International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-8 Issue-10, August 2019

Efficient Perturb and Observe Algorithm for Photovoltaic Maximum Power Point Tracking and Drift Avoidance using SEPIC Converter

Yogesh Y. Katdare, Pranita Chavan, Dhananjay Borse

Abstract: ***Maximum power point tracking is a commonly used technique for extracting maximum possible power from solar photovoltaic (PV) systems under all conditions. Various methods used for implementation of MPPT algorithm, out of those methods, perturb and observe (P&O) is very popular and commonly using method owing to its simplicity, easy implementation and highly efficient nature. However, P&O algorithm has disadvantage that it suffers from drift phenomenon in which during sudden change in atmospheric conditions, the algorithm drifts away from the maximum power point (MPP). This paper proposes modifications in the conventional P&O algorithm to overcome the drifting of MPP during suddenly changing atmospheric conditions. This algorithm takes change in current into consideration along with change in voltage and power and is verified using MATLAB/Simulink. DC/DC control is achieved using SEPIC converter and simulation results of the proposed algorithm show that the system can track the MPP in transient whether conditions and drifting is avoided.***

Index Terms: ***Maximum Power Point Tracking (MPPT), Perturb and Observe (P&O), PV, drift phenomenon, SEPIC Converter, MATLAB/Simulink***

I. INTRODUCTION

A solar PV system offers several promising advantages over conventional power generation sources which include reduction in carbon footprint, low cost, clean source of energy and is widely abundant in most of the parts of globe. The drawbacks associated with electricity generation using PV systems are: low efficiency under low irradiation and fluctuating power output according to weather conditions. Major factors which affect PV power generation are temperature and irradiation.

For improving efficiency of solar PV systems, several methods are put forward. These methods are nothing but the algorithms used to extract maximum power from solar PV array. For this reason these methods are also called as Maximum Power Point Tracking (MPPT) Algorithms. Some well-known and commonly used algorithms are Perturb & observe, Incremental Conductance, Open Circuit etc. Out of these algorithms, Perturb and observe algorithm is the most popular for achieving MPPT. The reason behind this is it is quiet easy to implement, its operation is simple and it is highly efficient. It works on the principle that, perturbation of voltage and power in any direction in such a way that operating point should follow the direction where power drawn from PV system is maximum. [1] – [9]

In the similar way, by reduction in the Power output by perturbation, the perturbation direction of power or voltage gets reversed to achieve maximum power point. Simply speaking, this algorithm makes system to oscillate around maximum power point.

Changing atmospheric conditions badly affect the performance of P&O algorithm. This affected performance results into drift, in which operating point drifts away from maximum power point. The speed of insolation change decides drift movement. In this paper, analysis of drift pattern is done. Also paper presents solution for drift problem by including one parameter (dI) which is called ‘change in current’ in traditional Perturb & Observe algorithm. This modification gives rise to new modified algorithm which is called as ‘Modified Perturb & Observe MPPT Algorithm.’ Modelling of Photovoltaic array and SEPIC dc-dc converter is conducted in section II & III respectively. In section IV traditional Perturb & Observe Algorithm is discussed along with flowchart. In section V modified Perturb & Observe Algorithm is explained along with its drift free nature. Simulation model along with results is discussed in section VI. Conclusions are summarized in section VII.

II. MATHEMATICAL MODELLING OF PV ARRAY

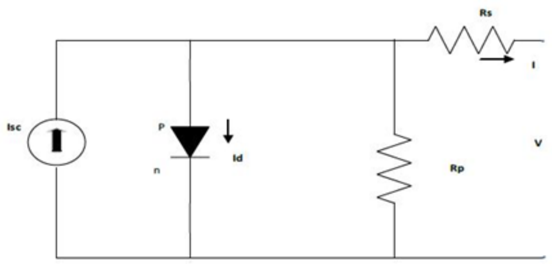

Fig. 1 Equivalent circuit of PV cell

Above fig. 1 shown equivalent circuit of PV cell. I_{Ph} is a current source which is photocurrent of PV cell. It is actually current given by PV cell when light energy falls on it. Intrinsic parallel resistance is represented by R_{sh}, while series resistance is represented by R_s. Normally $R_{sh} >> R_s$. This is basically single cell which cannot produce much larger current and voltage which may become useful for Electrical Power applications.

