A Novel Approach for Maximum Power Point Tracking in Photovoltaic System

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Abstract: The output power from the solar panel varies with solar irradiance level, temperature and load. In order to increase the efficiency of power extracted from the solar panel, it is necessary to operate the photovoltaic (PV) system near the maximum power point (MPP). There are different types of maximum power point tracking (MPPT) methods. This paper proposes a novel approach for tracking MPP. In this approach it tracks the MPP using normal perturb and observation method, the current-voltage curve corresponding to each MPP is obtained and stored. Whenever a new single data value is read, the algorithm finds which curve has maximum points nearest to the new value and assigns the voltage corresponding to the curve's MPP.

Keywords: MPPT, PV, MPP, Boost-converter, Lab VIEW.

I. INTRODUCTION

Renewable energy sources such as solar energy, wind energy are gaining more attention due to impacts and shortage of conventional fuels in environment. Concentrating on solar power, it can contribute much to the world's energy requirement.

Photovoltaic systems produce DC electricity when sunlight falls on the PV array. The DC power generated can be converted to AC power with an inverter which is used in many applications such as battery charging, water pumping, street lighting etc. Solar PV systems can be categorized as stand- alone PV systems and grid connected PV systems. Stand-alone systems are not connected with utility power lines and these are self-sufficient systems. A grid connected PV system will be interacted with utility grid. The advantage is that power can be drawn from the utility grid and when the power is not available from grid PV system can supplement that power. Currently solar panels are not very efficient in their ability to convert sunlight to electrical power; efficiency can drop further due to factors such as solar irradiation, temperature and load conditions. In order to maximize the power derived from the solar panel it is necessary to operate the panel at its MPP, to achieve the same maximum power point tracking is used. The setup consists of sensors to read the array output, an MPPT algorithm to track the MPP and hardware that can provide the input impedance to maintain the operation at the MPP. The algorithm part is performed in PC (Lab VIEW software) or a controller.

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There are many MPPT algorithm discussed in different papers. This paper proposes a new approach for tracking MPP. In this algorithm the MPP is tracked using perturb and observation method. The current-voltage curve corresponding to each MPP obtained is stored. Whenever a new single data value is given to the algorithm, it finds which curve has the maximum number of points nearest to the new value and assigns the voltage corresponding to the curve's MPP. With the new algorithm, it is expected to improve the tracking speed and accuracy of the MPPT system when compared to normal MPPTs.

II. PV MODELLING AND CHARACTERISTICS

A. PV Modelling

Solar cells have non-linear current-voltage characteristics and are dependent on solar irradiation and temperature. A solar cell can be modeled by a current source in parallel with a diode, as in Fig.1.

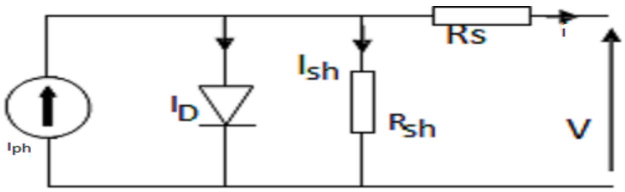

Fig. 1 Equivalent Circuit of a Solar Cell

Series resistance RS represent internal losses due to the current flow. Shunt resistance RSH corresponds to the leakage current to the ground. The mathematical model which relates the output current to the output voltage of solar cell is given by equation (1).

$$I = I_{PH} - I_D - I_{SH} \quad (1)$$

On expanding (1), we obtain

$$I(S,T,V) = I_{PH}(S) - I_{RS}(T)\left[exp\left(\frac{V+R_S I}{mV_T}\right) - 1\right] - \frac{V+R_S I}{R_{SH}} \quad (2)$$

$$V_T(T)=\frac{kT}{q} \quad (3)$$

$$I_{PH}(S) = [I_{SC} + k_i(T-T_R)]\frac{S}{S_R} \quad (4)$$

$$I_{RS} = I_{RR}\left(\frac{T}{T_R}\right)^3 exp\left(\frac{\varepsilon q}{mk}\left(\frac{1}{T_R}-\frac{1}{T}\right)\right) \quad (5)$$

$$I_{RR} = \frac{I_{SC}}{\left(exp\left(\frac{qV_{OC}}{kmT}\right)-1\right)} \quad (6)$$

