A Comprehensive Analysis of Classical and Variable Step Size P&O Algorithms for MPPT Technique used in Solar Photovoltaic System

Nitai Pal, Sk Aminul Islam

Indian Institute of Technology (Indian School of Mines), Dhanbad, India

Corresponding author: Sk Aminul Islam, Email: emd.aminul@gmail.com

There are some downsides to the conventional PO technique. A significant disadvantage is that it takes more time to reach MPPT, so ample power went lost throughout the day. Multiple ways to describe the P&O algorithms helps to track the MPPT faster than the traditional P&O approach with improved output efficiency by providing accurate duty cycle value into the DC-to-DC converter. Hence, this paper mainly discusses the performance comparison of P&O techniques in two different ways: fixed steps size (FSS) duty cycle and variable steps size (VSS) duty cycle.

Keywords: Maximum power point tracking (MPPT), Perturb and Observe (P&O) Algorithm, Duty cycle, Fixed step size (FSS), Variable step size (VSS), Photovoltaic system.

2021. In Rahul Srivastava & Aditya Kumar Singh Pundir (eds.), *New Frontiers in Communication and Intelligent Systems*, 595–603. Computing & Intelligent Systems, SCRS, India. https://doi.org/10.52458/978-81-95502-00-4-61

1 Introduction

Worldwide power request has been expanding consistently, so the conventional fossil fuels decreasing day by day very rapidly so; as an alternative have to accept Photovoltaic energy as a part of renewable energy, which not only supplies the power but also It helps the environment by reducing the carbon emission no greenhouse effect and its operating cost is low with fewer maintenances. MPP varies with temperature and irradiation [1][10].

Energy is the main asset for the development of any nation. Today, fossil fuel is a dominant energy source predominantly utilized by highly industrialized and populated countries like the USA, China and India. The ecosystem is getting badly affected daily due to the emission of different pollutants generated by fossil fuel consumption. Solar, wind, and other alternative energy sources will be the perfect solution to global energy needs to get rid of this. Wind, solar, tidal, hydro, and biomass are vital non-conventional sources. However, solar energy is the most abundantly available resource and acts as a leading alternative in all available renewable energies. The major problem occurs due to variation in solar irradiation & intensity, which can further change the output power and voltage of the solar panel. Geographical position highly affects the amount of solar irradiation that solar panels can receive at that place [2][14][15].

However, non-uniformity like radiance, temperature and other parameters directly affects solar power generation. It requires a very high-density energy storage system like Li-ion, Flow cell, solid-state battery etc. It can work as a buffer between the non-uniform production of energy from solar power plants throughout the day and the demand for energy by consumers. Much work needs to be done on 'MPPT' since conventional MPPTs like 'Voltage Sampling', 'Current Sampling', P&O, and IC etc., are not very efficient and are slow.

A 60.53 Watts rating PV system is modelled in MATLAB/SIMULINK® environment along with adequate power electronic interface units (such as Buck Converter) and using P&O algorithm with DC load Analyze of performance with varying temperature, irradiations and environmental conditions. The conventional P&O method and Variable step size P&O method, which is the best, is the leading comparison of rising time to reach MPP [18].

2 Solar Photovoltaic System

A photovoltaic solar cell converts solar radiation into electrical energy. It is designed on the principle of the p-n junction. 'Ideal-Solar-Cell' can be replicated using a 'Current-Source' & an 'Anti-Parallel-Diode' [3][5][16].

