# An Improved P&O MPPT Method Using Boost Converter for Photovoltaic Applications

Shuaibu Musa Adam, Huiqing Wen, Jieming Ma,
Kangshi Wang Wang and Ka Lok Man



November 20, 2021

# An Improved P&O MPPT Method using Boost Converter for Photovoltaic Applications

Shuaibu Musa Adam, Huiqing Wen, Jieming Ma, Kangshi Wang and Ka Lok Man

***Abstract*—A maximum power point tracker is required to improve the power conversion efficiency of the solar photovoltaic generation system (PVGS) and ensure maximum power transfer from panel to the load through continually matching their internal resistances. In this study, an improved fixed step-size perturb and observe (P&O) maximum power point tracking (MPPT) has been proposed and analysed using MATLAB/Simulink. Duty cycle ($\delta$) was used to control the DC-DC boost converter's switching signal in the system configuration. Several key performance indicators to evaluate the suitability of the proposed algorithm were tested. It was found that the algorithm has excellent tracking efficiency above 99% and is capable of tracking the maximum power point (MPP) correctly at a lower time interval. The overall efficiency of the system is remarkably good, with a value higher than 97%. The proposed algorithm is, therefore, appropriate for photovoltaic (PV) applications.**

***Index Terms*—Tracking efficiency, P&O MPPT, Boost converter, Maximum power point (MPP)***

## I. Introduction

The world has been facing the challenges of finding alternative sources of energy to mitigate the negative impacts of burning fossil fuels for power generation. It is believed that renewable energy sources will be the lasting and feasible solutions to the lingering world's energy crises [1]. Over the past few decades, significant advances in research and development focusing on renewable energy sources were recorded. Among all readily available renewables, solar PV energy has been described as the most attractive because of its relatively low power generation requirements compared to other renewables [1, 2]. Similarly, the power generation is noise-free as no moving parts are required. Variable system size (i.e., from very small to the largest), ease of installation and maintenance, amongst others, make it further competitive.

However, it is faced with issues of low power conversion efficiency. Out of all the insolation that falls on solar panels, only about 10-20% is converted into useful energy. Even the lower range may be recorded under varying conditions of panel operating temperature, solar irradiation, and the load type. Thus, for enormous power to be generated, several PV arrays need to be joined together, which, on the other hand, leads to additional cost to the overall system. To reduce the PV array size and cost while maintaining the maximum output power, the panels must continually operate at their peak power operating conditions. That is to say, states like impedance matching of the internal resistance with the voltage source have to be ensured for optimum power delivery [3], and for this to be achieved, there is a need for MPP tracker [2].

The tracker enables the panel to extract maximum power from the falling irradiance irrespective of their operating conditions or other physical constraints [1]. A typical MPPT system comprises of power conditioner (converter) placed in between the load and the panel [3], in which the MPPT algorithm controls the converter's duty cycle, thereby enabling the PV panel to operate at the MPP [4].

Many researchers, renewable energy engineers, and industrial designers have conducted a large volume of researches on how to control the power converters always to regulate the PV panel to work at the MPP to achieve maximum power output from the panel [1, 4-8]. Over those decades until now, several new techniques with different variations on automatically identifying and enabling MPP operations of the module are being designed, implemented, and published.

Waqas *et al.* and Chen *et al.* [9, 10] reviewed and summarised the pros and cons of various MPPT methods for photovoltaic applications. The objective is to offer helpful guides on appropriate techniques to choose, mainly on the working conditions and purposes. In general, the MPPT techniques classification is based on the following: impedance matching, zero dP/dV, and Constant Vmp/Voc [6]. The most commonly used MPPT methods are fuzzy logic control, load current-voltage maximisation, P&O, fractional open-circuit voltage, ripple correlation control, fractional short-circuit current, neural network, and incremental conductance (IncCond) [6].

