Estimating Efficiency of MPPT Techniques by Chattering Examination

Indresh Yadav, Sanjay Kumar Maurya

Abstract: ***Increasing the efficiency of MPPT techniques is the essential aspects of the Solar Photovoltaic System. This efficiency is affected by the chattering available with the MPPT techniques. An MPP technique which generates less chattering in the system is more efficient than the others. This paper presents the chattering analysis of the popular Maximum Power Point Tracking (MPPT) techniques Perturb & Observe (P&O) and Incremental conductance method for the fixed and variable step size. The algorithms are simulated under similar load and environment conditions. In the result it is found that the incremental conductance method has very less chattering in comparison with the P&O for the fixed step size and variable step size. Further, for the different solar radiation chattering is observed and tabulated.***

Keywords: Chattering, Incremental Conductance, MPPT, Perturb and Observe, SPV.

I. INTRODUCTION

Now days, the world is meeting with severe environmental consequences to fill the gap of energy inadequacy by use of the enormous consumption of fossil fuels. It has become a global challenge to develop renewable and sustainable energy to support the growth of society. In many renewable energy sources solar energy is one of the most favorable and rapidly growing renewable energy. The International Renewable Energy Agency (IREA) has reported in March 2019 that the total solar energy generation capacity is reached up to 486GW globally and it is increasing exponentially. Also, India has set the target to reach 100GW solar power generation by 2022. Electrical energy is the most suitable for of energy for various applications; hence photovoltaic power generation gained more attention than the solar thermal now these days. However, the solar photovoltaic system suffers from poor efficiency due to photovoltaic conversion efficiency and the extraction of maximum power form system in the varying irradiance of the sun naturally or environmentally. Many researchers focus on extraction of maximum power by developing the MPPT algorithms[1]-[2].

Revised Manuscript Received on November 22, 2019.
***** Correspondence Author
Indresh Yadav*, Department of Electrical Engineering,GLA University, Mathura, India. Email: indresh.yadav@gla.ac.in
Sanjay Kumar Maurya, Department of Electrical Engineering,GLA University, Mathura, India. Email: sanjay.maurya@gla.ac.in

Every MPPT algorithm is to achieve the product of voltage and current at maximum because the output power of PV panel is dependent on the solar radiation (SR) incident, panel temperature and the value & nature of the load. Fig. 1 shows that at constant SR intensity (SRI), temperature and load condition, there is a unique operating point on the current-voltage curve (CVC) at which maximum power point (MPP) occurs [3]. However, with the variation in load SRI and temperature of the PV panel, the MPP changes on CVC [4].

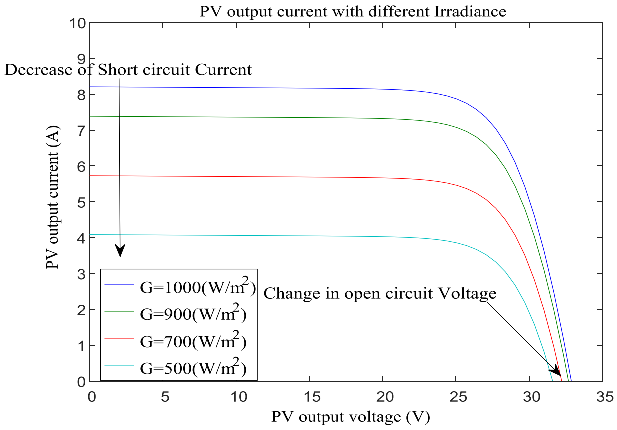

Fig.1 (a) Current response at $25c^0$ and different irradiance

To address the issue of moving MPP point under varying load and environment condition is to by change the duty cycle of the boost converter which consequently changes either the voltage or current or both the voltage and current output of for the solar PV applications.

