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PHOTOVOLTAIC POWER CONTROL USING MPPT AND BOOST CONVERTER

Amaresh Choudhury*, Saurav Biswas, Radha Rani Panigrahi
*Electrical and electronics engineering Department.
Electrical and electronics engineering Department.
Electrical and electronics engineering Department.

ABSTRACT
In this paper, we examine a schematic to extract maximum obtainable solar power from a PV module and use the energy for a DC application. This paper investigates in detail the concept of Maximum Power Point Tracking (MPPT) which significantly increases the efficiency of the solar photovoltaic system. photovoltaic (PV) power generation has an important role to play due to the fact that it is a green source. The only emissions associated with PV power generation are those from the production of its components. After their installation they generate electricity from the solar irradiation without emitting greenhouse gases. In their lifetime, which is around 25 years, PV panels produce more energy than that for their manufacturing The efficiency of a PV plant is affected mainly by three factors: the efficiency of the PV panel (in commercial PV panels it is between 8-15%) [3], the efficiency of the inverter (95-98 %) [5] and the efficiency of the maximum power point tracking (MPPT) algorithm (which is over 98% [6]). Improving the efficiency of the PV panel and the inverter is not easy as it depends on the technology available, it may require better components, which can increase drastically the cost of the installation. Instead, improving the tracking of the maximum power point (MPP) with new control algorithms is easier, not expensive and can be done even in plants which are already in use by updating their control algorithms, which would lead to an immediate increase in PV power generation and consequently a reduction in its price.

INTRODUCTION
Studies show that a solar panel converts 30-40% of energy incident on it to electrical energy. A Maximum Power Point Tracking algorithm is necessary to increase the efficiency of the solar panel. There are different techniques for MPPT such as Perturb and Observe (hill climbing method), Incremental conductance, Fractional Short Circuit Current, Fractional Open Circuit Voltage, Fuzzy Control, Neural Network Control etc. Among all the methods Perturb and observe (P&O) and Incremental conductance are most commonly used because of their simple implementation, lesser time to track the MPP and several other economic reasons. Under abruptly changing weather conditions (irradiance level) as MPP changes continuously, P&O takes it as a change in MPP due to perturbation rather than that of irradiance and sometimes ends up in calculating wrong MPP[11]. However this problem gets avoided in Incremental Conductance method as the algorithm takes two samples of voltage and current to calculate MPP. However, instead of higher efficiency the complexity of the algorithm is very high compared to the previous one and hence the cost of implementation increases. So we have to mitigate with a tradeoff between complexity and efficiency. It is seen that the efficiency of the system also depends upon the converter. Typically it is maximum for a buck topology, then for buck-boost topology and minimum for a boost topology. When multiple solar modules are connected in parallel, another analog technique TEODI is also very effective which operates on the principle of equalization of output operating points in correspondence to force displacement of input operating points of the identical operating system. It is very simple to implement and has high efficiency both under stationary and time varying atmospheric conditions. MPPT algorithms are necessary because PV arrays have a non linear voltage-current characteristic with a unique point where the power produced is maximum [7]. This point depends on the temperature of the panels and on the irradiance conditions. Both conditions change during the day and are also different depending on the season of the year. Furthermore, irradiation can change rapidly due to changing atmospheric conditions such as clouds. It is very important to track the MPP accurately under all possible conditions so that the maximum available power is always obtained. In the past years numerous MPPT algorithms have been published [8]. They differ in many aspects such as complexity, sensors required, cost or efficiency. However, it is pointless to use a more expensive or more complicated

method if with a simpler and less expensive one similar results can be obtained. This is the reason why some of the proposed techniques are not used.