Among all the techniques mentioned above, the most widely employed is the P&O. This is because of its easy implementation and control, fewer sensors requirement, and low cost compared to the other MPPT methods [1-3], in addition to its suitability in low power PV applications like microinverter. Above all, most of the MPPT operates using the basic principles of perturb and observe. Therefore, this study focuses on simulation and analyses of an improved P&O MPPT algorithm using a DC-DC boost converter in the MATLAB/Simulink environment, with the objectives of further validating its tracking speed and steady-state accuracy for applications in PVGS.

## II. Modelling of the PV Array

**1Soltech 1STH-215-P** PV panel was selected for the modelling. The I-V and P-V characteristics are determined under different solar insolation and temperature conditions. The solar cell strings are combined in a 2x2 matrix arrangement to achieve a maximum power of about **213W**. Table I shows the key parameters of the panel.

S. M. Adam, H. Wen J. Ma, and K. Wang are with the Department of Electrical and Electronic Engineering, Xi'an Jiaotong-Liverpool University, Suzhou 215123, China (e-mail: S.Adam19@student.xjtlu.edu.cn)

K. L. Man is with the Xi'an Jiaotong-Liverpool University, China; Swinburne University of Technology Sarawak, Malaysia and imec-DistriNet, KU Leuven, Belgium (e-mail: Ka.Man@xjtlu.edu.cn)

The array simulation results at a constant temperature of 25ºC and different solar insolation are shown in Fig. 2. It can be depicted that an increase in the irradiance levels causes a corresponding increase in the values of output power (W) and current (A) of the array. Similarly, the MPP at **1kW/m²** was found to be **852.6W**. It is expected that the proposed algorithm will be able to detect this MPP when it is set to work under similar operating conditions.

Further simulating the array at different values of temperatures and constant solar irradiance of **1kW/m²** produced the I-V and P-V characteristics result shown in Fig. 3. It was observed from both curves that an increase in the cells operating temperature causes a corresponding decrease in the values of the array power (W) and voltage (V). Similarly, the MPP at **25ºC** was found to be **852.6W**.

TABLE I. KEY PARAMETERS OF 1SOLTECH 1STH-215-P PANEL

| Parameter | Value |
|---|---|
| Cells per module ($N_{cell}$) | 60 |
| Open circuit voltage, $V_{oc}$ (V) | 36.3 |
| Voltage at Maximum Power, $V_{mp}$ (V) | 29.0 |
| Short circuit current, $I_{sc}$ (A) | 7.84 |
| Current at maximum power, $I_{mp}$ (A) | 7.35 |
| Temperature coefficient of Isc (%/°C) | 0.102 |
| Temperature coefficient of $V_{oc}$ (%/°C) | -0.36099 |
| Maximum Power (W) | 213.15 |

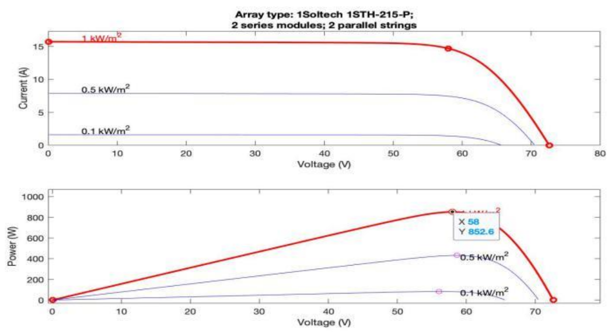


**Fig. 1.** I-V and P-V characteristics of the PV array at a constant temperature

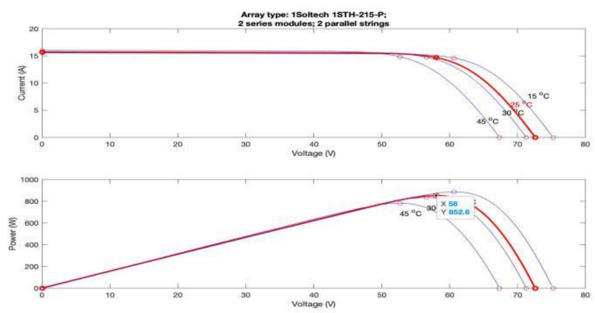


**Fig. 2.** I-V and P-V characteristics of the PV array at constant irradiance

## III. DC-DC Boost Converter

The non-isolated DC-DC power converters have been described as the most suitable for the photovoltaic power generation system [11]. The most commonly used types are Buck converter, Boost converter and Buck-Boost converter. Therefore, the choice of the converter topology depends on specific system requirements. 49

The converter used in this study is shown in Fig. 3., while Table II gives the key parameters of the converter. It can be observed that the component parts consist of input DC voltage source (i.e. the PV array), input and output capacitors, inductor, IGTBT switching device which is controlled by the PWM signal of the duty cycle, diode and the load resistance.

