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PROCEEDINGS

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Contents

Welcome Messages from Honorary Conference Chair

On behalf of Tokyo University of Science (TUS), I would like to welcome all of you to TUS. TUS, founded in 1881, is one of the oldest private universities of science and technology in Japan. We are very proud of all our alumni who have earned well deserved successes, including a Nobel Prize Laureate. As of 2019, TUS has around 20,000 students and four campuses.

As for hosting an international conference on business, big data, and decision sciences (ICBBD), jointly held with an international conference on education, psychology, and social sciences (ICEPS), an international conference on engineering, science, and industrial applications (ICESI) and an international conference on tourism, sports management, health and food nutrition (TSHF), I am honored and delighted to deliver to you the following welcoming remarks.

This year the joint conference received 544 manuscripts from 58 countries. Over 70% of the total submissions were accepted after a review process, and around 70% of the accepted papers were registered and arranged into oral and poster sessions. Therefore, over 300 participants from 48 countries or areas (Australia, Brazil, Canada, China, Colombia, Cyprus, Czech Republic, France, Georgia, Germany, Guam, Hong Kong, India, Indonesia, Iran, Iraq, Israel, Italy, Japan, Jordan, Korea, Kuwait, Macau, Malaysia, Mexico, Morocco, Myanmar, Nigeria and Pakistan) are attending this joint conference.

As the honorary conference chair of ICBBD, ICEPS, ICESI and TSHF, I realize that the success of hosting such an international conference of this scale depends ultimately on the many people who have worked with us in planning and organizing both the technical program and supporting social arrangements. Therefore, I would like to take this opportunity to express my heartfelt thanks to all committee members, reviewers, keynote speakers, session chairs, presenters, and organization staff. Beyond regular oral and poster sessions, this year the joint conference has offered one academic laboratory tour, one local sightseeing tour, four keynote speeches and one welcome reception.

Sincere thanks also go to ICBBD conference chair Adrian E. Coronado Mondragon (Royal Holloway University of London, UK), ICEPS conference chair Chikako Morimoto (Tokyo University of Technology, Japan), ICESI conference chair Yannick Le Moullec (Tallinn University of Technology, Estonia), TSHF conference chair Valentina Naumenko (Florida Institute of Technology, USA), program chair Jung-Fa Tsai (National Taipei University of Technology, Taiwan) and local conference chair Jianming Shi (Tokyo University of Science, Japan).

Tokyo is very easy to get around because of its superb rail and subway networks. Accordingly, I hope that you will find the academic sessions and social occasions both enjoyable and valuable. Please enjoy the cultural and natural attractions of Tokyo.

Yoichiro Matsumoto
President of Tokyo University of Science, Japan
Honorary Conference Chair
2019.08.22

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International Conference on

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Tokyo University of Science, Tokyo, Japan

August 22-24, 2019

We Hereby Confirm That

Yannick Le Moullec

Yannick Le Moullec
Conference Chair

Aryuanto Soetedjo

Gave The Following Presentation Titled

A Modified Step Size Perturb and Observe Maximum Power Point Tracking for PV System

A Modified Step Size Perturb and Observe Maximum Power Point Tracking for PV System

A. Soetedjo, *Member, IEEE,* I.B. Sulistiawati, *Member, IEEE,*Y.I. Nakhoda, *Member, IEEE*

***Abstract*— The Perturb and Observe (P&O) is an algorithm to find the maximum power point in the photovoltaic (PV) system. This paper presents a new method to modify the step size of P&O algorithm by categorizing the step size into the large value during the sun irradiation change where the drift occurs, the medium value when the operating point is far away from the maximum point, and the small value when the operating point is close to the maximum point. The simulation results show that the proposed method achieves the high performance in tracking the maximum power point in the terms of the fast response, the small oscillation in the steady state condition, and avoiding the drift problem. Further, the method yields the highest generated power compared to the existing techniques.**

I. Introduction

A Maximum Power Point Tracking (MPPT) is a popular method in the photovoltaic (PV) system, which is used to operate the PV in the maximum power condition. The MPPT finds an operating point in which the current and the voltage of the PV produce the maximum power regardless of the weather conditions. It is based on the fact that the relationship between the current and the voltage (I-V curve) of the PV is the non-linear function. Further, the I-V curve is affected by the solar irradiation and the PV temperature.