SOLAR CELL

Solar cells are the basic components of photovoltaic panels. Most are made from silicon even though other materials are also used. Solar cells take advantage of the photoelectric effect: the ability of some semiconductors to convert electromagnetic radiation directly into electrical current. The charged particles generated by the incident radiation are separated conveniently to create an electrical current by an appropriate design of the structure of the solar cell, as will be explained in brief below. For further details, the reader can consult references [4] and [10]. A solar cell is basically a p-n junction which is made from two different layers of silicon doped with a small quantity of impurity atoms: in the case of the n-layer, atoms with one more valence electron, called donors, and in the case of the p-layer, with one less valence electron, known as acceptors. When the two layers are joined together, near the interface the free electrons of the n-layer are diffused in the p-side, leaving behind an area positively charged by the donors. Similarly, the free holes in the p-layer are diffused in the n-side, leaving behind a region negatively charged by the acceptors. This creates an electrical field between the two sides that is a potential barrier to further flow. The equilibrium is reached in the junction when the electrons and holes cannot surpass that potential barrier and consequently they cannot move. This electric field pulls the electrons and holes in opposite directions so the current can flow in one way only: electrons can move from the p-side to the n-side and the holes in the opposite direction. A diagram of the p-n junction showing the effect of the mentioned electric field is illustrated in Figure 1.
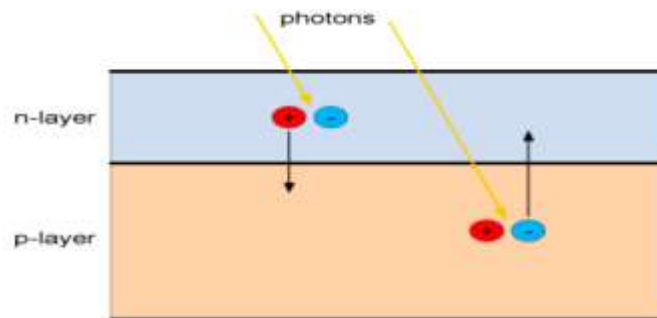

Figure 1 - Solar cell

Metallic contacts are added at both sides to collect the electrons and holes so the current can flow. In the case of the n-layer, which is facing the solar irradiance, the contacts are several metallic strips, as they must allow the light to pass to the solar cell, called fingers. The photons of the solar radiation shine on the cell. Three different cases can happen: some of the photons are reflected from the top surface of the cell and metal fingers. Those that are not reflected penetrate in the substrate. Some of them, usually the ones with less energy, pass through the cell without causing any effect. Only those with energy level above the band gap of the silicon can create an electron-hole pair. These pairs are generated at both sides of the p-n junction. The minority charges (electrons in the p-side, holes in the n-side) are diffused to the junction and swept away in opposite directions (electrons towards the n-side, holes towards the p-side) by the electric field, generating a current in the cell, which is collected by the metal contacts at both sides. This can be seen in the figure above, Figure 1. This is the light-generated current which depends directly on the irradiation: if it is higher, then it contains more photons with enough energy to create more electron-hole pairs and consequently more current is generated by the solar cell.
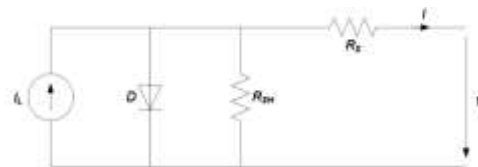

Figure 2 - Equivalent circuit of a solar cell

The solar cell can be represented by the electrical model shown in Figure 2. Its current-voltage characteristic is expressed by the following equation (1)

$$I = I_{pv}N_p - I_{ds}\,N_p\left[exp\left(\frac{(qV + IR_s)}{\beta V_t}\right) - 1\right] - \frac{V + IR_s}{R_{sh}}$$

Where ,
I = Cell current(A) N_P = Number of solar cell connected in parallel
I_{PV} = Photon current R_S = Series Resistance (ohm) R_{Sh} = Shunt Resistance (ohm)

DIODE FORWARD BIAS CURRENT IS GIVEN BY:
$I_d = I_{ds}\,[exp(qV/\beta kT)\text{-}1]$
          Where I_d = Diode forward biased current (A), q = charge of electron (coulomb)
           k = Boltzmann's constant ,   T= Cell temperature (K)
           I_{ds}= Diode saturation current , V= Diode voltage , β = Diode quality factor