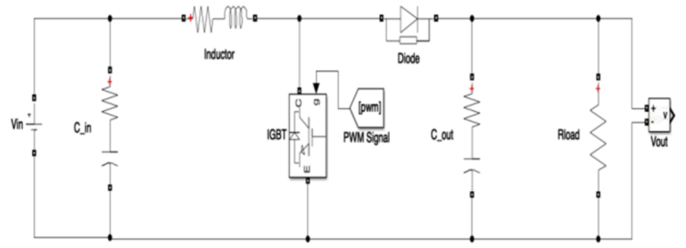


**Fig. 3.** DC-DC boost converter

TABLE II. DC-DC CONVERTER KEY PARAMETERS

| Parameters | Value |
|---|---|
| Inductance, L (H) | 2e-3 |
| Input & Output capacitance, C (F) | 1e-4 |
| Switching frequency, $F_s$ (Hz) | 5000 |
| Load resistance, $R_L$ (Ω) | 20 |

## IV. P&O Algorithm

The P&O MPPT technique has been generally regarded as one of the most widely employed because of its simplicity, fewer sensors requirements, low complexity in control [3, 12, 13] and so on. As earlier discussed, its primary function is the constant adjustment of the duty cycle of the power converter to operate at the maximum voltage for maximum output power delivery from the PV panel to the load. It is simply described as the iterative approach characterised by constant oscillations of the operating points around the MPP [10]. According to Verma *et al.* [13], "this method is applied by perturbing the duty ratio at regular intervals and oscillating around the point dP/dV=0 i.e. MPP".

In this research, the P&O MPPT control algorithm was developed in MATLAB/Simulink using the math function blocks.

In order to achieve a fast-tracking record and to minimise oscillation of the operating point near the MPP, **0.000125** was chosen as the step size for change in the duty cycle $\Delta\boldsymbol{\delta}$. The block diagram of the algorithm is shown in Fig. 4.

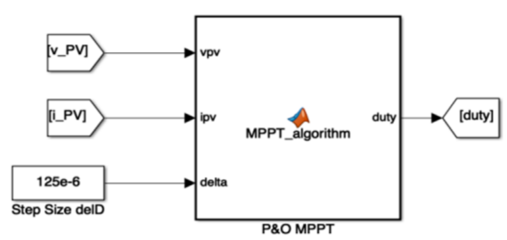


**Fig. 4.** Block diagram of the P&O MPPT algorithm

## V. SIMULATION MODEL

The simulation model was built in MATLAB/Simulink. New simulation files were created on the Simulink window; the circuit and device modules were extracted from the Library Browser. The circuit components were carefully connected following the procedures described in [14]. The first model has a standard block as the source of irradiance values, whereas in the second model, a signal builder was used as the irradiance source to the array. The major components of the models are PV array (which serves as the voltage and current basis to the MPPT and converter), DC-DC boost converter, P&O MPPT algorithm earlier described in sections 2, 3 and 4 respectively. A constant temperature of 25°C with different values of solar irradiance was used as the input to the PV module. The duty of the MPPT algorithm was fed to the converter via a pulse width modulation generator, thereby matching the PV output with the load. The duty cycle **($\delta$)** was varied from **0.00 to 0.85**. Parameters for the PV module and the boost converter have been listed in Tables 1 and 3. The simulation termination time of 1.5s was used to simulate the first model, while 4s was used for the second model. The simulation model diagrams are shown in Fig. 5 & 6 respectively.

