_c)} \end{bmatrix} \begin{bmatrix} i_L \\ v_C \end{bmatrix} + \begin{bmatrix} \frac{1}{L} \\ 0 \end{bmatrix} v_{in}$$

Where the parasitic elements r_i and r_c are the resistance of the inductor and capacitor respectively.

V. Control of DC-DC Converters

In dc-dc converters, the average dc output voltage must be controlled to equal a desired level,through the input voltage and the output load may fluctuate.Switch mode dc-dc converters utilize one or more switches to transform dc from one level to another.In a dc-dc converter with a given input voltage,output voltage is controlled by controlling the switch on and off durations (ton and toff). The average value of the output voltage V depends on ton and toff.One of the methods for controlling the output voltage employs switching at a constant frequency (hence, a constant switching time period Ts= ton+toff) and adjusting the on duration of the switch to control the average output voltage. In this method, called pulse-width modulation (PWM) switching, The switch duty ratio D is varied. In the PWM switching at a constant switching frequency, the switch control signal, which controls the state (on or off) of the switch, is generated by comparing a signal-level control voltage Vcontrol with a repetitive waveform as shown in Figs. The control voltage signal generally is obtained by amplifying the error, or the difference between the actual output voltage and its desired value. The frequency of the repetitive waveform with a constant peak, which is shown to be a saw tooth, establishes the switching frequency. This frequency is kept constant in a PWM control and is chosen to be in a few kilohertz to a few hundred kilohertz range. When the amplified error signal, which varies very slowly with time relative to the switching frequency ,is greater than the saw-toothed waveform, the switch control signal becomes high, causing the switch to turn on. Otherwise, the switch is off. In terms of Vcontrol and the peak of the saw tooth wave form Vst in Fig.

The switch duty ratio can be expressed as---

$D = t_{on}/ T_s = V_{control} / V_{st}$

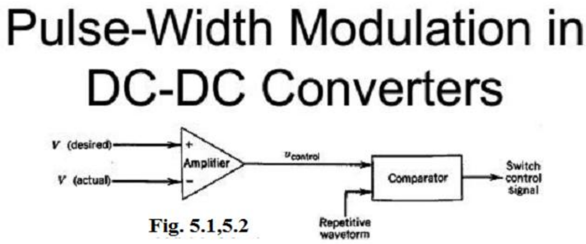
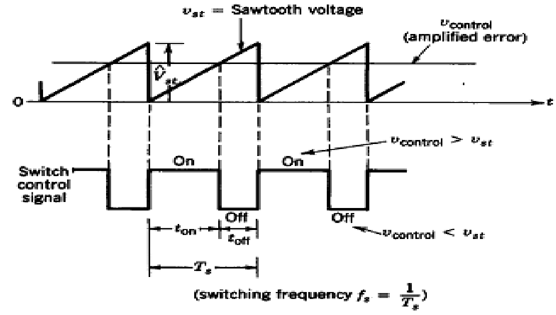


Fig. 5.1,5.2



VI. Single-phase DC-AC inverter:

A single phase inverter shown in Fig. It converts DC voltage of boost converter in to AC voltage.

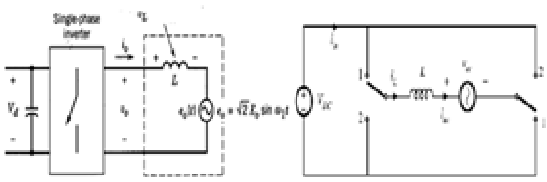
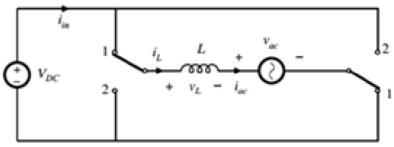


Fig.6.1 Single-phase DC-AC Inverter

Switches in position 1 during DTs, in position 2 during (1−D)Ts Switching frequency fs is much greater than the AC line frequency (50 Hz) By controlling the switch duty ratio D, it is possible to generate a sinusoidal AC.