Where the symbols are defined as following varying atmospheric conditions

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IPH : photocurrent, generated by the PV conversion process.
ID : reverse saturation current of diode.
IR : reverse saturation current is a loss in the conversion process due to a reverse current which flows through the diode.
I : cell output current.
V : cell output voltage.
VT : thermal voltage for a given temperature in Kelvin.
IRR : reverse saturation current at the reference temperature.
ISC : cell short-circuit current. VOC : cell open – circuit voltage.
k : Boltzmann constant (1.39×10^{-23} J/K). q: Electron charge(1.6×10^{-19}C).
m : PN junction ideality factor.
 : band gap energy of the semiconductor used to manufacture the cell(1.12 eV for silicon).
ki : temperature coefficient of ISC(1.2 mA/^{0}c). S : solar irradiation, W/m^2.
T : temperature, K.
SR : reference level of solar irradiation(1000 W/m^2).
TR : reference temperature(25^{0}c).

Assuming RS is sufficiently low and RSH is sufficiently high (2) can be simplified to obtain (7).

$$I(S,T,V) = I_{PH}(S) - I_{RS}(T)\left(exp\left(\frac{V}{mV_T(T)}\right) - 1\right)(7)$$

B. PV Characteristics

The current-to-voltage characteristic of a solar cell is non-linear and is dependent on insulation and cell temperature. A smaller irradiance will result in reduced power output from the solar panel and is shown in fig.2. It is observed from fig.3 that the terminal voltage increases with decreasing temperature. The irradiance mainly affects the output current whereas temperature mainly affects the terminal voltage. The maximum power point has to be determined by calculating the product of the voltage and the output current due to the non-linear characteristics of the solar panel. In order to extract maximum power from the solar cell, the latter must always be operated at or very close to where the product of the voltage and output current is measured the highest. This point is referred to as the maximum power point (MPP) which is located around the knee of the I-V characteristics. It is clear from Fig.2 and Fig.3 that maximum power point is different for each combination of solar irradiation and temperature. Therefore, it is necessary to continuously track the MPP for varying atmospheric conditions.