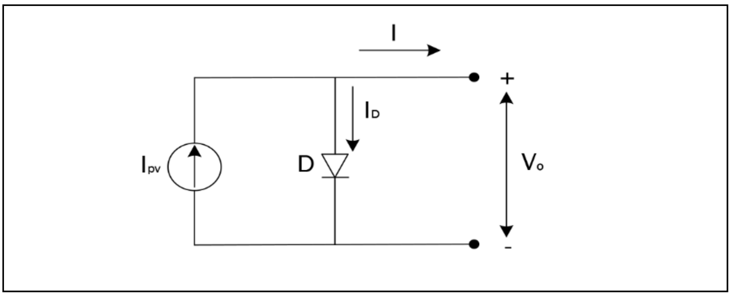

Fig. 1. Ideal Photovoltaic Cell

2.1 Solar System Modelling

The major drawback of solar energy is its unsteady power generation caused by external climatic factors and variations in load. The prime objective of the project is to generate maximum output power supplied by solar panels irrespective of changes in environmental condition & load impedance. The proposed system is realized by integrating different MPPT technologies into a system that contains solar PV modules, power electronic interfacing devices (i.e., a buck converter) and different load impedances [2][6][13][17] [19].

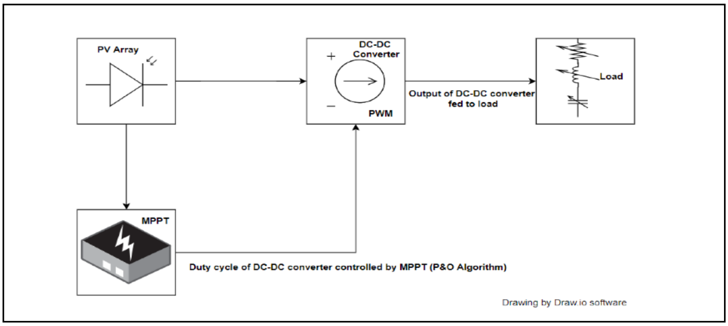

Fig. 2. Single Line Diagram of Solar System Modelling along with MPPT

2.2 MPPT for Photovoltaic Systems

P&O algorithm is one of the commonly used algorithms in the industry. This method involves the perturbation of input voltage for the power switch and measuring the change in output power. The following conditions are considered to establish the Simulink model by the P&O method.

For a Buck-Converter, V_{in}: 'Input-Voltage', V_o: 'Output-Voltage'.

Then Duty-Cycle, $D = \frac{V_o}{V_{in}}$ or, $V_{in} = \frac{V_o}{D}$, Vin is inversely proportional to the D. So, if D increases Vin decreases and vice versa. Also, $D = \frac{T_{on}}{T}$.

Duty cycle is directly proportional to On-time of the power switch. So, if TON increases D increases and vice versa.

Now, to increase D, TON should be increased, and to increase TON, Control Voltage 'Vc' need to be increased. i.e. ↑Vc↓ ⇔ ↑Ton↓ ⇔ ↑D↓

Fig. 3 shows a sampling of control voltage Vc in the presence of a High-Frequency Triangular Carrier Pulse. This is the reason for TON and TOFF.[8][9][13]

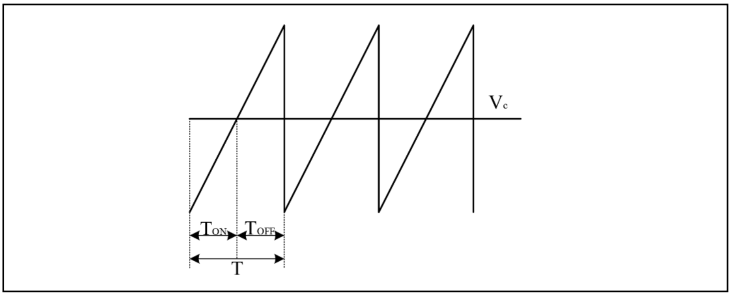

Fig. 3. Sampling of Control Voltage Vc

3 P&O Algorithm and Flowchart

The most widely used MPPT algorithms in the market are the P&O algorithms. This technique involves the perturbation of input voltage for the power switch and measuring the change in output power. The conventional P&O method is the FSS increment or decrement of duty-cycle (D) to meet the MPPT, the incremental and decremental factor, i.e., the duty cycle change in a fixed way.