MAXIMUM POWER POINT TRACKING ALGORITHMS

MPPT algorithms are necessary in PV applications because the MPP of a solar panel varies with the irradiation and temperature, so the use of MPPT algorithms is required in order to obtain the maximum power from a solar array. Over the past decades many methods to find the MPP have been developed and published. These techniques differ in many aspects such as required sensors, complexity, cost, range of effectiveness, convergence speed, correct tracking when irradiation and/or temperature change, hardware needed for the implementation or popularity, among others. A complete review of 19 different MPPT algorithms can be found in [8]. Among these techniques, **the P&O** and **the InCond algorithms** are the most common. These techniques have the advantage of an easy implementation but they also have drawbacks, as will be shown later. Other techniques based on different principles are fuzzy logic control, neural network, fractional open circuit voltage or short circuit current, current sweep, etc. Most of these methods yield a local maximum and some, like the fractional open circuit voltage or short circuit current, give an approximated MPP, not the exact one. In normal conditions the V-P curve has only one maximum, so it is not a problem. The solar cell V-I characteristic is nonlinear and varies with irradiation and temperature. In general, there is a unique point on the V-I or V-P curve, called the Maximum Power Point (MPP), at which the entire PV system (array, converter, etc) operates with maximum efficiency and produces its maximum output power. The location of the MPP is not known, but can be located, either through calculation models or by search algorithms. Therefore Maximum Power Point Tracking (MPPT) techniques are needed to maintain the PV array's operating point at its MPP. There are a number of maximum power point tracking (MPPT) algorithms which track the optimal current and voltage in a changing environment. An MPPT technique is therefore used to maintain the PV array's operating point at its MPP.
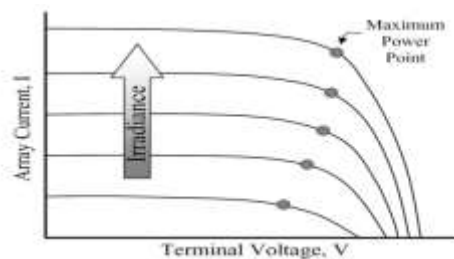

Figure 3 Maximum power point tracking

WHAT IS MPPT

MPPT is an algorithm that included in a charge controller for extracting maximum available power from PV module under certain condition. The voltage at which the PV module can produce maximum power is known as MPPT. Maximum power varies with solar radiation, ambient temperature and solar cell temperature.

WORKING PRINCIPLE OF MPPT

The major principle of MPPT is to extract the maximum available power from PV modules by making them operate at the most efficient voltage. MPPT checks output of PV module compares it to the battery voltage then fixes what is the best power that PV module can produce to charge the battery and converts it to the best voltage to get maximum current in the battery.

PV SYSTEM WITH MPPT CONTROL
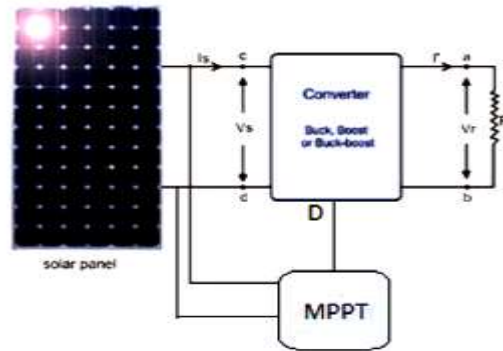
Figure 4 Configuration of PV System For MPPT

WHY MPPT IS REQUIRED
The MPPT controller in addition to perform the function of the basic controller which include a dc voltage converter, converting the voltage of the panel to that of the required by the battery, with practical no loss of power or in other words they attempt to keep the panel voltage at their MPP while supplying the varying voltage requirements of the battery.

DIFFERENT TRACKING METHODS OF MPPT
Many maximum power point tracking techniques for photovoltaic systems have been developed to maximize the produced energy and a lot of these are well established in the literature. These techniques vary in many aspects as: simplicity, convergence speed, digital or analogical implementation, sensors required, cost, range of effectiveness, and in other aspects. There are many MPPT methods available in the literature; the most widely-used techniques are described in the following sections, starting with the simplest method:
    [1] Hill climbing method
    [2] Perturb and Observe methods
    [3] Incremental Conductance methods

BOOST CONVERTER
A boost converter (step-up converter), as its name suggests steps up the input DC voltage value and provides at output. This converter contains basically a diode, a transistor as switches and at least one energy storage element. Capacitors are generally added to output so as to perform the function of removing output voltage ripple and sometimes inductors are also combined with.
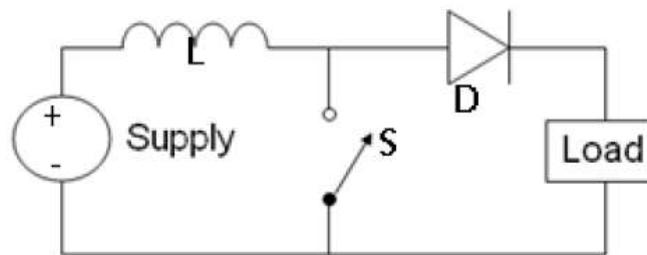
Figure 5 Schematic diagram of boost converter

Charging Mode
In this mode of operation; the switch is closed and the inductor is charged by the source through the switch. The charging current is exponential in nature but for simplicity is assumed to be linearly varying. The diode restricts the flow of current from the source to the load and the demand of the load is met by the discharging of the capacitor.