## VI. RESULTS AND ANALYSES

The simulation results and analyses are presented in this section. Fig. 7(a) & 7(b) show results of the input and output voltage and current of the PV array, which are ***three level***. It can be seen that the DC-DC boost converter has boosted up the PV input voltage. While Fig. 8 shows the results for the input and output power of the PVGS with the P&O algorithm.

The figure shows the ability of the developed algorithm to make the PVGS extract the maximum possible power from the PV array. In this case, input power from the PV of about 852W at 1kW/m$^2$ was tracked by the algorithm. Meanwhile, the time taken to reach the MPP is small. The algorithm then continued to operate at that point (MPP) until the solar irradiance changes.

A comparison between ideal power and the PV power obtained gives the efficiency of the algorithm. The result is shown in Fig. 19. It can be observed from the figure that the efficiency obtained is higher than 98%, which is pretty much better than most of the efficiencies recorded in previous studies.

All the above results were analysed using the first model. Therefore, by changing the irradiation source to the second model, after analyses, the following results are obtained.

Fig. 10 shows the tracking efficiency results. It can be observed that the proposed algorithm has excellent tracking with a value above 99%.

Fig. 11 shows the overall system efficiency results. It can be seen from the figure that the efficiency is also excellent, with a value of about 98%.

## VII. CONCLUSION

The solar output voltage and current are characterised to be non-linear. Thus, for maximum power transfer from the panel to the load, a maximum power point tracker is needed. To improve the efficiency of the PVGS, fixed step-size P&O MPPT has been developed and analysed using MATLAB/Simulink. The duty cycle was used in controlling the switching signal controller (PWM) of the DC-DC boost converter in the system configuration. Several performance indicators to evaluate the suitability of the proposed algorithm were tested. It was concluded from the analyses of the results that the algorithm has excellent tracking efficiency and able to track the MPP correctly at a smaller time. Hence, the overall system efficiency is good. Therefore, the proposed algorithm is suitable for low power PV applications like microinverter.

## ACKNOWLEDGEMENT

This paper is partially funded by the Key Programme Special Fund (KSF-P-02) and AI University Research Centre (AI-URC) of the Xi'an Jiaotong-Liverpool University, Suzhou, China.