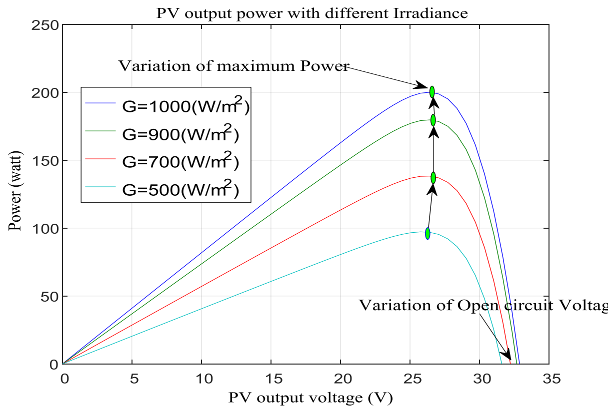

Fig.1 (b) Power response at $25c^0$ and different irradiance

*Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication*

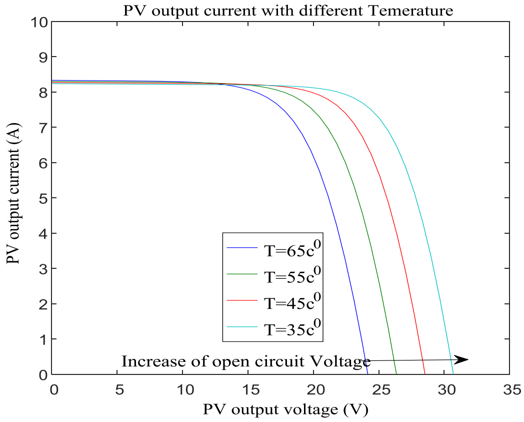

Fig.1 (c) Current response at $1000 W/m^2$ and different temperature

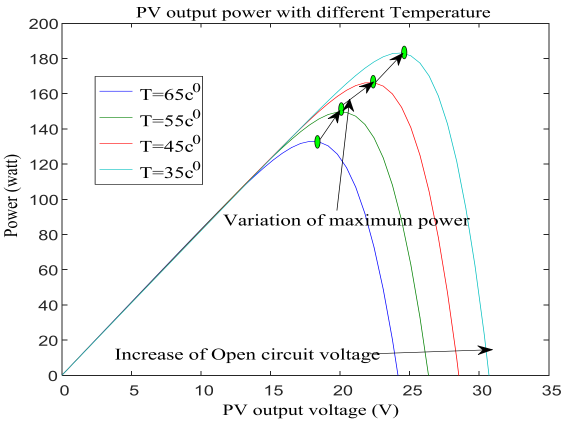

Fig.1 (d) Power response at $1000 W/m^2$ and different temperature

Fig.1 Solar PV characteristics for a different variation of solar irradiance and panel temperature

The MPP algorithms are evaluated on the basis of the tracking response, Steady-state Error, Energy-efficient, Complexity of algorithm, Global MPPT tracking ability & Reliability. The MPP technique, Perturb and Observe (P&O) is widely used and accepted MPPT because of simple controller design and implementation [5]. In P&O method, the operating voltage is changed by varying the duty cycle of dc-dc converters to achieve the MPP. It suffers from continuous oscillations around its MPP, thereby increasing the transient and fails to achieves the global maximum global MPP (GMPP) under rapid changing environment and partial shading situations[6]. During partial shading condition the shaded PV array behaves like a passive load, which is connected across rest of the solar PV panel, so it also consumes the power. However the soft computing MPPT controller (MPPTC) based on the fuzzy logic and neural network gives better time response, very adaptive to handle nonlinearity and performance but it suffers due to tuning issue, design based on technical knowledge for different locations and a massive data is required for the training of neurons.

Consequently, the researchers refocus on conventional techniques such as Incremental conductance (IC) based MPPTM is more effective [2]. IC along with variable step size gives excellent steady-state time response. Further improvement in IC is made using addition of residual method, but testing is done only for fixed irradiance [7]. This paper focused work chattering analysis for the P&O and IC with direct duty cycle step size control is proposed using MATLAB Simulink. The chattering is an essential aspect in deciding the reliability of the system.

