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# A Novel Technique for Maximum Power Point Tracking of Photo-Voltaic Energy Conversion System

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*Abstract:* This paper presents the novel technique for maximum-power point tracking of photovoltaic (PV) energy conversion system. In order to obtain the maximum power extracted from the PV array, usually two parameters are considered, namely solar irradiation and temperature, most of the research work has been carried out by considering these two parameters. But in this paper, a new technique is proposed where maximum power is extracted when the load current is 0.9 times the short circuit current. The proposed technique gives optimum utilization of PV array and enhances the applications of PV systems for both stand alone and grid connected systems. The study has been carried out in the MATLAB-Simulink environment via the graphical user interface. And also validation of the simulated results with the theoretical results shows proper matching.

***Keywords- Converter, Maximum power point tracking (MPPT), photovoltaic, solar irradiation***

## I. INTRODUCTION

IN India there are about 300 clear sunny days in a year and solar energy is available in most parts of the country, including the rural areas. But still we have miles to cover before solar power is effectively utilized to replace the fossil fuels and become a cheap and effective solution for domestic and commercial applications. With the growing demand for renewable sources of energy, the manufacturing of solar cells and photovoltaic arrays has advanced dramatically in recent years. Its efficient usage has led to increasing role of photovoltaic technology as scalable and robust means of renewable energy.

This paper presents a photovoltaic energy conversion system for converting solar power in to useable DC at 5V for charging low power devices like mobile phones etc. The energy obtained from the photovoltaic module is directly useable (approx 12V).But for charging applications we require 5V DC supply. The 12V DC obtained from the PV module is stepped down to 5V by DC-DC buck converter. Fig.1 shows the complete structure of PV energy conversion system, which comprises PV array with DC-DC buck converter. The inductor design of the buck converter circuit is discussed in detail which is a significant part in designing of the converter. For efficient usage of photovoltaic energy conversion system, it is essential to design a maximum power point tracking (MPPT) system. This paper also presents modeling of PV cell along with MPPT with a buck converter. The concept of MPPT is to automatically vary a PV array's operating point so it can produce its maximum output power. This is necessary because a PV cell has non-linear current-voltage relation. The power delivered by array increases, to maximum as the current drawn rises and suddenly the voltage falls making the power zero. A boost converter is not preferred here because it cannot track maximum power point at low radiation levels, as this point is located in the non-operating region. Simulation of the whole system has been carried out using Matlab-Simulink environment via the graphical user interface.

## II. PV SYSTEM CONFIGURATION

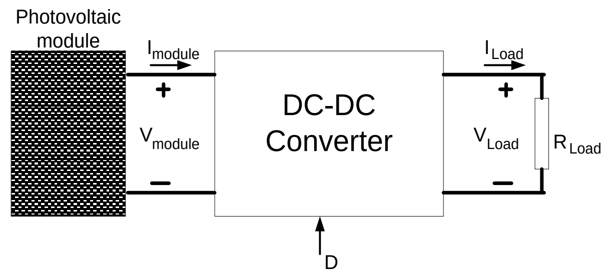


Fig.1. Block diagram of the PV system

### A. Photovoltaic Array Simulation

By arranging PV solar cells in series and parallel combinations the complete formation of the desired PV array is obtained. These are generally represented in a simplified equivalent circuit model such as the one given below in Fig 2.

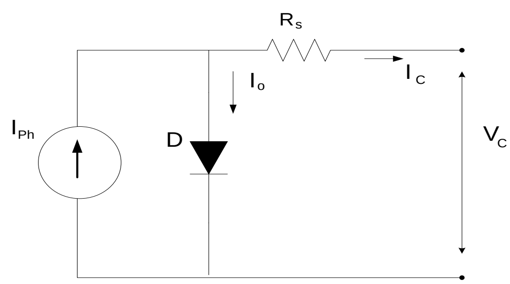


Fig.2. Simplified equivalent circuit of PV cell

The PV cell output voltage is a function of the photocurrent which mainly determined by load current depending on the solar radiation level during the operation.

$$V_c = \frac{AKT_c}{e} \ln\left\{\frac{I_{ph}+I_0-I_c}{I_o}\right\} - R_s I_c \tag{1}$$

where symbols are defined as follows:
*e*: electron charge ( $1.602 \times 10^{-19}$ C )
*k*: Boltzmann constant ( $1.38 \times 10^{-23}$ J/K )
$I_c$: Cell output current, A
$I_{ph}$: Photocurrent, a function of irradiation level and junction temperature (5 A).
$I_o$: Reverse saturation current of diode (0.0002 A).
$R_S$: Series resistance of cell (0.001 Ω).
$T_C$: Reference cell operating temperature (20 °C).
$V_C$: Cell output voltage, V.