Fig. 6.2 Position 1: When switch in position 1,

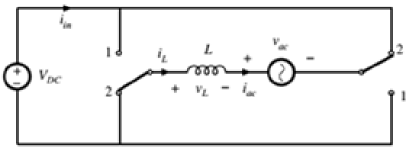


$V_L = V_{DC} - V_{ac}$

$i_L = i_{ac}$

$i_{in} = i_L$

Fig. 6.3 Position 2: When switch in position 2,



$V_L = -V_{DC} - V_{ac}$

$i_L = i_{ac}$

$i_{in} = -i_L$

6.1) Control of AC current:

$i_{ac} = I_m \sin(\omega t)$, in phase with AC line voltage Vac(t).Amplitude Im adjustable to control power delivered to home.To do this a current controller need. First Imref multiply with sin (ωt) signal. Im sin (ωt) signal compare with feedback current.If error signal generate then the signal feed to comparatorwith hysteresis and then switch control.Due to use hysteresis controller the output current always within Δi/2 of i_{ref}.

VII. Evaluation of the Boost Converter:

The following experiments show the behaviour of the Boost-Converter under different switching frequencies and duty cycle ratios that could affect the power conversion efficiency of the Boost-Converter. Since the DC power supply can supply constant voltage and current, therefore it is a suitable device for the experiments that can be use to simulate the PV array.

7.1) Switching Frequency vs. Power Efficiency:

In this experiment a function generator was used to generate saw-tooth signals that performed PWM on the designed Boost-Converter. The duty cycle ratio was set and kept constant at 50%. The current vary with varying pv array voltage. The input voltage, input current, output voltage and output current were measured and recorded in Table 5.1 under various PWM switching frequency. The input power (P_{in}) and output power (Pout) then calculated by using the relationship P = V ×I. Hence the power efficiency can be found by using the relation η= Pout/ P_{in}.

Table-1	Switching Frequency vs. Power Efficiency				
Switching Frequency(kHz)	Input Voltage(V)	Input Current(A)	Output Voltage(V)	Output Current(A)	Power Efficiency(%)
10	103.2	4.95	200.3	2.003	78.53
15	104.2	4.90	206.9	2.069	83.84
20	105.1	4.85	209.6	2.096	86.43
25	105.8	4.80	212	2.12	88.5
30	106.6	4.75	213.6	2.136	90.1
50	107.2	4.70	215.1	2.151	91.79
70	105.8	4.80	212.2	2.122	88.63
80	105.1	4.85	210.6	2.106	87.00
90	104.2	4.90	208.8	2.088	85.338
100	103.2	4.95	206.8	2.068	83.7

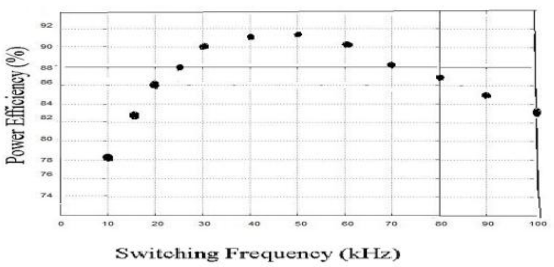


Fig. 7.1 Switching Frequency vs. Power Efficiency

VIII. SIMULATION RESULTS :

In a Solar Panel Maximum Power Point Tracker for Power Utilities whole system model,MPPT algorithm are implimented in Matlab/Simulink.Here 6 module (100 watt each) PV array with full sun (1,000W/m2 insolation) operates at MPP, output power Ppv= 6*100 W = 600 Watt. The specification of the control parameters and main characteristics of the PV array (Table2), boostconverter (Table3), Switching frequency vs. Power efficiency(Table1),DC-ACInverter (Table4) shown. The proposed MPPT is evaluated from two aspects:
1) Provide high conversion efficiency,
2) Maintain tracking for a wide range of variation in environmental conditions.

The Output Voltage Of Boost converter and DC-AC Inverter shown in fig. For all the results above, the optimized P&O track maximum power point in fast variation of the external conditions with best accuracy.