II. SYSTEM DESIGN

A. PV system

A PV panel is made of PV cells, which are connected in series and parallel combination to get Solar PV array (SPVA) [8]. A complete PV system uses a SPVA as the main source for the generation of electricity from the solar energy. Single PV panel is not enough to give sufficient power for normal use as most of the manufactures are designing SPV panel with a voltage rating 12V or 24V, so to get desired power output different combination of PV panel is required. The current coming out from SPV is governed by the following equation-[9].

$$I_L = I_{PV} n_P - I_S n_p \left[\exp\{V_L + R_S (n_S / n_P) I_L / \eta V_T n_S\} - 1\right] - V_L + R_S (n_S / n_P) I_L / R_P (n_S / n_P) \quad (1)$$

Where the thermal voltage of the PV array is governed by the following equation -

$$V_T = n_S kT / q \quad (2)$$

Current the PV array is governed by the following equation-

$$I_{PV} = \left[I_{PV(S)} + K_{SC}(T - T_S)\right] * G / G_S \quad (3)$$

Saturation current of the diode is governed by the following equation-

$$I_S = I_{S(S)} (T_S / T)^3 \exp\left[q E_g / \lambda k (1/T_S - 1/T)\right] \quad (4)$$

Standard saturation current of the diode is governed by the following equation-

$$I_{S(S)} = I_{SC(S)} / [\exp(V_{OC(S)} / \lambda V_T) - 1] \quad (5)$$

The final power output of the SPV array is given as-

$$P_L = V_L * I_L \quad (6)$$

B. *Dc-dc Boost converter*

In practical SPV system output voltage reduces from its standard value because of reduction of SRI, so dc-dc boost converter is most suitable in terms of simplicity of design, efficiency and with reduced cost. It can regulate the output voltage smoothly from its unregulated input voltage [10]. The components used to design of the boost converter are IGBT as a switch, Inductor with inductance L, diode and capacitor with capacitance C as shown in fig.2.

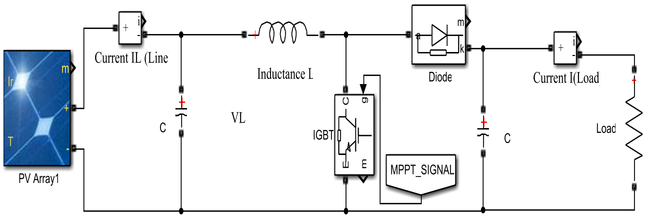

Fig.2 SPV system using dc-dc boost converter

Mathematical modelling governing dynamic condition of the boost converter is as follows-

When switch is on:

$$V_L = L\, di_L/dt \tag{7}$$

$$C\, dv_{Load}/dt + v_{Load}/R = 0 \tag{8}$$

When the switch is off:

$$v_{Load} = V_L - L\, di_L/dt \tag{9}$$

$$i_L - C\, dv_{Load}/dt - v_{Load}/R = 0 \tag{10}$$

If D is the duty ratio of the dc-dc boost converter [11],[7], then assuming for the continuous conduction mode, averaging model for the boost converter can be written as-

$$di_L/dt = V_L/L - (1-D)V_{Load}/L \tag{11}$$

$$dv_{Load}/dt = (1-D)I_L/C - V_{Load}/RC \tag{12}$$

From above equations load with resistance R and line voltage of PV output are the independent parameter.

III. MAXIMUM POWER POINT TRACKING METHODS

(A) P&O with fixed step size

To track MPP, duty cycle of boost converter is changed directly with fixed step size; hence there is change in operating point voltage. To change step size of the duty cycle is totally based on hit and trail method. If with the increase of operating voltage output power of boost converter increases, then-

$$D_{new} = D_{Old} + \Delta D \tag{13}$$

If with the increase of operating voltage output power of boost converter decreases, then

$$D_{new} = D_{Old} - \Delta D \tag{14}$$

This process is repeated till the MPP is obtained.

(B) P&O with variable step size

The main problem associated with fixed duty cycle step size is that slow response, large computation and noisy with low step size and large oscillation around its $dp_L/dv_L = 0$ MPP, less efficient with high step size. So instead of To obtain fast and accurate variable step size is required for the duty cycle of the dc-dc $dp_L/dv_L < 0$ boost converter[12] using following equations.

$$D_{new} = D_{Old} \pm \chi * \left(P_{New} - P_{Old}/V_{New} - V_{Old}\right) \tag{21}$$

Where, χ is scaling factor, and it is responsible to change the duty cycle with variable step size. The above equation can be rewritten from the duty cycle versus power curve as-

$$D_{new} = D_{Old} \pm \chi * (\Delta P/\Delta D) \tag{22}$$

The scaling factor χ is chosen using following equations-

$$\chi * abs(\Delta P/\Delta D) < D_{Max} \tag{23}$$

searching the entire region, initially decide tracking region [3],[2], then keep large step size of duty cycle at initial state and less step size in tracking region.