Manuscript published on 30 August 2019.
*Correspondence Author(s)
Mr. Yogesh Yashwant Katdare, Department of Electrical Engineering, Mumbai University, VPM’s Maharshi Parshuram College of Engineering, Velneshwar, Maharashtra, India
Mrs. Pranita Chavan, HOD, Electrical Engineering Department, Pillai HOC College of Engineering, Rasayani, Mumbai University, Maharashtra, India
Mr. Dhananjay Borse, R&D department, Radium Engineering, Bavdhan, Pune, Maharashtra, India.

© The Authors. Published by Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP). This is an open access article under the CC-BY-NC-ND license http://creativecommons.org/licenses/by-nc-nd/4.0/

Therefore multiple solar cells are grouped in series and parallel fashion to produce large unit which is termed as solar PV arrays. PV array is electrically represented by following equivalent circuit shown in fig.2. [10]

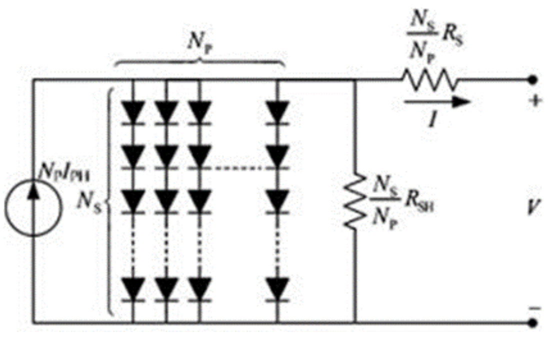

Fig. 2 Photovoltaic array equivalent circuit

The various current equations of solar cell are as under [10]:

I_{ph}: (Solar module photo current)

$I_{ph} = [I_{sc} + K_i(T - 298)] \times I_r / 1000$ (1)

I_{sc} is current supplied by cell under short circuit condition

I_r is solar irradiation

T is temperature of atmosphere in Kelvin (K).

reverse saturation current of Solar module is I_{rs}:

$I_{rs} = [I_{sc} / \exp(qV_{OC} / N_s k_n T) - 1]$ (2)

Here, q is charge on single electron = 1.6×10^{-19} C,

V_{oc} is voltage across the module under no load or open circuit condition

N_s is number of series connected cells; n: diode ideality factor,

k: Boltzmann's constant = 1.3805×10^{-23} J/K

III. SEPIC CONVERTER

SEPIC means Single-ended primary-inductor converter which is basically a dc to dc converter. It can either step up or step down the output voltage than input voltage. This can be achieved by adjusting 'duty cycle' of switching device of SEPIC converter. Generally MOSFET or Transistor can be used as a switching device of SEPIC converter. [11].

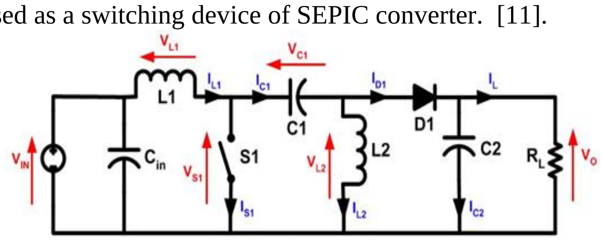

Fig. 3 SEPIC converter circuit diagram

From fig. 3 it is clear that SEPIC converter can exchange energy amongst its components (capacitors, inductors) by which it can convert input voltage into output as per requirement. Magnitude of output voltage is adjusted by 'duty cycle.'

Under normal operating condition input voltage V_{in} gets as it is applied across the capacitor C1. Capacitor C1 block DC current, so Ic1 must have to be zero. Under such condition, inductor L2 can only provide load current to the output. Average value of this current through inductor L2 is represented by IL2 which itself average load current. It does not depend on input voltage.