TABLE II
MAIN CHARACTERISTICS OF THE PV GENERATION SYSTEM

Maximum power	P_{max}	100 W
Output voltage at Pmax	V_{max}	20 v
Open-circuit voltage	V_{oc}	24 v
Short circuit	I_{sc}	5 A
Total output Power of PV array		599.5 W

TABLE III
Control parameters used in the simulation of BOOST converter

parameters	Value	unit
V_{in}	121.6	V
C	10	µF
L	200	µ H

TABLE IV
Control parameters used in the simulation of DC-AC Inverter

parameters	Value	OUTPUT	
V_{in}	240.9 V	Vout	121.8 V
L	2 mH	Frequency	50 HZ

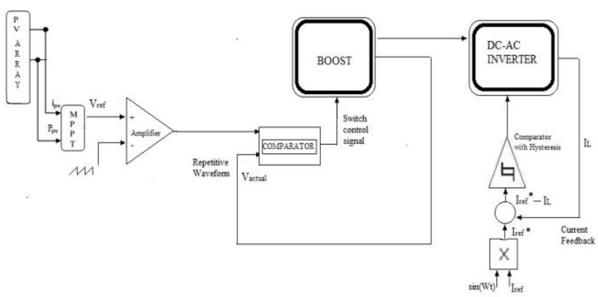
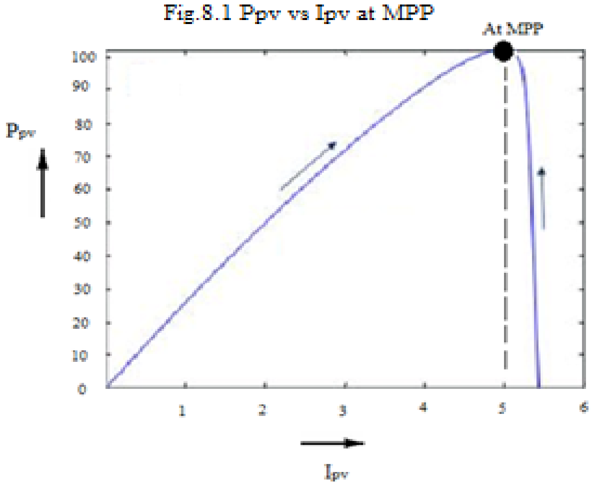
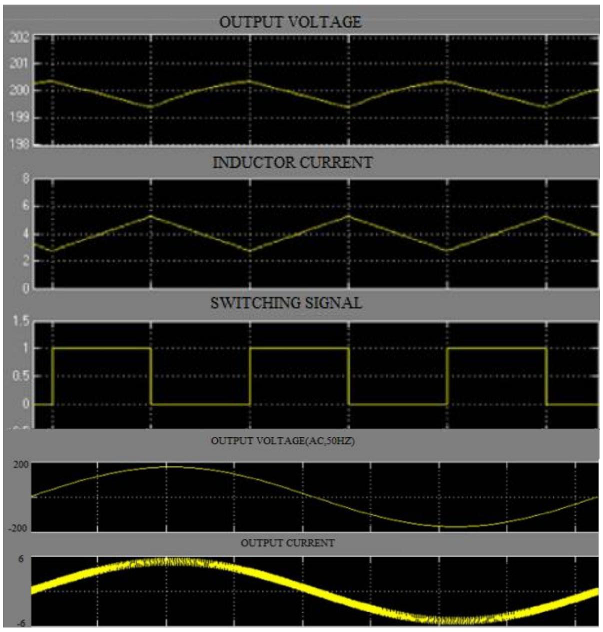


Fig.7.2 Whole system Model

Fig.8.1 Ppv vs Ipv at MPP





IX. CONCLUSION

When the PV array is used as a source of power supply to Boost converter, it is necessary to use the MPPT to get the maximum power point from the PV array. Boost-Converter, which Used to boost up input voltage by varing Duty ratio, is designed to operate under continuous conduction mode control the PWM signals to control switch. Peturbation and Oserbation Algorithm is used as the control algorithm for the MPPT. Experimental results have shown that the MPPT has the conversion efficiency of 91.79%.

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