Discharging Mode
In this mode of operation; the switch is open and the diode is forward biased . The inductor now discharges and together with the source charges the capacitor and meets the load demands. The load current variation is very small and in many cases is assumed constant throughout the operation.
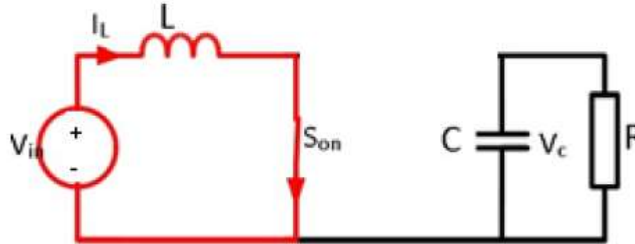
Equation involved

Figure 6(a) ON mode of boost converter

In a Boost Converter, During 'On' Mode:-

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

From KCL $\quad \frac{v_c}{R} + C\frac{dv_c}{dt} = 0$

In State Space form:-
$$\begin{bmatrix} \frac{di_L}{dt} \\ \frac{dv_C}{dt} \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ 0 & -\frac{1}{RC} \end{bmatrix} \begin{bmatrix} i_L \\ v_C \end{bmatrix} + \begin{bmatrix} \frac{1}{L} \\ 0 \end{bmatrix} v_{in} \; ; v_o = \begin{bmatrix} 0 & 1 \end{bmatrix} \begin{bmatrix} i_L \\ v_C \end{bmatrix}$$
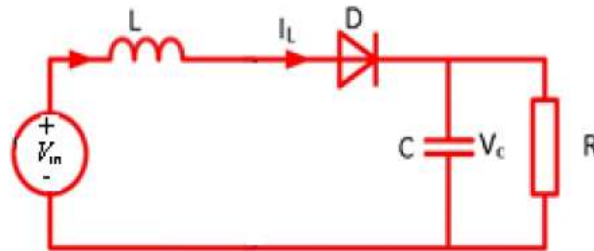
During 'OFF' Mode:-

Figure 6(b) Off mode of boost converter

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

From KCL $\quad i_L - \frac{v_c}{R} - \frac{Cdv_C}{dt} = 0$

In State Space form:-
$$\begin{bmatrix} \frac{di_L}{dt} \\ \frac{dv_C}{dt} \end{bmatrix} = \begin{bmatrix} 0 & -\frac{1}{L} \\ \frac{1}{C} & -\frac{1}{RC} \end{bmatrix} \begin{bmatrix} i_L \\ v_C \end{bmatrix} + \begin{bmatrix} \frac{1}{L} \\ 0 \end{bmatrix} v_{in} \; ; v_o = \begin{bmatrix} 0 & 1 \end{bmatrix} \begin{bmatrix} i_L \\ v_C \end{bmatrix}$$
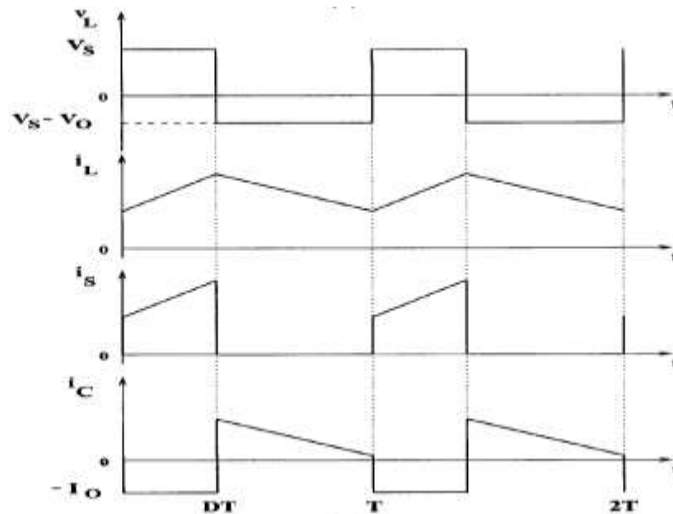
Waveforms

Figure 7 waveforms of boost converter

RESULTS

MATLAB/SIMULATION RESULTS OF MODELLING OF PV SYSTEM Table 1 :Electrical specification of PV module:

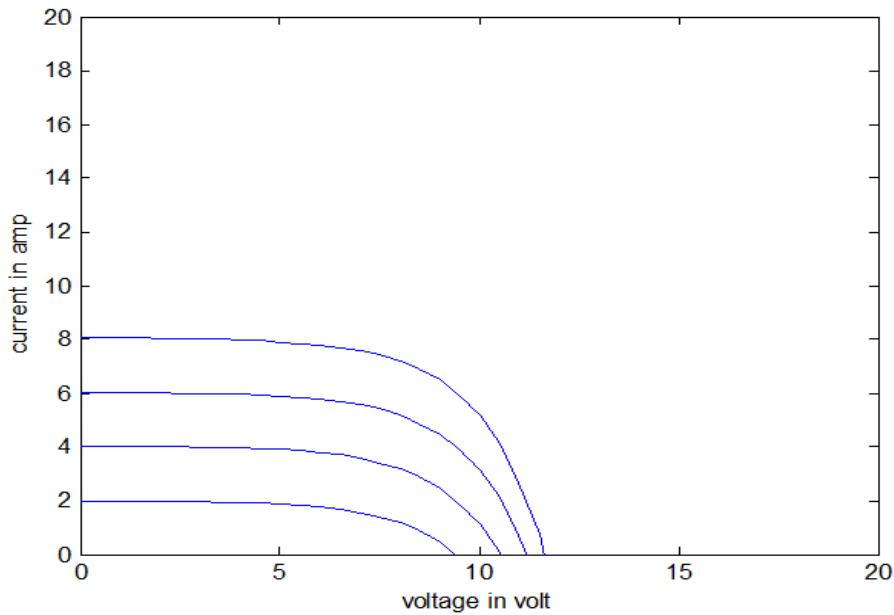| Parameters	value
Maximum power(Pm)	55 W
Short circuit current(Isc)	3.8 A
Open circuit voltage(Voc)	21.7 V