Beyond the tracking zone $D_{new} = D_{Old} \pm \Delta D_{Large}$

(15)

Within the tracking zone $D_{new} = D_{Old} \pm \Delta D_{Small}$ (16)

Under smooth change in $dp_L/dv_L > 0$ SRI, P&O is a good choice, but under rapid variation of SRI, temperature and shading, it confuses between GMPP and local MPP (LMPP).

(C) IC with fixed step size

The IC is governing with following equations-

$$dp_L/dv_L = i_L + v_L\, di_L/dv_L \tag{17}$$

At the point of the MPP, this gives

$$D_{new} = D_{Old} + (\Delta D = 0) \tag{18}$$

If with the increase of operating voltage output power of boost converter increases, which gives

$$di_L/dv_L > -i_L/v_L \text{ and } D_{new} = D_{Old} + \Delta D \tag{19}$$

If with the increase of operating voltage output power of boost converter decreases, means

$$di_L/dv_L < -i_L/v_L \text{ and } D_{new} = D_{Old} + \Delta D \tag{20}$$

(D) IC with the variable step size

To obtain fast and accurate variable step size is required for the duty cycle of the dc-dc boost converter [10] using following equations.

$$D_{new} = D_{Old} \pm \chi * \left(P_{New} - P_{Old}/V_{New} - V_{Old}\right) \tag{21}$$

Where, χ is scaling factor, and it is responsible to change the duty cycle with variable step size. The above equation can be rewritten from the duty cycle versus power curve as-

$$D_{new} = D_{Old} \pm \chi * (\Delta P/\Delta D) \tag{22}$$

The scaling factor χ is chosen using following equations-

$$\chi * abs(\Delta P/\Delta D) < D_{Max} \tag{23}$$

Now from the above equation, scaling factor can be written as-

$$\chi < D_{Max}/abs(\Delta P/\Delta D) \tag{24}$$

Now from the above equation, scaling factor can be written as-

IV. RESULTS AND DISCUSSION

Dc to dc boost converter is simulated using SPV array for the resistive load. The switching frequency of the boost converter is 25 kHz with direct duty step size is 5×10^{-4}. The value of L and C are 2mH and 22 μF respectively. Experiment is performed under varying SRI with standard operating temperature both for the P&O and IC MPPTM. Fig. 3 and 4 show response of the P&O and fig. 5 and 6 show the response of the IC. The green curve shows the deviation in the output power.

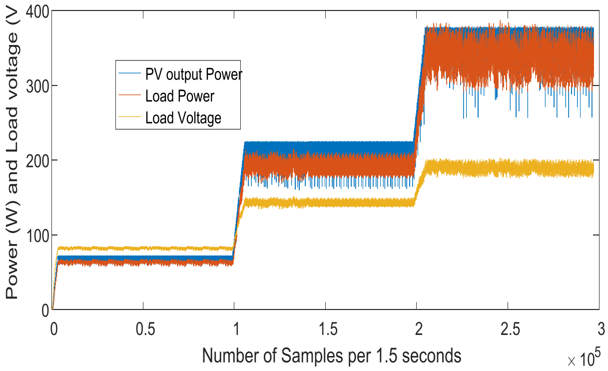

Fig. 3 Load power tracking response with different increment in SRI for the p&O at the fixed temperature

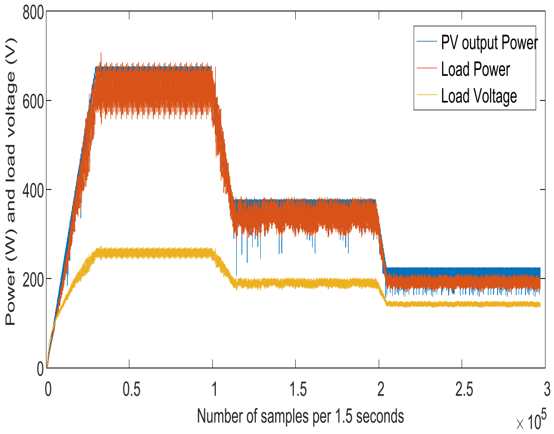

Fig. 4 Load power tracking response with different decrement in SRI for the p&O at the fixed temperature