Example: Dt =Dt-1 + ΔD, here the ΔD value is fixed.

Another method is known as VSS method, which is faster than the conventional method, where the value of ΔD is variable, so it helps to reach MPPT very fast.

Example: Dt =Dt-1 + ΔD *M, here the M is the multiplication factor. Moreover, it is not a fixed value.

Multiplication factor M is the absolute value of Pt2 -Pt1

And the equation of duty cycle is Dt =Dt-1 + ΔD *M [ΔD *M, is a variable value]

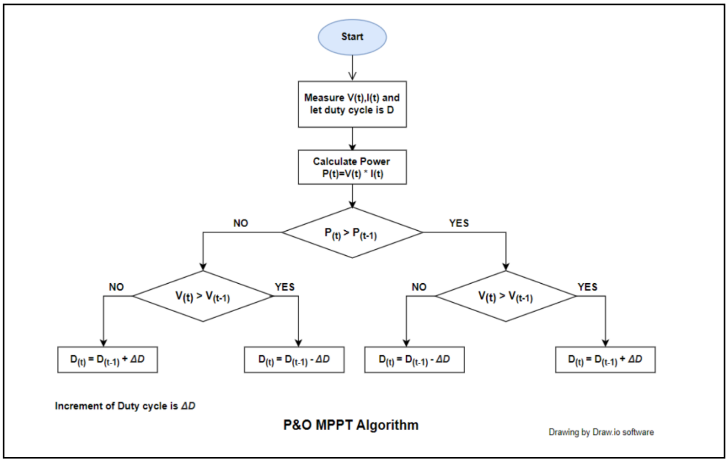

Fig. 4. Flowchart of P&O Algorithm

4 Different Types of P&O Methods

4.1 Simulink Circuit Diagram of P&O Algorithm for MPPT by Fixed Step Size Duty-Cycle Method

The Simulink model is executed by considering the following parameters and taking multiple reading types to compare with the VSS P&O algorithm. In this paper, the input variable parameters are 1) Temperature 2) Irradiation. Temperature values are 0 °C and 25 °C. Irradiation values are (in Watt per square meter): 1000, 900, 800, 700, 600, 500, 400, 300, 200, 100 [4][7][11][12].

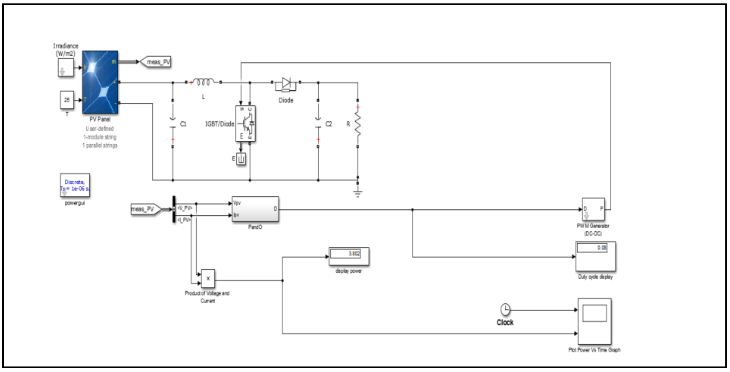

Fig. 5. Simulink Block Circuit of P&O by Fixed Step Size duty cycle for MPPT

4.2 Simulink Result of 'P&O Algorithm' by Fixed Step Size (FSS)Duty-Cycle Method for 'MPPT'

Time is taken to reach the MPP position by FSS at 0°C when irradiation is 1000 Watt per square meter is 0.054 sec, faster than the high temperature at the same irradiation.