Enter the temperature 390

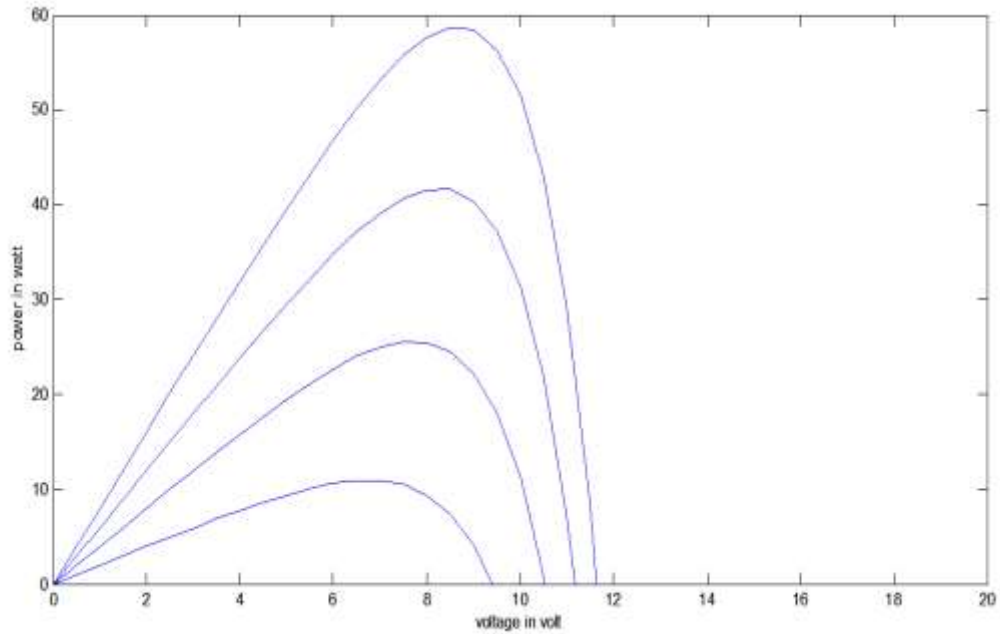*Figure 8 shows V-I curve of pv system*

Figure 9 shows V-P curve of pv system
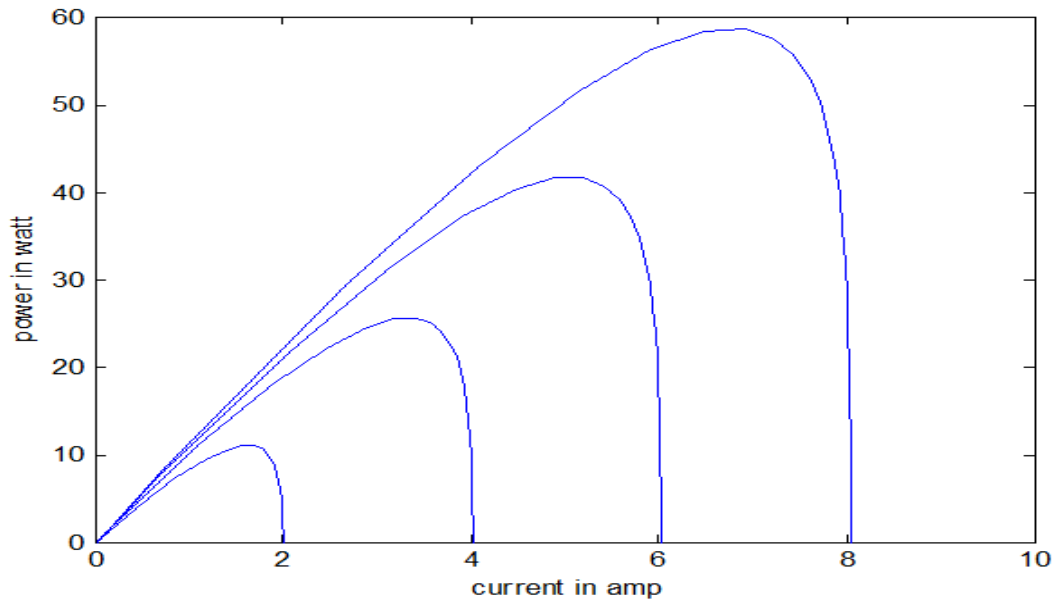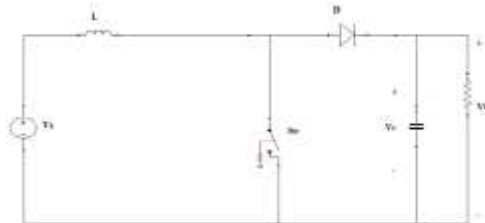

Figure 10 shows I-P curve of pv system

MATLAB/SIMULATION RESULTS OF MODELLING OF BOOST CONVERTER

L= Inductance value used   **C=** Capacitance value used
Son= ON state resistance of switch   RL= Load resistance
In this modelling, an ideal condition has been taken, with constant inputs. The MATLAB/SIMULATION RESULTS are:

Boost converter design specification: TABLE 2

| Design parameters	Ratings
Load	100W
Load current	4.7A
Desired output voltage	24V
On time(Ton)	50%
Off time(T off)	50%
Switching period(T)	50KHZ
Inductor current ripple(in percentage)	10%
Voltage ripple(in percentage)	10%
Input enter pv voltage	15
Input enter duty cycle	0.5
Input enter load resistence	16
Input inductance value of the filter	17
Input capacitance value of the filter	18
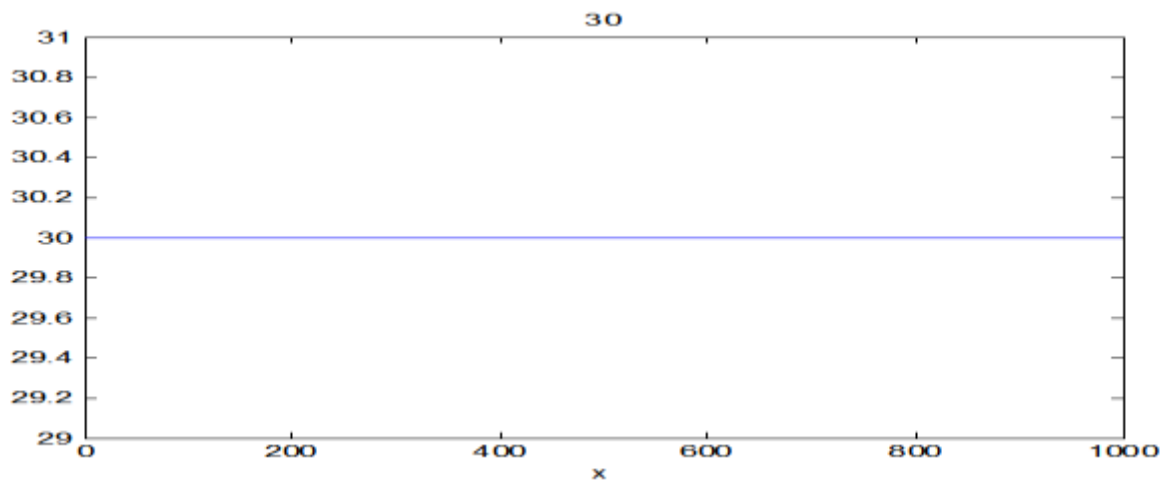
Figure 11 simulation result for the mathematical model of boost converter Simulation time veres Voltage
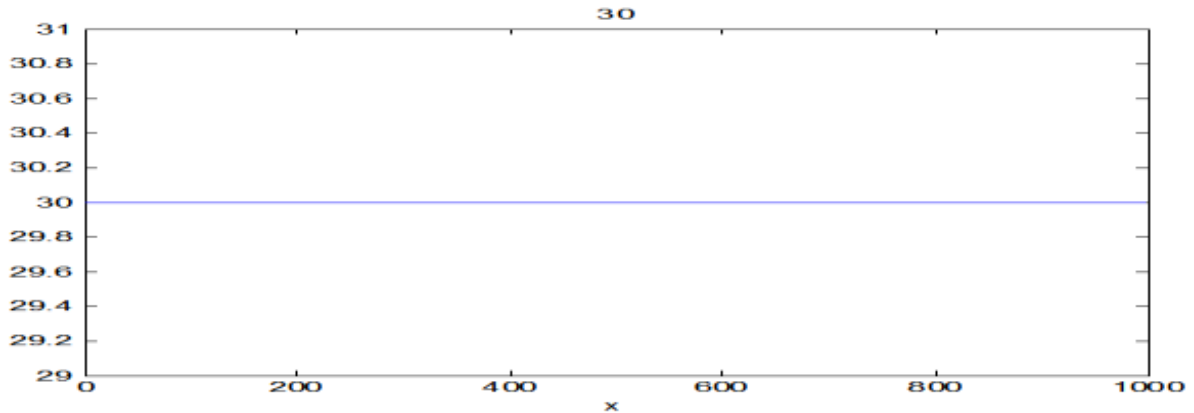
Figure 12 simulation result for the mathematical model of boost converter Simulation time veres current

CONCLUSION

In this paper, we study most of the MPPT algorithms which can find the real MPP were reviewed. For simplicity and effectiveness reasons, P&O, InCond, and FLC were selected for further analysis. The traditional P&O and InCond algorithms were proposed, which allow the hill-climbing algorithms to track the MPP even under changing irradiation and adapt the increment in the reference voltage to the operating point, as the variation of the MPP voltage is not linear. The dynamic efficiency measured according the standard was 99.4 %. It was concluded that the modified hill-climbing algorithms perform better than the FLC. it can be concluded that the best algorithm is the modified P&O. Its dynamic MPPT efficiency is similar to that of the modified InCond, but the P&O algorithm is simpler. MATLAB/SIMULATION of modeling of PV module is done, MATLAB/SIMULATION of modeling of boost converter is done

REFERANCE

[1] L. Piegari, R. Rizzo, "Adaptive perturb and observe algorithm for photovoltaic maximum power point tracking," Renewable Power Generation, IET, vol. 4, no. 4, pp. 317-328, July2010.

[2] N. Femia, G. Petrone, G. Spagnuolo, M. Vitelli, "Optimizing sampling rate of P&O MPPT technique," in Proc. IEEE PESC, 2004, pp. 1945- 1949.

[3] T. Esram, P.L. Chapman, "Comparison of Photovoltaic Array Maximum Power Point Tracking Techniques," IEEE Transactions on Energy Conversion, vol. 22, no. 2, pp. 439-449, June 2007.

[4] Overall efficiency of grid connected photovoltaic inverters, European Standard EN 50530, 2010.

[5] T. Markvart, Solar electricity, Wiley, 2000, p. 280.

[6] G. M. S. Azevedo, M. C. Cavalcanti, K. C. Oliveira, F. A. S. Neves, Z. D. Lins, "Evaluation of maximum power point tracking methods for grid connected photovoltaic systems," in Proc. IEEE PESC, 2008, pp. 1456-1462.

[7] "BP Solar limited warranty certificate", BP Solar, 2010. http://www.bp.com/liveassets/bp_internet/solar/bp_solar_usa/STAGING/local_assets/downloads_pdfs/2010_Warranty.pdf.