The voltage obtained from Eq (1) gives the voltage for a single solar cell and then it is multiplied by number of cells connected in series to calculate the total array voltage. For certain cell operating temperature $T_C$ and corresponding solar insolation level $S_C$ the cell current $I_C$

is obtained by dividing array current by number of cells connected in parallel. Change in $T_C$ and $S_C$ is reflected in voltage and current outputs of PV array. So effects of these changes have been taken into consideration in the final PV array model.

A methodology has been devised to handle the effects of change in $T_C$ and $S_C$, according to which, a model is obtained for a known temperature and solar insolation level. Later this model is modified accordingly to handle various changes in temperature and insolation level. Using correction factors $C_{TV}$, $C_{TI}$, $C_{SV}$ and $C_{SI}$, the new values of the cell output voltage $V_{CX}$ and photocurrent $I_{phx}$ are obtained for the new temperature $T_x$ and solar irradiation $S_x$ as follows.

$$V_{CX} = C_{SV} C_{TV} V_C \tag{2}$$
$$I_{phx} = C_{SI} C_{TI} I_{ph} \tag{3}$$

where $C_{TV}$ and $C_{TI}$ are temperature coefficients. $V_C$ and $I_{ph}$ are the benchmark reference cell output voltage and reference cell photocurrent respectively.

### B. *The Buck Converter*

These converters produce a lower average output voltage than the DC input voltage. The fig 3 shows a step down or a buck converter. It consists of a DC input voltage source $V_s$, inductor *L*, controlled switch (MOSFET), diode *D*, filter capacitor *C*, and load resistance *R*.

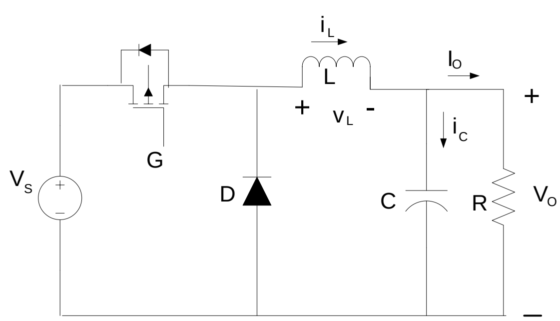


Fig.3. Buck Converter

## III. Inductor Design

The inductor design for the buck converter has been done at the maximum input voltage $V_{IN\_MAX}$. This represents the worst-case for all the inductor parameters: the core loss, the peak or RMS inductor current, the copper loss, the temperature rise, the energy it must handle and the peak flux density. We define *D* as the duty cycle and r the ripple current ratio $\frac{\Delta I}{I_o}$, r is related to the inductance through equation

$$r = \frac{E_t}{L.I_{DC}} \tag{4}$$

where $E_t$ is the applied volt$\mu$secs, $I_{Dc}$ is the maximum rated load in Ampere and *L* is the inductance in µH. The Duty cycle is

$$D = \frac{V_o + V_D}{V_{IN} - V_{SW} + V_D} \tag{5}$$

$V_D$ is the diode forward voltage drop ($\cong 0.5V\ for\ schottky\ diode$) and $V_{SW}$ is the drop across the switch when it is ON plus any parasitic voltage ($\cong 1.5V$).