Average input voltage equation is given by,

$$V_{IN} = V_{L1} + V_{C1} + V_{L2} \quad (3)$$

And current equation by,

$$I_{D1} = I_{L1} - I_{L2} \quad (4)$$

Power supply internal resistance is reduced by capacitor C_{in}. It also reduces parasitic inductance effect. Inductor L2 and capacitor C1 play vital role in deciding whether output voltage is less than or greater than input voltage.

IV. TRADITIONAL MPPT ALGORITHM BASED ON P&O

P&O algorithm is a very popular and advantageous MPPT technique [1] - [5]. It can operate with very less number of parameters. Its structure is very easy and simple. Following Fig. 4 shows conventional P&O algorithm flowchart.

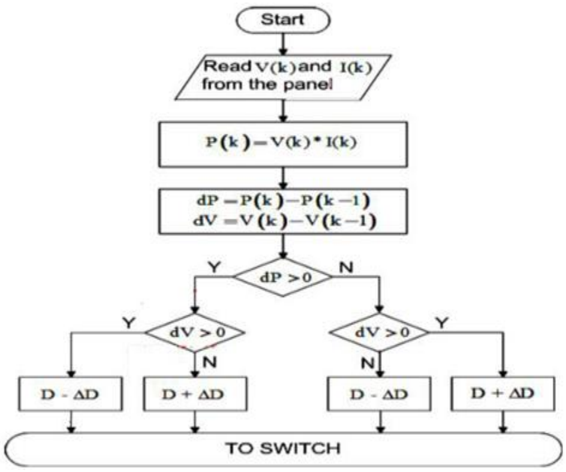

Fig. 4 Traditional P&O Algorithm Flowchart

Terminal voltage of PV array is perturbed periodically and compared with PV output power of previous cycle. ΔD get added or subtracted from the duty cycle depending on whether PV power and voltage has increased or decreased in that given time so as to achieve MPP point.

A. Three Levels of Steady State Operation

It is assumed that operating point moves from point 1 to 2 then algorithm has to decide the new position by considering dP and ΔV. dP is difference between P2 and P1. And ΔV is difference between V2 and V1. Both these differences are nonzero positive, that's why algorithm moves operating point to 3. This can be achieved by decreasing duty cycle. At this new position, now P3 becomes less than P2, so dP becomes negative, but ΔV is still positive. So operating point again goes back to position 2. This is achieved by increasing duty cycle.

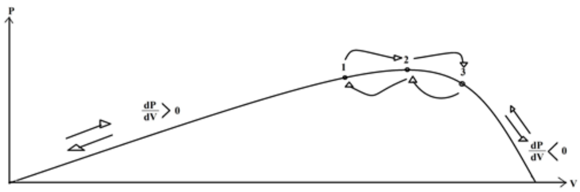

Fig. 5 Three level operation under steady state condition

Retrieval Number: J88040881019/19©BEIESP
DOI: 10.35940/ijitee.J8804.0881019
Journal Website: www.ijitee.org

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)
© Copyright: All rights reserved.

B. Study of Drift Phenomenon

Drift problem becomes dominant because of increment in insolation. This is major disadvantage of conventional P&O algorithm. Because of this, algorithm becomes unsuccessful to achieve maximum Power Point, as it cannot choose proper maximum power point, instead of that it chooses wrong operating point. The overall result of this is decrease in overall efficiency in the system as system losses increase. Fig. 6 shows how exactly drift occurs.