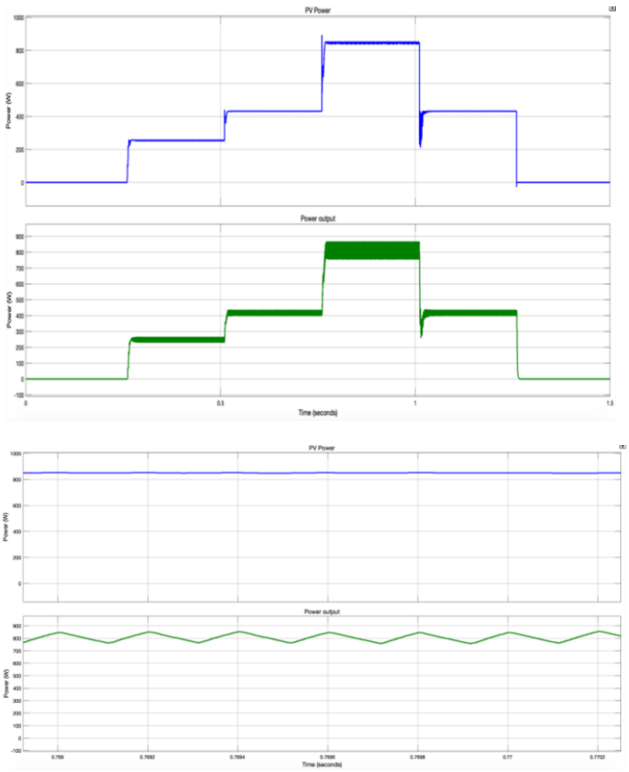

**Fig. 8.** Input and output power of the PVGS system with MPPT

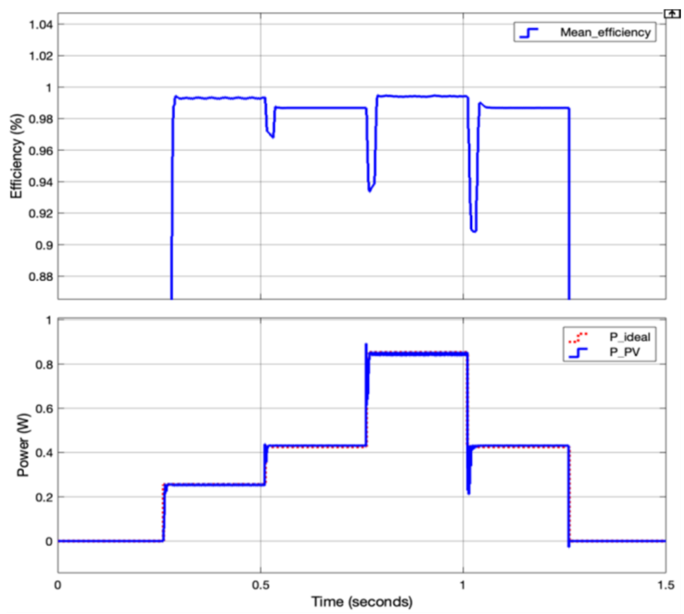


**Fig. 9.** P&O MPPT efficiency

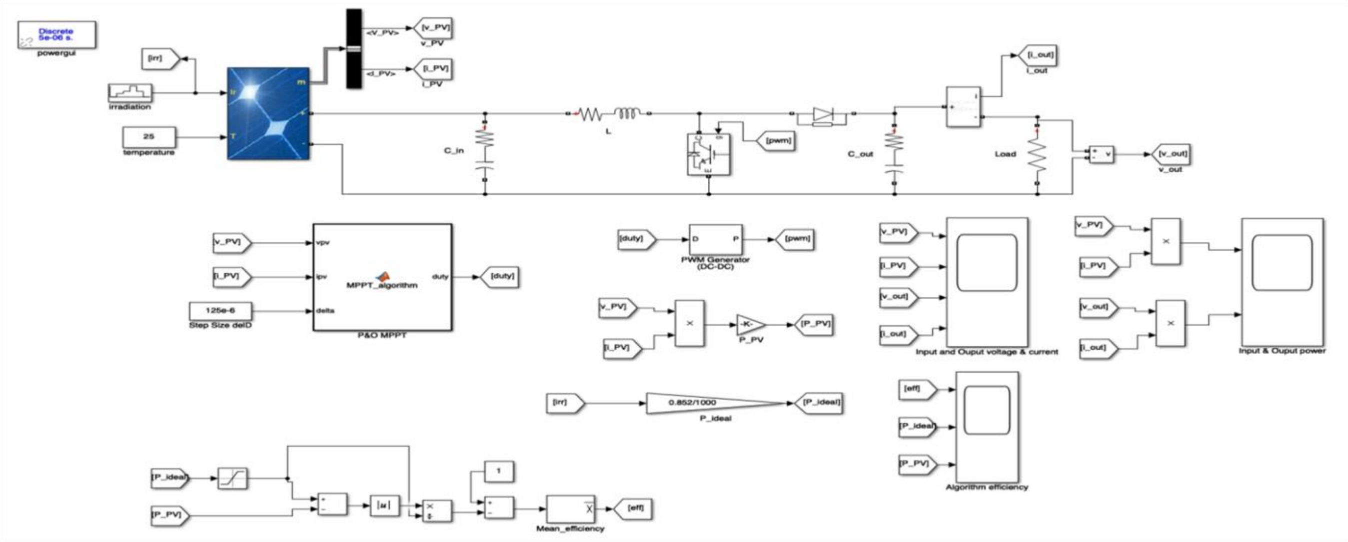


**Fig. 5.** First model of P&O MPPT algorithm with a boost converter

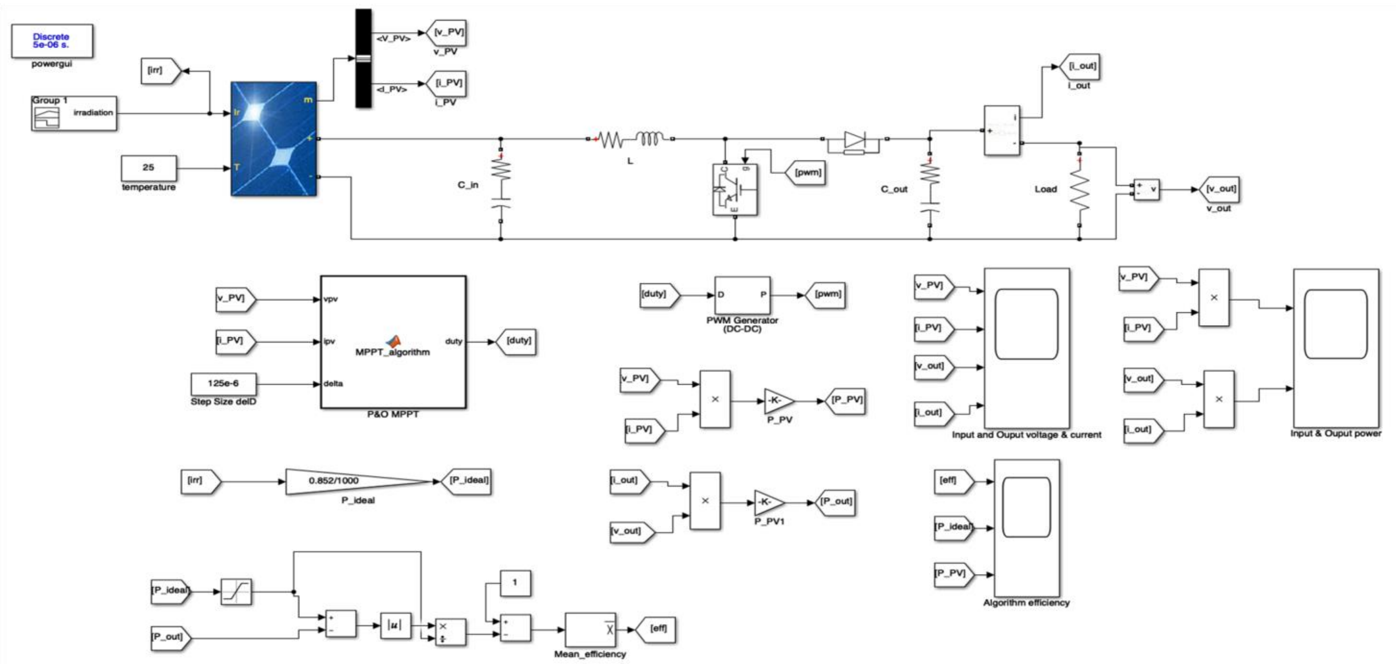


**Fig. 6.** Second model of P&O MPPT algorithm with a boost converter

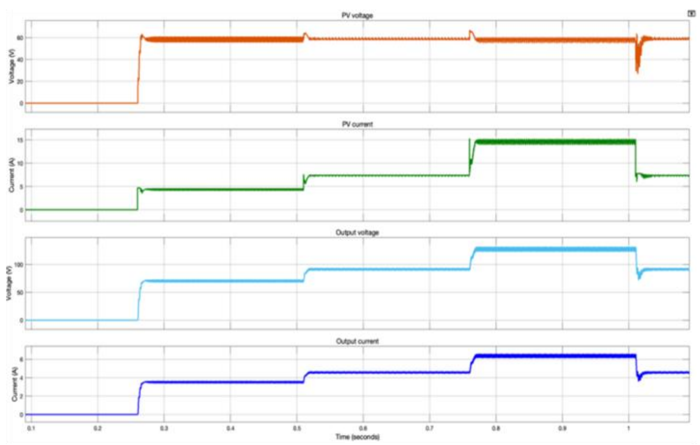


**Fig. 7(a).** Input and output voltage and current

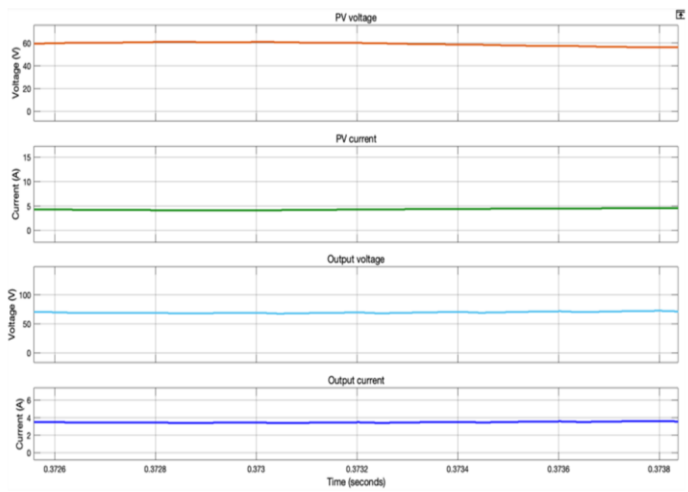