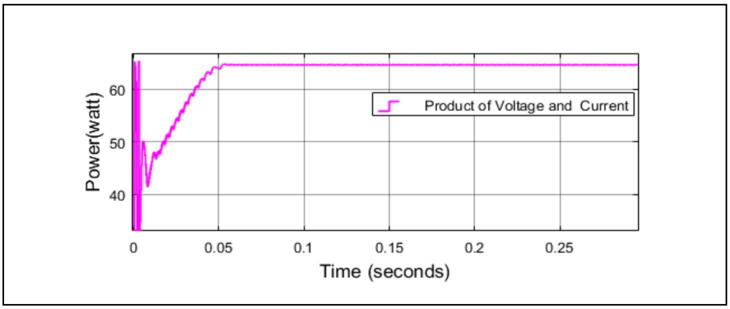

Fig. 6. Simulink Result, P&O FSS method, Temperature 0°C, Irradiation 1000 watt per square meter

Table 1. Result from fig-6

Temperature (T) in °C	Irradiance (G) in watts/m2	Output Power (P)In watt	Duty Cycle (D)	Time to reach saturated MPP (Sec)
0	1000	64.72	0.5705	0.054

Time is taken to reach MPP position by FSS at 25ºC when irradiation is 1000 Watt per square meter is 0.062 sec which is slower than the low temperature at the same irradiation.

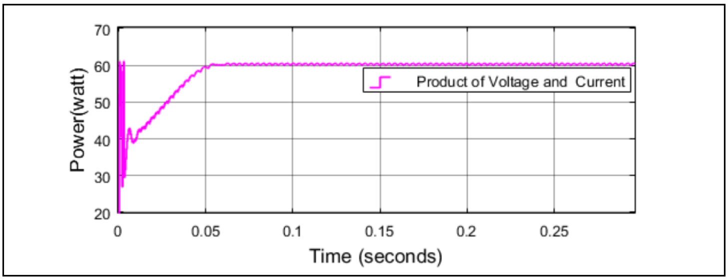

Fig. 7. Simulink Result, P&O FSS method, Temperature 25ºC, Irradiation 1000 watt per square meter

Table 2. Result from fig-7

Temperature (T) in ºC	Irradiance (G) in watts/m2	Output Power (P)In watt	Duty Cycle (D)	Time to reach saturated MPP (Sec)
25	1000	60.32	0.5902	0.062

4.3 Simulink Result of 'P&O Algorithm' by Variable Step Size (VSS) Duty-Cycle Method for 'MPPT'

Time is taken to reach MPP position by VSS at 0ºC when irradiation is 1000 Watt per square meter is 0.022 sec which is slower than the high temperature at the same irradiation.

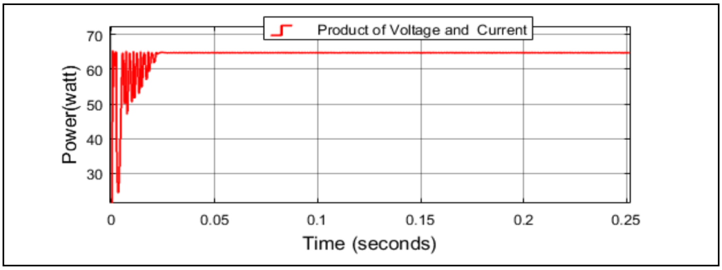

Fig. 8. Simulink Result, P&O VSS method, Temperature 0ºC, Irradiation 1000 watt per square meter.

Table 3. Result from fig-8

Temperature (T) in ºC	Irradiance (G) in watts/m2	Output Power (P)In watt	Duty Cycle (D)	Time to reach saturated MPP (Sec)
0	1000	64.69	0.5739	0.022

Time is taken to reach MPP position by VSS at 25ºC when irradiation is 1000 watt per square meter is 0.017 sec which is faster than the low temperature at the same irradiation.