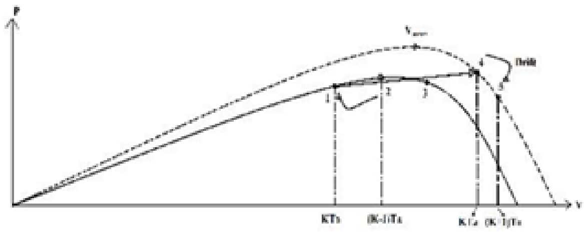

Fig. 6 Drift Analysis

As the information on increase in power (dP > 0) may be wrongly interpreted as it is difficult to confirm whether it is due to insolation or perturbation. Assume that insolation increases while 1 is currently operating point. Algorithm decides new operating point at 4. This point is on new insolation curve. At this point change in power and change in voltage both are positive. So that duty cycle will be reduced and again new operating point gets shifted to point 5. This point 5 is not MPP, but far away from it. This phenomenon is called as drift.

V. PROPOSED MPPT ALGORITHM BASED ON P&O FOR DRIFT AVOIDANCE

Problem of conventional P&O algorithm is occurrence of drift during rapidly changing atmospheric conditions. It is eliminated in modified perturb and observe algorithm by including ‘dI.’ The new operating point can be identify by V-I characteristics of PV module shown in fig. 7.

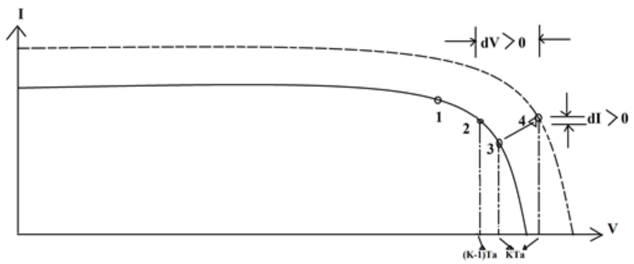

Fig. 7 Change in current due to Drift

From Above characteristics it can be concluded that for single insolation, change in voltage and change in current will never have same polarity. If insolation is increasing, they both will be positive. Hence ΔV and dI used together for drift elimination and achieving operating point more and more closer to maximum power point. Fig. 8 shows flowchart for this drift free modified perturb and observe algorithm. This algorithm solves problem of drift which was in conventional perturb and observe algorithm. It is done by incorporating dI. From fig. 9 & 10 it is clear that this algorithm gives drift free operation.

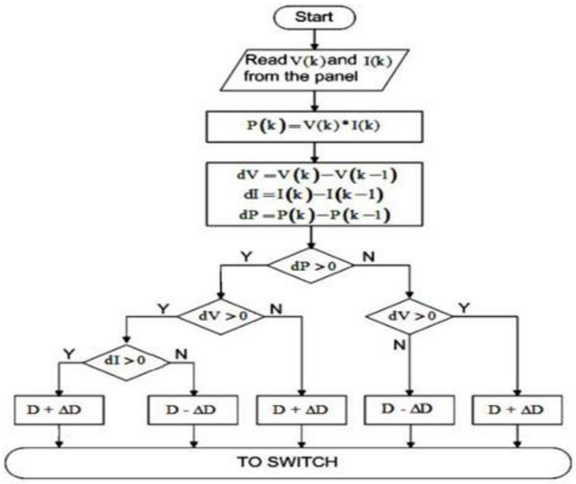

Fig. 8 Drift free modified P&O Algorithm Flowchart

VI. SIMULATION AND RESULTS

The circuit model is used to design PV module for simulation study. Parameters of the module are: Series Resistance Rs = 0.2300 ohm, Parallel Resistance Rp = 45 ohm, number of panels in series = 50, number of panels in parallel = 5 and total power output of module = 7.5kW. The values of components used for SEPIC converter are: L1 = 180 H , L2 = 180 H,

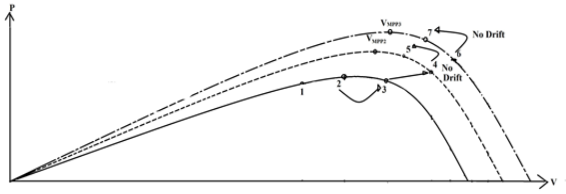

Fig. 9 P-V characteristics for drift free modified P&O algorithm during one time increase in insolation