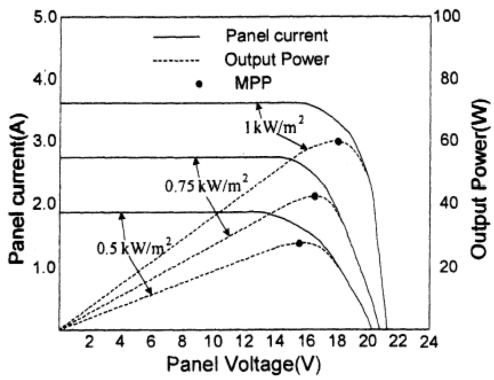

Fig. 2 Insolation Characteristics of Solar Panel

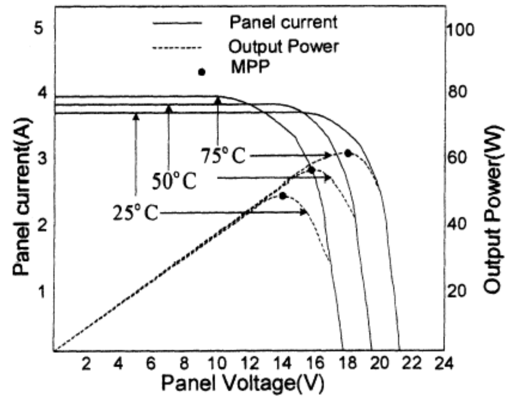

Fig. 3 Temperature Characteristics of Solar Panel

III. DC-DC CONVERTER AND BLOCK REPRESENTATION

MPPT is used to control the PV panel at its MPP and is a high-efficiency DC-DC converter which functions as an optimal electrical load for a solar array. In this paper, a boost-converter has been used as DC-DC converter. A boost converter provides an output voltage greater than input voltage. It provides impedance matching between the solar array and load to aid maximum power transfer from source to load. By adjusting the duty cycle, the gain and impedance provided by boost converter circuit can be varied. Practically, the MPPT algorithm reads the panel voltage, load voltage and load current, then it tracks the MPP. Based on the values of voltage and current for particular MPP, it calculates the duty cycle to achieve the same values in practical.

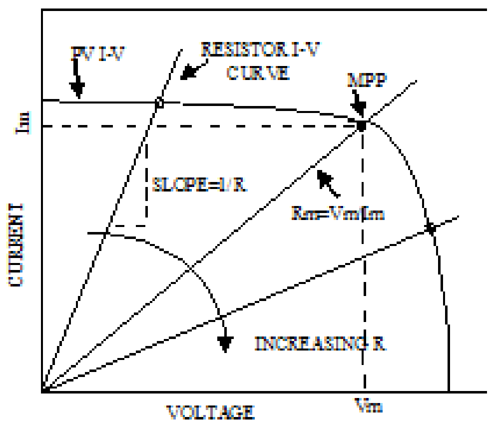

Fig. 4 Operating points moves with resistance changes on I-V curve

Block representation of the MPP tracker is depicted in Fig.5. In this system, the MPPT algorithm part can be implemented in PC or microcontroller. In PC, Lab VIEW software can be used to realize the algorithm. The panel output is fed as input to both boost converter and algorithm. Output of boost converter is fed as input to the load and the algorithm. PWM output generated by the algorithm is used to control the on-off time of boost converter.

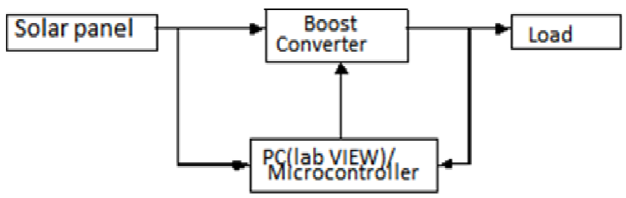

Fig. 5 Block Diagram of MPPT System

IV. MAXIMUM POWER POINT TRACKING METHODS

The most important part of the system is the control algorithm. There are various types of algorithms such as perturb and observation method, incremental conductance method, dither routine algorithm, global search algorithm etc. Perturb and observation is the most used method in MPPT systems because of its simplicity. The panel terminal voltage is perturbed and compared with previous power point by periodically. As the perturbation is applied continuously, an oscillation occurs around the maximum power point which acts as a disadvantage. In incremental conductance method, the panel terminal voltage is changed with respect to its value relative to the maximum power point voltage. This method is independent of the solar panel characteristics.

The improved MPPT methods are discussed in several papers. A learning-based KNN MPP tracking method [1] for rapidly changing atmospheric conditions, modified perturb & observe, estimate-perturb-perturb method [2], three-point weight comparison method [3] as an improvement on normal P&O, delta adaptive method [4] as an improvement on incremental conductance, second power derivative and harmonic approach [5] with increased tracking speed, MPPT by matching impedance [6], dynamic approach by ripple correlation [7] and fuzzy-based MPP tracker [8] are some of them.

V. PROPOSED NEW METHOD

During rapidly changing atmospheric conditions, the MPP also varies rapidly by a large value. In case of normal MPPT algorithms, the tracking speed is very low as they are making fixed size adjustments to the operating voltage. The proposed new algorithm is a learning based algorithm. The goal of the algorithm is to improve the tracking speed of MPPT system. In this algorithm using perturbation and observation method, MPPs for different situations is found and the corresponding set of voltage and current for each situation is stored as separate curves. Whenever a new point is read the algorithm calculates the Euclidean distance of the point to the already stored points in each curve, then finds the shortest distance among all the obtained distances. Then it counts the number of points in each curve with distance less than (shortest distance+ delta distance). The voltage corresponding to MPP of the curve which is having maximum number of points within the above specified distance is assigned to Vo. The algorithm consists of four states ‗ PO_TRACK, STORE_CURVE, WATCH, and CURVE_TRACK.