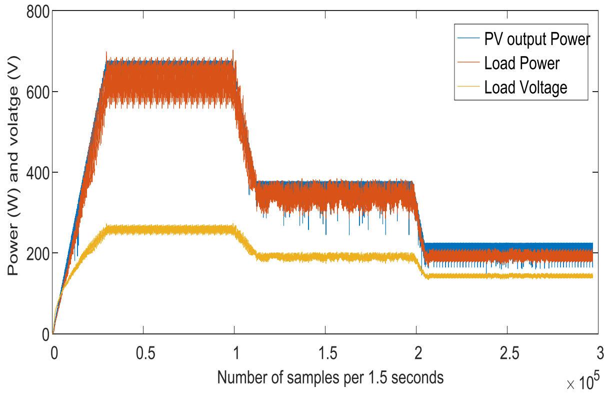

Fig. 5 Load power tracking response with different decrement in SRI for the IC at the fixed temperature

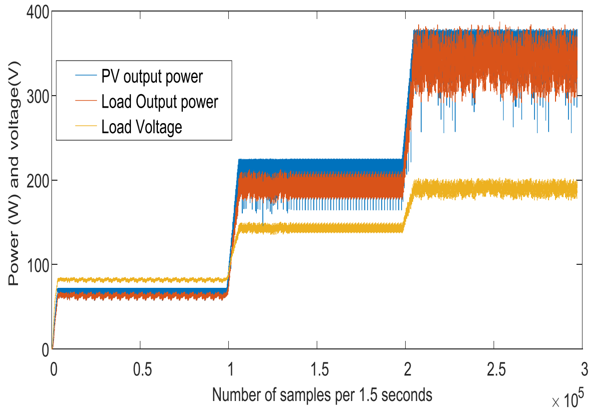

Fig. 6 Load power tracking response with different increment in SRI for the IC at the fixed temperature

Table 1 Chattering analysis for the P&O at 25^0C

SRI (W/m^2)	Input power (W)		Input Chattering(W)	Out Power (W)		Output Chattering(W)	Output Chattering (%)	Efficiency (%)
	Min	Max		Min	Max			
100	58.5	72	6.75	57.75	67	4.625	7.4	95.6
300	162.25	225	31.325	172.75	215.5	21.375	11	98.48
500	257	378.5	60.75	288	387.5	49.75	13.17	95.5
900	636	676	20	558	684.4	63.2	10.173	94.7

Table2 Chattering analysis for the IC at 25^0C

SRI (W/m^2)	Input power (W)		Input Chattering(W)	Out Power (W)		Output Chattering(W)	Output Chattering (%)	Efficiency (%)
	Min	Max		Min	Max			
100	57.5	72	7.25	58.25	67.25	4.5	7.1	96.91
300	164.4	225	30.3	176.86	210	30.3	8.5	99.35
500	270	378	54	292	381.5	44.75	13.28	95.6
900	636	676	20	566	680	57	9	94.96

From the result, it shows that in each and every case the output power trying to track the input power by changing the operating point voltage, hence changing duty cycle of boost converter so that the condition of MPP is met. Because of the nonlinear system, input power is changing with nonlinear fashion. So to track that power there is continuous chattering at the load side. Chattering for the different SRI is observed both for the P&O and IC as shown in table 1 and 2 respectively.

V. CONCLUSION

In this paper, mathematical modeling of the SPV system, dc to dc boost converter, P&O and IC both for the fixed and variable step size is done.

Simulation model is design and chattering analysis is tested for the widely accepted MPPTM. The efficiency of MPPT technique is estimated using analysis of chattering across the settling of MPP on PV curve. From the above discussion it shows both techniques have a chattering problem. From the above observation IC gives slightly better response and the extent of better response is tabulated in the table 1 and 2.

REFERENCES

[1] S. Lyden, M. E. Haque, A. Gargoom, and M. Negnevitsky, "Review of maximum power point tracking approaches suitable for PV systems under partial shading conditions," *2013 Australas. Univ. Power Eng. Conf. AUPEC 2013*, no. October, pp. 1–6, 2013.