**Fig. 7(b).** Input and output voltage and current

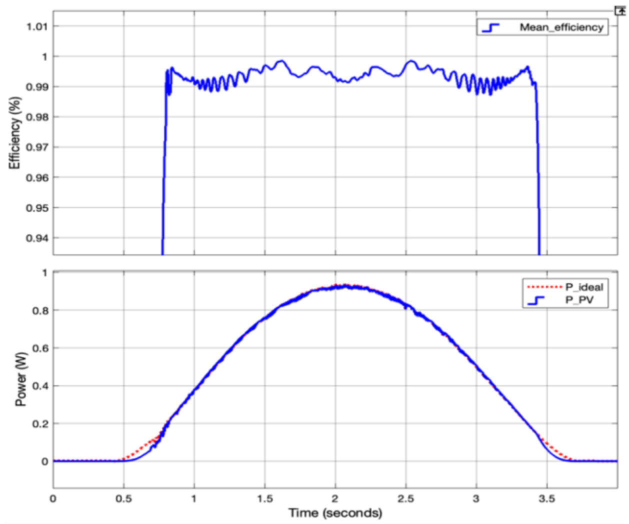


**Fig. 10.** P&O tracking efficiency

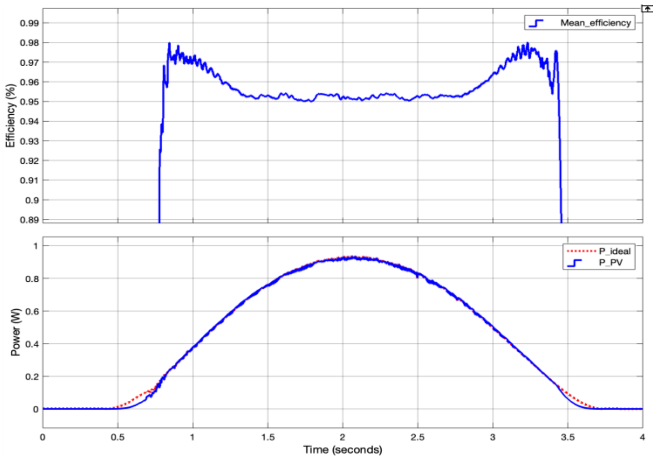


**Fig. 11.** Overall system efficiency

## REFERENCES

[1] A. Kchaou, A. Naamane, Y. Koubaa, and N. M' sirdi, "Second order sliding mode-based MPPT control for photovoltaic applications," *Solar Energy*, vol. 155, pp. 758-769, 2017, doi: https://doi.org/10.1016/j.solener.2017.07.007.

[2] Y. Yang and H. Wen, "Adaptive perturb and observe maximum power point tracking with current predictive and decoupled power control for grid-connected photovoltaic inverters," *Journal of Modern Power Systems and Clean Energy*, vol. 7, no. 2, pp. 422-432, 2019, doi: 10.1007/s40565-018-0437-x.

[3] S. Govindasamy, K. Narashiman, and R. Sasi Rama, "High Step-Up DC—DC Converter for AC Photovoltaic Module with MPPT Control," *Journal of Electrical Engineering*, vol. 65, no. 4, pp. 248-253, Aug. 2014, doi: https://doi.org/10.2478/jee-2014-0038.