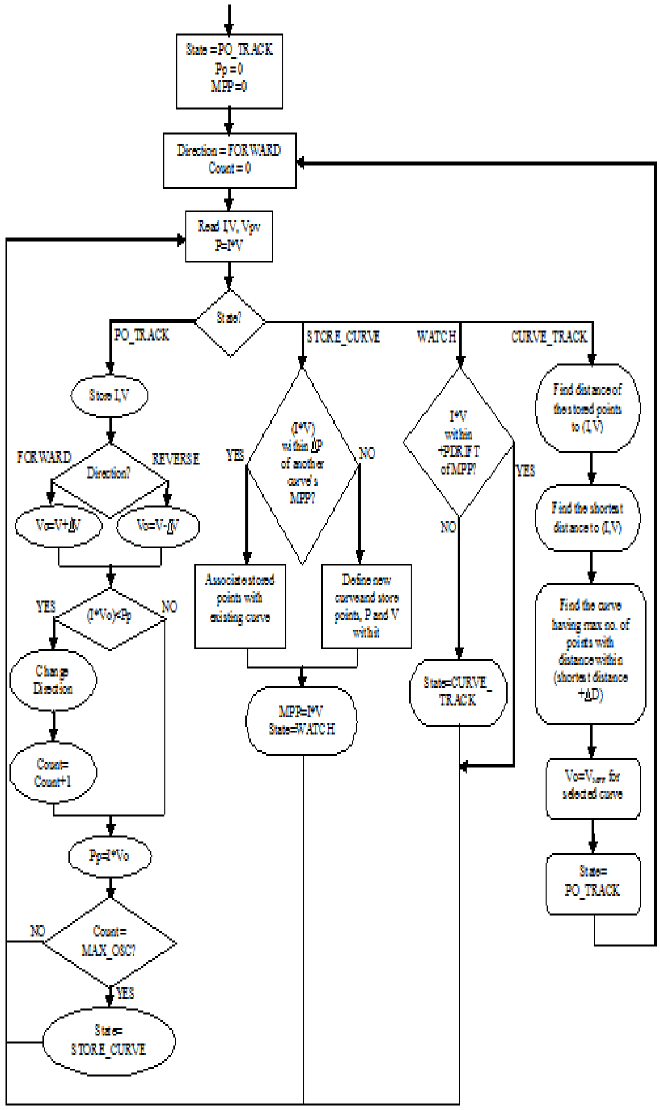

Fig. 6 Flowchart for the proposed new minimum Euclidean distance neighbors algorithm for MPPT

In the state PO_TRACK, the current-voltage-power values are stored, followed by normal tracking process by incrementing the voltage by a small value and comparing the resulting power to the previously obtained power. If the resulting power is less than the previous power then tracking is done in the same direction else it will be conducted in the opposite direction. As the MPP is reached, there is oscillation around the point due to the nature of algorithm. This is a disadvantage of perturbation and observation algorithm. Exploiting this feature if the number of oscillations reaches a value MAX_OSC then it changes the state to STORE_CURVE. In the state STORE_CURVE, the MPP obtained from previous state of tracking is compared to the already stored curve's MPPs. If the MPP falls within a range of $\pm$P of any of the previously stored curve's MPP then obtained points is associated with existing curve, else a new curve is defined. In the state WATCH, the algorithm waits till the power of the solar panel changes by more than a value PDFRIFT.

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If panel output power changes by more than PDRIFT then it enters the state CURVE_TRACK. In this state, it assigns the voltage corresponding to the MPP of the curve which has the maximum possibility to contain the new point to Vo. Thus it will take less time to track the MPP.