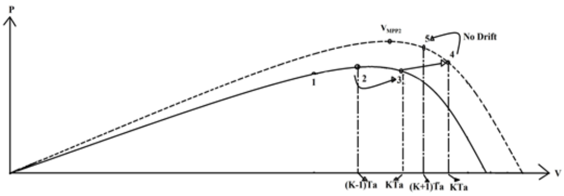

Fig. 10 P-V characteristics for drift free modified P&O algorithm during rapid increase in insolation

C1 = 47 F, C2 = 3300 F, f_s = 5kHz and R_{Load} = 47 ohms. MATLAB/Simulink model of the proposed system is shown in Fig. 11 and the design of proposed P&O subsystem is shown in Fig. 12.

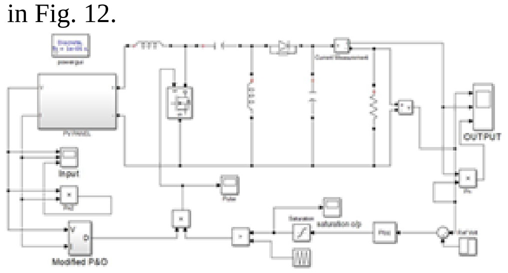

Fig. 11 MATLAB/Simulink model of proposed MPPT based PV system

Retrieval Number: J88040881019/19©BEIESP
DOI: 10.35940/ijitee.J8804.0881019
Journal Website: www.ijitee.org

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)
© Copyright: All rights reserved.

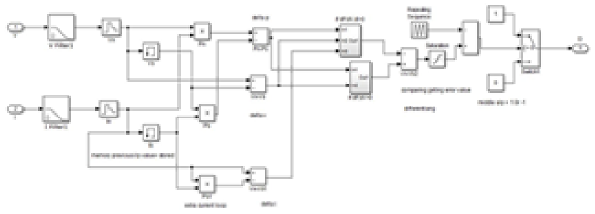

Fig. 12 Construction of proposed MPPT algorithm using MATLAB/Simulink

Testing done on modified perturb and observe algorithm at 0.5s. for insolation level change from 500 w / m^2 to 1000 w / m^2. Perturbation time is selected as 0.1 milliseconds and perturbation step size is 0.001. Following fig. 13 shows simulation results for both conventional and modified perturb and observe MPPT algorithms.

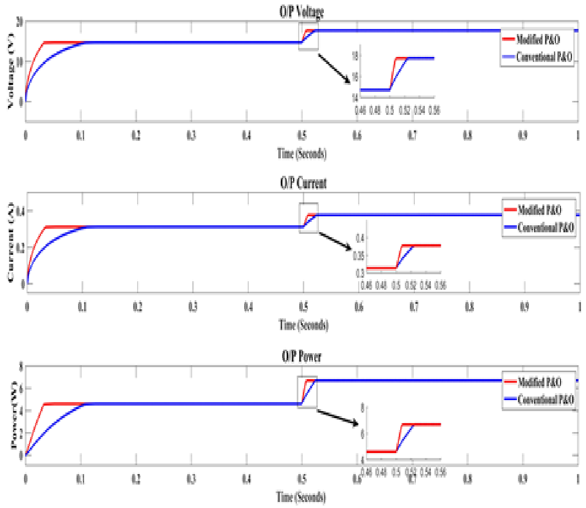

Fig. 13. Output waveforms of simulation for conventional and modified drift free perturb and observe MPPT algorithms (a) output voltage (b) output current and (c) output power

From above waveforms it is clear that modified perturb and observe MPPT algorithm gives improved waveform and fast convergence to MPP. It can also be noted that even during rapid rise in insolation the modified algorithm operates efficiently.

VII. CONCLUSION

This paper proposes a modified perturb and observe based MPPT algorithm for drift avoidance in solar PV systems. Drift condition and issues associated with it are explained in this paper. Inclusion of checkpoint for change in current (dI) gives advantage to overcome the problem of drift. SEPIC converter is used to control the output power using direct duty ratio control owing to its numerous advantages. The modified P&O algorithm was validated using MATLAB/Simulink and the results of the simulations prove that the proposed method is drift free. Moreover, it was shown from the results that the algorithm tracks maximum power point accurately during sudden transients thus improving the efficiency of solar PV systems. This method can result in creating greener environment by reducing considerable carbon footprint during entire life span of PV array.