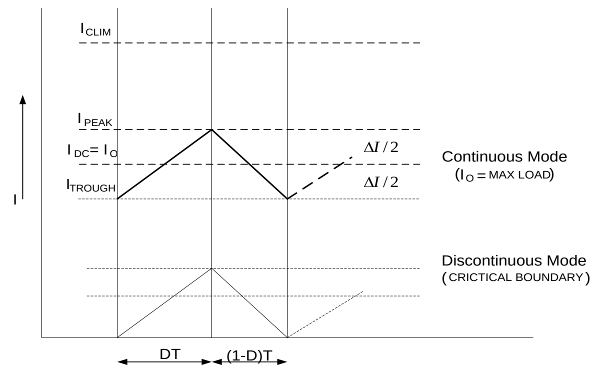


Fig.4. Inductor current waveform

In fig 4, $I_{DC}$ is the current to the load, since the average current through the output capacitor as for any capacitor in steady state is zero, $I_{PEAK}$ is $I_{DC} + \frac{\Delta I}{2}$, and it determines the peak energy in the core (*e* = 0.5L $I^2$), which in turn is directly related to the peak field the core must withstand without saturating, $I_{TROUGH}$ is $I_{Dc} - \frac{\Delta I}{2}$ and determines the constant residual level of current or energy in the inductor it depends on the load, even though it is not itself transferred to the load. The AC component of the current is

$$I_{AC} = \Delta I = I_{PEAK} - I_{TROUGH} \tag{6}$$

The DC component is the load current for the case shown in the fig 4 $I_{DC} = I_O$ where $I_O$ is the maximum rated load. The defined *r* is a constant for a given converter/application (as it is calculated only at maximum load), and it is also defined only for continuous conduction mode.

$$r = \frac{\Delta I}{I_O} \tag{7}$$

A high inductance reduces Δ*I* and results in lower *r* (and lower RMS current in the output capacitor), but may result in a very large and impractical inductor. So practically, for this buck converter, r is chosen to be in the range of 0.25–0.5 (at the maximum rated load).

From the general rule $V = L\frac{dI}{dt}$ we get during the ON time of the converter.

$$V_{IN} - V_{SW} - V_O = L\frac{\Delta I}{D/f} \tag{8}$$

where $f$ is the switching frequency in hertz. The switch ON time $t_{ON} = \frac{D}{f}$

$$E_t = (V_{IN} - V_{SW} - V_O)\, t_{ON} \qquad (9)$$

Solving for ΔI we can write 'r' as

$$r = \frac{(V_{IN} - V_{SW} - V_o)D}{Lf I_o} \qquad (10)$$

And L is therefore,

$$L = \frac{(V_{IN} - V_{SW} - V_O)(V_o + V_D)}{(V_{IN} - V_{SW} + V_D) r f I_o} \qquad (11)$$

will guarantee continuous conduction for all D. The inductor is designed for specific scheme in this paper.

## IV. Maximum Power Point Tracking

The photovoltaic system displays an inherently nonlinear current-voltage (*I-V*) relationship, requiring an online search and identification of the optimal maximum operating power point. The MPPT controller is a power electronic DC/DC chopper or DC/AC inverter system inserted between the PV array and its electric load to achieve the optimum characteristic matching, so that PV array is able to deliver maximum available power which is also necessary to maximize the photovoltaic energy utilization. PV cell has a single operating point where the values of the current and Voltage of the cell result in a maximum power output. These values correspond to a particular resistance, which is equal to *V/I* as specified by Ohm's Law. Also the PV cell has an exponential relationship between current and voltage, so the maximum power point occurs at the knee of the curve, where the resistance is equal to the negative of the differential resistance ($\frac{V}{I} = -\frac{dV}{dI}$). The aim of this MPPT subsystem is to determine just where that point is, and to regulate current accordingly and thus to allow the converter circuit to extract the maximum power available from a cell.

The control methodology presented in this paper will adopt an approach in which designing of the power converter is done by using the relationship existing between the short-circuit current ($I_{SC}$) and the MPP current ($I_m$). By simulating with various sample data for $I_{SC}$ and $I_m$ it is ascertained that the ratio of $I_m$ to $I_{SC}$ remains constant at 0.9. One such control scheme is shown in the fig 5. Determining the MPP for a specific insolation condition and operating the converter for this condition is the critical part in the design of PV conversion system. Initially the Short-circuit current $I_{SC}$ is measured and then the actual load current adjusted in such a way it is equal to a desired fraction (0.9) of $I_{SC}$.