[4] F. A. O. Aashoor and F. V. P. Robinson, "A variable step size perturb and observe algorithm for photovoltaic maximum power point tracking," in *2012 47th International Universities Power Engineering Conference (UPEC)*, London, UK, 4-7 Sept. 2012: IEEE, pp. 1-6, doi: 10.1109/UPEC.2012.6398612.

[5] T. Chee Wei, T. C. Green, and C. A. Hernandez-Aramburo, "Analysis of perturb and observe maximum power point tracking algorithm for photovoltaic applications," in *2008 IEEE 2nd International Power and Energy Conference*, Johor Bahru, Malaysia, 1-3 Dec. 2008: IEEE, pp. 237-242, doi: 10.1109/PECON.2008.4762468.

[6] Y. Du, X. Li, H. Wen, and W. Xiao, "Perturbation optimisation of maximum power point tracking of photovoltaic power systems based on practical solar irradiance data," in *2015 IEEE 16th Workshop on Control and Modeling for Power Electronics (COMPEL)*, Vancouver, BC, Canada, 12-15 July 2015: IEEE, pp. 1-5, doi: 10.1109/COMPEL.2015.7236502.

[7] K. H. Hussein, I. Muta, T. Hoshino, and M. Osakada, "Maximum photovoltaic power tracking: an algorithm for rapidly changing atmospheric conditions," *IEE Proceedings - Generation, Transmission and Distribution*, vol. 142, no. 1, pp. 59-64, 1995, doi: 10.1049/ip-gtd:19951577.

[8] T. Sahu, T. Dixit, and R. Kumar, "Simulation and Analysis of Perturb and Observe MPPT Algorithm for PV Array Using! UK Converter," *Advance in Electronic and Electric Engineering*, vol. 4, no. 2, pp. 213-224, 2014. [Online]. Available: http://www.ripublication.com/aeee.htm.

[9] A. Waqas, J. Ji, L. Xu, M. Ali, Zeashan, and J. Alvi, "Thermal and electrical management of photovoltaic panels using phase change materials – A review," *Renewable and Sustainable Energy Reviews*, vol. 92, pp. 254-271, Sept. 2018, doi: 10.1016/j.rser.2018.04.091.

[10] P.-C. Chen, P.-Y. Chen, Y.-H. Liu, J.-H. Chen, and Y.-F. Luo, "A comparative study on maximum power point tracking techniques for photovoltaic generation systems operating under fast changing environments," *Solar Energy*, vol. 119, pp. 261-276, Sept. 2015, doi: 10.1016/j.solener.2015.07.006.

[11] M. Khelif, A. M. raoui, and A. Malek, "Simulation, optimisation and performance analysis of an analog, easy to implement, perturb and observe MPPT technique to be used in a 1.5 KWp photovoltaic system," in *2013 International Renewable and Sustainable Energy Conference (IRSEC)*, Ouarzazate, Morocco, 7-9 Mar. 2013: IEEE, pp. 10-17, doi: 10.1109/IRSEC.2013.6529663.

[12] O. Ibrahim, N. Z. Yahaya, N. Saad, and M. W. Umar, "Matlab/Simulink model of solar PV array with perturb and observe MPPT for maximising PV array efficiency," in *2015 IEEE Conference on Energy Conversion (CENCON)*, Johor Bahru, Malaysia, 19-20 Oct. 2015: IEEE, pp. 254-258, doi: 10.1109/CENCON.2015.7409549.

[13] D. Verma, S. Nema, and R. K. Nema, "Implementation of perturb and observe method of maximum power point tracking in

SIMSCAPE/MATLAB," in *2017 International Conference on Intelligent Sustainable Systems (ICISS)*, Palladam, India, 7-8 Dec. 2017: IEEE, pp. 148-152, doi: 10.1109/ISS1.2017.8389387.

[14] Naki Güler, MPPT and Boost Converter for PV. (Aug. 31, 2019). Accessed: May. 27, 2020. [ Online Video]. Available: https://www.youtube.com/watch?v=CLbLkmci5SU