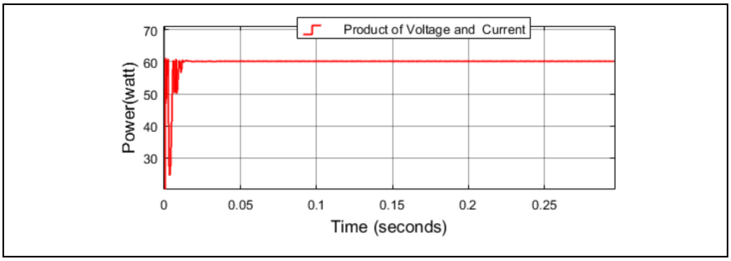

Fig. 9. Simulink Result, P&O VSS method, Temperature 25°C, Irradiation 1000 watt per square meter.

Table 4. Result from fig-9

Tempera-ture (T) in °C	Irradiance (G) in watts/m2	Output Power (P)In watt	Duty Cycle (D)	Time to reach saturated MPP (Sec)
25	1000	60.11	0.5801	0.017

5 Comparative Study and Results

Compare the two methods at different irradiation levels, and temperatures collected the simulator readings and represented in a graphical interface as shown in Figs. 10 and 11 respectively.

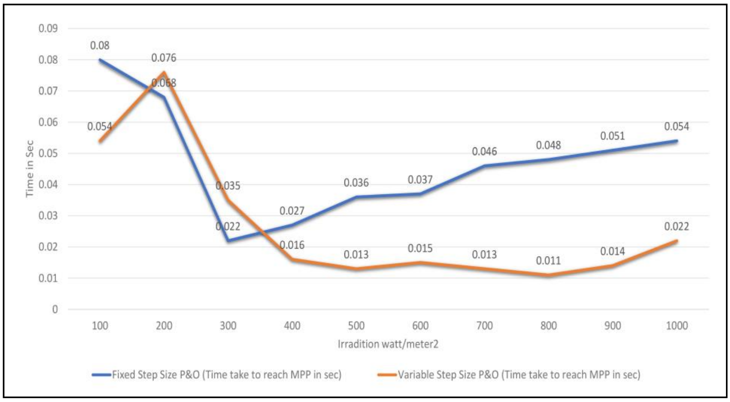

Fig. 10. Comparison between FSS and VSS methods at Temperature 0 °C, Irradiation 1000 watt per square meter

6 Conclusion

As per the analytical data, it can be concluded that the two P&O methods, Fixed Step Size (FSS) and Variable Step Size (VSS), comparison depends on the two external factors one is temperature, and another is the irradiations changes. If the temperature is kept constant, then the above methods act differently at different irradiance levels and vice-versa.

At constant temperature and lower irradiance (lets 100 to 400 Watts per square meter), the FSS method is more suitable than the VSS P&O. For higher irradiance (lets 500 to 1000 Watts per square meter), the

VSS method is most convenient. Another finding is FSS P&O takes less time to reach MPP at a higher temperature (lets 25°C) than the lower temperature (lets 0°C), so it is concluded that at higher temperature with high irradiations, VSS P&O suitable than the FSS.

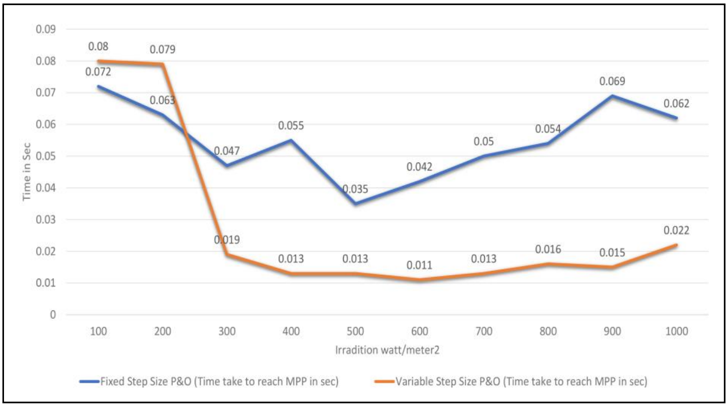

Fig. 11. Comparison between FSS and VSS methods at Temperature 25 °C, Irradiation 1000 watt per square meter

References

[1] Al-Diab, A. and Sourkounis, C. (2010). Variable step size P&O MPPT algorithm for PV systems. In *12th International Conference, Optimization of Electrical and Electronic Equipment*, 1097-1102.