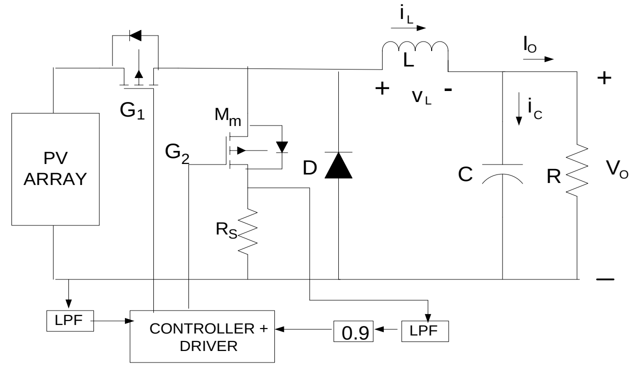


Fig.5. Control scheme for MPPT

Measurement of the current $I_{SC}$ is done by switching ON the MOSFET $M_m$ in fig 5 for extended interval ie. in turn it is the way of shorting the panel. In this approach an extended pulse is applied to MOSFET $M_m$ once in several switching cycles so that the short-circuit current is sensed in accordance with the switching instance.

## V. Results and Discussion

The complete PV power conversion system was developed and simulated with Matlab-Simulink. Power MOSFET switches were used in developing the power converter along with the MPPT.Fig.6 is the complete simulation block for PV with MPPT.

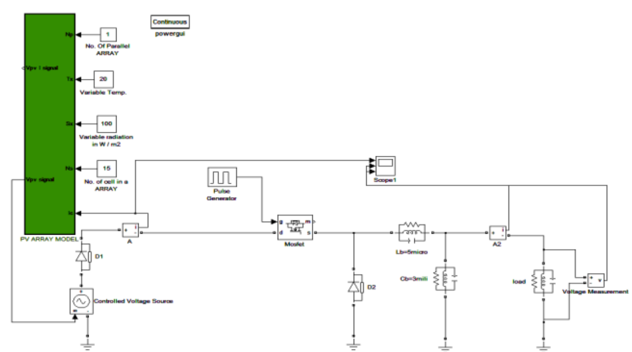

Fig.6. Simulation block of PV with MPPT

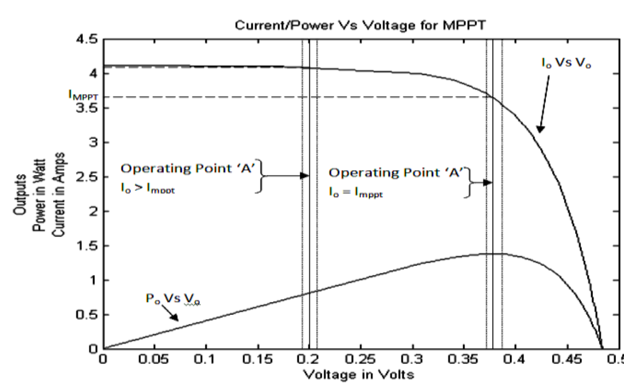


Fig.7. Current/power Vs Voltage plot with MPPT

Fig.7 shows the simulation output curves. It clearly shows the operating point condition. The I-V and P-V curves are plotted for a typical PV array with the exposure to standard solar insolation level (intensity of $1KW/m^2$). Standard design approach shows that an increased number of cells can provide a nominal level of usable charging currents for normal range of solar insolations. In figure 8 the zero current indicates the condition of open circuit, so the value of voltage at that point gives the value of open circuit voltage of the PV array. Similarly a zero voltage indicates a short circuit condition; the current at this point is used to determine the optimum value of current drawn for maximum power. The value of the maximum current increases for increase in temperature.

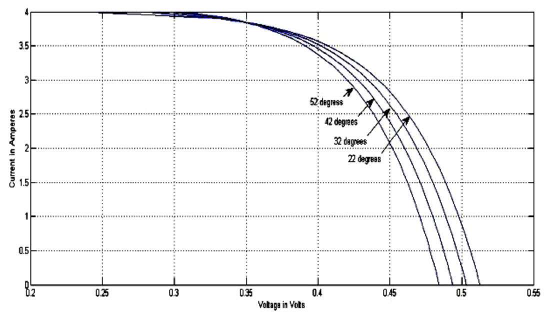


Fig.8. Plot for output current vs Voltage

Fig. 9 is the plot between voltages versus the power of PV module. This graph has been plotted for different values of temperatures. From this curve it was ascertained that the maximum power decreases for increase in temperature.