REFERENCES

1. Muralidhar Killi, Susovon Samanta, , "Modified Perturb & Observe MPPT algorithm for drift avoidance in Photovoltaic systems" 2015 IEEE
2. Dezso Sera, Remus Teodorescu, Jochen Hantschel, Michael Knoll, "optimized maximum power point tracker for fast changing environmental conditions," IEEE, July 2008
3. Mohammed A. Elgendy, Bashar Zahavi, David J. Atkinson, "Assessment of perturb and observe MPPT algorithm implementation techniques for PV pumping applications", IEEE, January 2012
4. Nicola Femia, Giovanni Petrone, Giovanni Spagnuolo, Massimo Vitelli, "Optimization of Perturb and observe maximum power point tracking method," IEEE, July 2005
5. BOC Group, Operngasse 20b, Vienna, Austria, "An improved perturb & observe MPPT algorithm with variable step", Scientific Bulletin of the Electrical Engineering faculty, ISSN 2286-2455, [2017]
6. M. Quamruzzaman& K. M. Rahman, "A modified P&O MPPT technique for single stage grid connected PV inverter", WSEAS TRANSACTIONS on POWER SYSTEMS, E-ISSN: 2224-350X, Volume 9, [2014]
7. Luigi Piegari, Renato Rizzo, Ivan Spina, Pietro Tricoli "An optimized adaptive perturb and observe maximum power point tracking control for PV generation", Energies 2015, 8, 3418-3436, ISSN 1996-1073 [2015]
8. Jehun Hahm, Euntai Kim, Heejin Lee, Changyong Yoon, "A modified Perturb and Observe sliding mode Maximum Power Point Tracking method for PV system under partially shaded condition", International Journal of Fuzzy Logic & Intelligent Systems, December 2016
9. Syafaruddin, E. Karatepe, T. Hiyama, "Artificial neural network-polar coordinated fuzzy controller based maximum power point tracking control under partially shaded conditions", IET Renewable Power Generation, October 2008
10. Xuan Hieu Nguyen and Minh Phuong Nguyen, "Mathematical modeling of photovoltaic cell/module/arrays with tags in Matlab/Simulink", Environmental Systems Research, vol.4, no.1, Dec. 2015.
11. E. Mamarelis, G. Petrone, and G. Spagnuolo, "Design of a sliding mode controlled sepic for PV mppt applications," IEEE Trans. Ind. Electron., vol. 61, no. 7, pp. 3387-3398, Jul. 2014.

AUTHORS PROFILE

Mr. Yogesh Yashwant Katdare was born in Chiplun on 5th October 1989. He received the B.E. degree from Finolex Academy of Management & Technology, Ratnagiri in 2012. His area of interest includes Power Systems.(E-mail: yogeshkatdare221@gmail.com)

Mrs. Pranita Chavan has completed B.Tech from Dr. Babasaheb Ambedkar Technological University in 2001. She also completed M.E. in Electrical Power system from Pune University in 2004. She is working as a Head of the Department in Pillai HOC college of Engineering & Technology, Rasayani.

Mr. Dhananjay Borse was born in Nashik, India on December 21, 1986. He received B.E. degree from AISSMS Engineering College, Pune, in 2011 & ME degree in Power Systems from PVG's Engineering College Pune, Pune University in 2015. At present, he is working in R&D department, in Radium Engineering, Bavdhan, Pune. His area of interest includes Power Electronics & Drives. (E-mail: borse25@gmail.com)

Retrieval Number: J88040881019/19©BEIESP
DOI: 10.35940/ijitee.J8804.0881019
Journal Website: www.ijitee.org

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)
© Copyright: All rights reserved.