[2] Femia, N. et al. (2005). Optimization of perturb and observe maximum power point tracking method. *IEEE Transactions, Power Electronics*, 20(4): 963-973.

[3] Al-Atrash, H. and Batarseh, I. (2007). Digital controller design for a practicing power electronics engineer. In *Twenty-Second Annual IEEE Applied Power Electronics Conference and Exposition*, 34-41.

[4] Ding, K. et al. (2012). A MATLAB-Simulink-Based PV Module Model and Its Application under Conditions of Nonuniform Irradiance. *IEEE Transactions, Energy Conversion*, 27(4): 864-872.

[5] Hu, J., Zhang, J. and Wu, H. (2011). A Novel MPPT Control Algorithm Based on Numerical Calculation for PV Generation Systems. *Key Laboratory of Power System Protection and Dynamic Security Monitoring and Control (North China Electric Power University), Baoding, China.*

[6] Batzelis, E. I., Anagnostou, G. and Pal, B. C. (2018). A State-Space Representation of Irradiance-Driven Dynamics in Two-Stage Photovoltaic Systems. *IEEE Journal of Photovoltaics*, 8(4): 1119-1124.

[7] Tian, H. et al. (2012). A Detailed Performance Model for Photovoltaic Systems. *National Renewable Energy Laboratory, Solar Energy Journal*, Journal Article NREL/JA-5500-54601.

[8] Takimoto, T. and Kuchii, S. (2009). Control of DC-DC converters with pulse width modulation inputs. *ICCAS-SICE*, 896-898.

[9] Wang, F. et al. (2005). Research on Photovoltaic Grid-Connected Power System. *Transactions of China Electrotechnical Society*, 20(5): 72-74.

[10] Yetayew, T. T. and Jyothsna, T. R. (2013). Improved single-diode modeling approach for photovoltaic modules using data sheet. In *Annual IEEE India Conference (INDICON)*, 1-6.

[11] Hongmei, T. et al. (2012). A cell-to-module-to-array detailed model for photovoltaic panels. *Solar Energy*, 86(9): 2695-2706.

[12] Paul, S. and Thomas, J. (2014). Comparison of MPPT using GA optimized ANN employing PI controller for solar PV system with MPPT using incremental conductance. In *International Conference, Power Signals Control and Computations (EPSCICON)*, 1-5.

[13] Gowda, N. M. M. et al. (2014). Modelling of buck DC-DC converter using Simulink. *International Journal of Innovative Research, Science, Engineering and Technology*, 3(7): 14965–14975.

[14] Sigalo, M. and Osikibo, L. (2016). Design and simulation of DC-DC voltage converters using MATLAB/Simulink. *American Journal of Engineering Research*, 5(2): 229–236.

[15] Elbaset, A. A. and Hassan, M. S. (2017). *Design and Power Quality Improvement of Photovoltaic Power System*. Springer.

[16] Erickson, R. W. (2004). *Fundamentals of Power Electronics*. 5th edition, Kluwer Academic Pub USA.

[17] Piqué, G. V. and Alarcón, E. (2011). CMOS Integrated Switching Power Converters. *Springer Nature*, 121.

[18] Saravanan, D. et al. (2020). A Comprehensive Study of Well-Konown Maximum Power Point Tracking Techniques. In *IEEE International Conference on Computing, Power and Communication Technologies (GUCON)*, 829-837.

[19] Yap, K. Y., Sarimuthu, C. R. and Lim, J. M. Y. (2020). Artificial Intelligence Based MPPT Techniques for Solar Power System: A review. *Journal of Modern Power Systems and Clean Energy*, 8(6): 1043-1059.