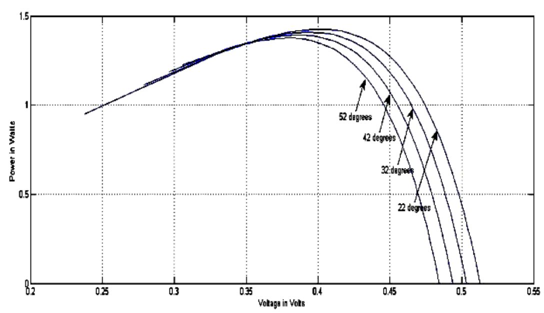


Fig.9. Plot for output power Vs Voltage

Fig 10 and Fig 11 shows the output curves of the Buck converter. Fig.10 shows the graph of output current versus Time in milli second. Figure 11 shows the graph of buck converter output voltage versus time in milli second.

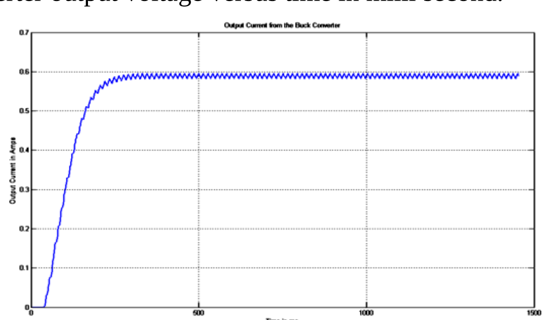


Fig.10.Response of output current buck converter

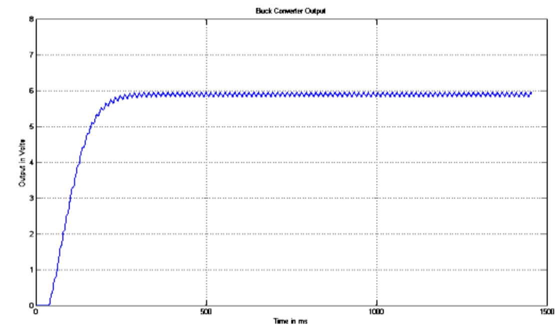


Fig.11. Response of the output voltage of buck converter

## VI. Conclusion

Modeling of photovoltaic array has been validated with the theoretical results obtained and a GUI has been developed in the Simulink environment. An attempt has been made to develop an economical photovoltaic energy conversion for charging low power devices. The inductor design proposed has shown significant output in accordance with the desired performance. A robust MPPT methodology has been devised, which can prove more useful in terms of providing usable voltage with very little fluctuations.

## VII. References

[1] S. S.Yuvarajan, Dachuan Yu and Shanguang Xu, ―A novel power converter for photo voltaic applications Elsevier Journal of Power Sources, June-2004.

[2] Y. Kuo, et al., Maximum-power-point-tracking controller for photo-voltaic energy conversion system,IEEE Trans. Ind. Electron. 48 (3) (2001) 594–601.

[3] D..L. King, J.H. Dudley, W.E. Boyson, PVSIM: a simulation program for photovoltaic cells, modules and arrays, in: Proceedings of the 25th IEEE Photovoltaic Specialists Conference, May 1996.

[4] I. H. Altas, and A.M. Sharaf, A Photovoltaic Array Simulation Model for Matlab-Simulink GUI Environment, 1-4244-0632-3/07 IEEE.

[5] C.G. Steyn, Analysis and optimization of regenerative linear snubbers, IEEE Trans. Power Electron 4 (3) (1989) 362–370.

[6] I.H. Altas and A.M. Sharaf: A Novel On-Line MPP Search Algorithm for PV Arrays, IEEE Transactions On Energy Conversion, Vol. 11, No.4, December 1996.

[7] M. Buresch: Photovoltaic Energy Systems Design and Installation,McGraw-Hill, New York, 1983.