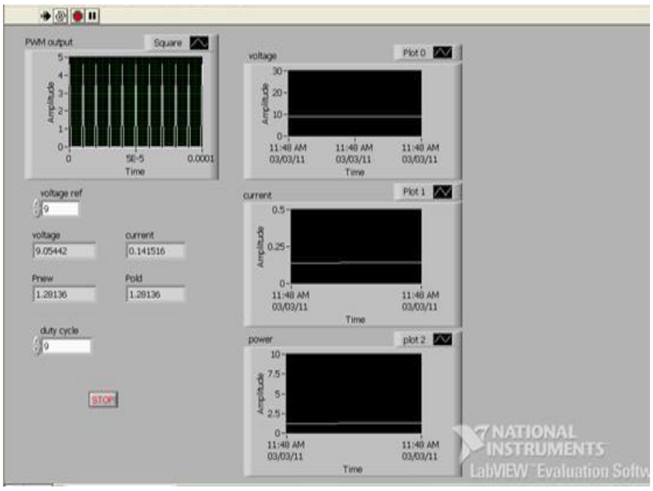

Fig. 7 Graph obtained using Lab VIEW Software

VI. CONCLUSION

In this paper, a novel minimum distance neighbor's algorithm for maximum power point tracking of solar panels has been proposed. Under rapidly changing atmospheric conditions ,the new algorithm is expected to provide improved and more accurate MPP tracking when compared to normal tracking methods such as perturb and observation algorithm, incremental conductance algorithm, Dither-Routine algorithm and KNN tracking method. The algorithm is expected to track the MPP faster. To address some shortcomings of the algorithm further work is required. To select the best combination of parameters for the algorithm, more closely examining of the real-time operation of the system is to be done. Hardware consisting of voltage sensor, current sensor and boost converter is done. At present Lab VIEW is used to carry out the proposed approach. In future it is planned to develop the system as an embedded system to charge a battery, using ARM7 microcontroller. The new algorithm will be loaded into the microcontroller and the microcontroller will be designed to operate on the power supplied from the panel itself.

REFERENCES

1. L.MacIssac, A.Knox, "Improved Maximum Power Point Tracking Algorithm for Photovoltaic Systems" International Conference on Renewable Energies and Power Quality(ICREPQ'10), Granada (Spain),23rd to 25th March 2010.
2. A. Yafaoui., B. Wu and R. Cheung, "Implementation of maximum power point tracking algorithm for residential photovoltaic systems", 2nd Canadian Solar Buildings Conference Calgary, June 10 – 14, 2007.
3. Joe-Air Jiang, Tsong-Liang Huang, Ying-Tung Hesiao and Chia-Hong Chen, "Maximum Power Tracking for Photovoltaic Power Systems", Tamkang Journal of Science and Engineering, Vol. 8, No 2,pp. 147153 (2005).
4. J. Kouta, A. El-Ali, N. Moubayed and R. Outbib, "Improving the incremental conductance control method of a solar energy conversion system".
5. S. Armstrong, W.G. Hurley, "Self-regulating Maximum Power Point Tracklng for Solar Energy Systems" IEEE.
6. Tun-Ping Teng, Hwa-Ming Nieh, Jiann-Jyh Chen, Yu-Cheng Lu, "Research and development of maximum power transfer tracking system for solar cell unit by matching impedance", Renewable Energy (2009), doi: 10.1016/j.renene.2009.09.001,ww.elsevier.com/locate/renene.
7. Pallab Midya, Philip T Krein, Robert J Turnbull, Robert Reppa, Jonathan Kimball, "Dynamic Maximum Power Point Tracker for Photovoltaic Applications", 1996 IEEE.
8. A. Chouder, F. Guijoan and S. Silvestre"Simulation of fuzzy-based MPP tracker and performance comparison with perturb & observe method", Revue des Energies Renouvelables Vol. 11 N°4 (2008) 577 – 586.