[8] Norjasmi Bin Abdul Rahman, "Inverter Topologies for Photovoltaic Systems", Master's Thesis, Dept. Electrical Engineering, Aalto University School of Science and Technology, Espoo, Finland, 2010.

[9] Tat Luat Nguyen, Kay-Soon Low, "A Global Maximum Power Point Tracking Scheme Employing DIRECT Search Algorithm for Photovoltaic Systems," IEEE Transactions on Industrial Electronics, vol. 57, no. 10, pp. 3456-3467, Oct. 2010.

[10] D. Sera, T. Kerekes, R. Teodorescu, F. Blaabjerg, "Improved MPPT Algorithms for Rapidly Changing Environmental Conditions," in Proc. 12th International Conference on Power Electronics and Motion Control, 2006, pp. 1614-1619.

[11] D. Sera, T. Kerekes, R. Teodorescu, F. Blaabjerg, "Improved MPPT method for rapidly changing environmental conditions," in Proc. IEEE International Symposium on Industrial Electronics, 2006, vol. 2, pp. 1420-1425.

[12] N. Femia, G. Petrone, G. Spagnuolo, M. Vitelli, "Optimization of perturb and observe maximum power point tracking method," IEEE Transactions on Power Electronics, vol. 20, no. 4, pp. 963-973, July 2005.

[13] K.H. Hussein, I. Muta, T. Hoshino, M. Osakada, "Maximum photovoltaic power tracking: an algorithm for rapidly changing atmospheric conditions," IEE Proceedings on Generation, Transmission and Distribution, vol. 142, no. 1, pp. 59-64, Jan 1995.

[14] C. Zhang, D. Zhao, J. Wang, G. Chen, "A modified MPPT method with variable perturbation step for photovoltaic system," in Power Electronics and Motion Control Conference, 2009, pp. 2096-2099.

[15] W. Xiao, W. G. Dunford, "A modified adaptive hill climbing MPPT method forphotovoltaic power systems," in Proc. IEEE PESC, 2004, pp. 1957-1963.

[16] S. Jain, V. Agarwal, "Comparison of the performance of maximum power point tracking schemes applied to single-stage grid-connected photovoltaic systems," Electric Power Applications, IET, vol. 1, no. 5, pp. 753-762, Sept. 2007.

[17] P. Midya, P. T. Krein, R. J. Turnbull, R. Reppa, and J. Kimball, "Dynamic maximum power point tracker for photovoltaic applications," in Proc. 27th Annual IEEE Power Electronics Specialists Conference, 1996, pp. 1710-1716.

[18] N. Patcharaprakiti, S. Premrudeepreechacharn, "Maximum power point tracking using adaptive fuzzy logic control for grid-connected photovoltaic system," in Proc. IEEE Power Engineering Society Winter Meeting, 2002, pp. 372-377.

[19] Chao Zhang, Dean Zhao, "MPPT with asymmetric fuzzy control for photovoltaic system," in Proc. 4th IEEE Conference on Industrial Electronics and Applications, 2009, pp. 2180-2183.

[20] J. Li, H. Wang, "Maximum power point tracking of photovoltaic generation based on the fuzzy control method," in Proc. International Conference on Sustainable Power Generation and Supply, 2009, pp. 1-6.

[21] T. Noguchi, S. Togashi, R. Nakamoto, "Short-current pulse-based maximum-power-point tracking method for multiple photovoltaic-and-converter module system," IEEE Transactions on Industrial Electronics, vol. 49, no. 1, pp. 217-223, Feb 2002.

[22] S. Yuvarajan, S. Xu, "Photo-voltaic power converter with a simple maximum-power-point-tracker," in Proc. International Symposium on Circuits and Systems, 2003, vol. 3, pp. 399-402.

[23] B. Bekker, H. J. Beukes, "Finding an optimal PV panel maximum power point tracking method," in Proc. 7th AFRICON Conference in Africa, 2004, vol. 2, pp. 1125-1129.

[24] M. Bodur, M. Ermis, "Maximum power point tracking for low power photovoltaic solar panels," in Proc. 7th Mediterranean Electrotechnical Conference, 1994, vol. 2, pp. 758-761.

[25] E. V. Solodovnik, S. Liu, and R. A. Dougal, "Power Controller Design for Maximum Power Tracking in Solar Installations," IEEE Transactions in Power Electronics, vol. 19, pp. 1295-1304, Sept. 2004.