[2] N. Kumar, I. Hussain, B. Singh, and B. K. Panigrahi, "Self-Adaptive Incremental Conductance Algorithm for Swift and Ripple-Free Maximum Power Harvesting from PV Array," *IEEE Trans. Ind. Informatics*, vol. 14, no. 5, pp. 2031–2041, 2018.

[3] Indresh yadav and Sanjay kumar Maurya, "A Literature Review on Industrially Accepted MPPT Techniques for Solar PV System," *Int. J. Electr. Comput. Eng.*, accepted on 17 July 2019.

[4] S. Devassy and B. Singh, "Design and Performance Analysis of Three-Phase Solar PV Integrated UPQC," *IEEE Trans. Ind. Appl.*, vol. 54, no. 1, pp. 73–81, 2018.

[5] M. A. Elgendy, B. Zahawi, and D. J. Atkinson, "Evaluation of perturb and observe MPPT algorithm implementation techniques for PV Pumping Applications," *IEEE Trans. Sustain. ENERGY*, vol. 3, no. 1, pp. 21–33, 2012.

[6] A. K. Abdelsalam, A. M. Massoud, S. Ahmed, and P. N. Enjeti, "High-performance adaptive Perturb and observe MPPT technique for photovoltaic-based microgrids," *IEEE Trans. Power Electron.*, vol. 26, no. 4, pp. 1010–1021, 2011.

[7] M. Alsumiri, "Residual Incremental Conductance Based Nonparametric MPPT Control for Solar Photovoltaic Energy Conversion System," *IEEE Access*, vol. 7, pp. 87901–87906, 2019.

[8] H. M. El-Helw, A. Magdy, and M. I. Marei, "A Hybrid Maximum Power Point Tracking Technique for Partially Shaded Photovoltaic Arrays," *IEEE Access*, vol. 5, pp. 11900–11908, 2017.

[9] A. Belkaid, J. P. Gaubert, and A. Gherbi, "Design and implementation of a highperformance technique for tracking PV peak power," *IET Renew. Power Gener.*, vol. 11, no. 1, pp. 92–99, 2017.

[10] M. A. G. De Brito, L. Galotto, L. P. Sampaio, G. De Azevedo Melo, and C. A. Canesin, "Evaluation of the main MPPT techniques for photovoltaic applications," *IEEE Trans. Ind. Electron.*, vol. 60, no. 3, pp. 1156–1167, 2013.

[11] Indresh yadav and Sanjay kumar Maurya, "Modeling and Simulation of dc-dc Converter Based Power Electronics Learning 'a review,'" in *International Conference on Differential Equations and Control Problems : Modeling , Analysis and Computations(ICDECP19)*, 2019, p. 17.

[12] Q. Mei, M. Shan, L. Liu, and J. M. Guerrero, "A novel improved variable step-size incremental-resistance MPPT method for PV systems," *IEEE Trans. Ind. Electron.*, vol. 58, no. 6, pp. 2427–2434, 2011.

AUTHORS PROFILE

Indresh Yadav has earned his B.Tech. in Electrical Engineering (with First-Class) from G.B.T.U. (now A. K. T.U.) Lucknow, Uttar Pradesh, India, in 2010 and his M.Tech. in, Power Electronics and Drives, Electrical Engineering (with First-Class) from K.N.I.T. Sultanpur, Uttar Pradesh, India, in Feb 2013. Now he is pursuing Ph.D. in Renewable Energy from Institute of Engineering and Technology, GLA University Mathura, Uttar Pradesh, India. His research interests include the area of energy efficient control and application of power electronics on machine and renewable energy sources. He is a member IET.

Sanjay Kumar Maurya has received his Bachelor Degree from Dayalbagh Educational Institute, Agra, in 1998. And he has earned his M.Tech. &Ph.D. from Motilal Nehru National Institute of Technology, Allahabad. His research Interests includes Image processing, Electric Vehicle and Solar Power Generation. He has supervised Six Master Dissertation and supervising three Research Scholars. The research Scholars working under his supervision is working on Solar Power, Electric Vehicle. He has published many research papers in Referred Journal and International Proceeding. He is senior member IEEE, ICEIT and student advisor in IEEE PES student chapter in GLA University.