Basically, the MPPT method could be divided into two categories, i.e. conventional and intelligent methods [1,2]. The most popular conventional methods are Perturb and Observe (P&O) [3-8] and Incremental Conductance (INC) [9-12]. While intelligent methods use Fuzzy Logic Control (FLC) [13-17], Artificial Neural Networks (ANN) [18,19], Particle Swarm Optimization (PSO) [20].

The P&O method is based on the perturbation and observation procedure. It perturbs the operating point by changing the voltage and observing the change in power to decide the direction of perturbation. The maximum point is achieved when there is no change in power. The basic algorithm uses the fixed step size for increasing/decreasing the perturbation voltage [3-4]. Since the DC-DC converter such as the buck, the boost, and the buck-boost converter is usually employed to connect the PV and the DC load or the battery, the changing of PV voltage could be implemented by changing the duty cycle of the converter.

The drawback of this method is that a large step size decreases the response time, but produces the high oscillation around the maximum point. While the small step size works oppositely. The overcome the drawback, the variable step size is adopted [5-8].

Besides the step size issue, the P&O suffers from a drift problem, i.e. a situation in which the algorithm could not identify the power change whether it is caused by the perturbation process or the irradiation change. It leads to the wrong perturbation change. To avoid this problem, drift-free P&O methods are proposed [7,8].

The INC method finds maximum power by measuring the conductance and its incremental (derivative) of the PV. The PV operates in the maximum point when the conductance is equal with its derivative. The method changes the voltage to fulfill such a requirement. Similar to the P&O, the selection of step size for changing the voltage is a challenging problem. The fixed step size is employed in [9,10[, while the variable step size is employed in [11,12].

The intelligent techniques such as FLC, ANN, PSO could be employed to overcome the drawbacks of the conventional technique as described previously. In [13-15], the FLC is used to change the duty cycle for finding the maximum power point. In [13,14], the FLC has two inputs, i.e. the error which is defined as the slope of P-V curve, and the change of error. While the output is the change of the duty cycle. The FLC in [16[is used to set the variable step size of the P&O method, where the FLC inputs are the error and the fixed perturbation step.

The ANN is used to generate the duty cycle of boost converter to find the maximum power point [17]. The inputs of ANN are the temperature and solar irradiance. While the voltage and the current of PV are used as the input of the ANN [18].

Other techniques to improve the performance of MPPT is by switching method that selects the P&O or INC according to certain criteria [20,21]. In [20], when the change of irradiation is nearly equal to a threshold then the INC method is employed, otherwise the P&O method is employed.

As discussed previously, the selection of duty cycle, more specifically the step size in the MPPT technique is a challenging problem. In this paper, we propose a new method to handle the problems of the step size and the drift problem in the P&O. The conventional P&O technique is proposed rather than the intelligent techniques due to the facts of the following

A Soetedjo is with the National Institute of Technology (ITN) Malang, Jalan Raya Karanglo KM 2, Malang, East Java, Indonesia (e-mail: aryuanto@gmail.com)

I.B. Sulistiawati is with the National Institute of Technology (ITN) Malang, Jalan Raya Karanglo KM 2, Malang, East Java, Indonesia

Y.I. Nakhoda is with the National Institute of Technology (ITN) Malang, Jalan Raya Karanglo KM 2, Malang, East Java, Indonesia.

reasons. The FLC method requires the proper tuning of membership functions and the rules, though it could be tuning automatically. However, it needs a bigger effort. The ANN method requires a lot of samples during the training process. While the PSO method is not suitable for real-time implementation.

On the proposed method, the step size is categorized into three, i.e. during irradiation change, far away from the maximum point, and near to the maximum point. Using these three step sizes, the performance of MPPT in terms of fast response time, minimizing the oscillation in the steady state, and avoiding the drift could be improved,

The rest of paper is organized as follows. Section 2 describes the related work in the P&O methods. Section 3 presents the proposed method. The simulation results are presented in Section 4. The conclusion is covered in Section 5.

II. RELATED WORK

A. Perturb and Observe Method

The typical characteristic of I-V and P-V curves of the PV is depicted in Fig. 1. As shown in the figure, when the irradiation change, the maximum power is achieved at different voltage. Therefore the operating point of PV voltage could not be fixed, but it should be tracked to move to the maximum one.

The P&O method changes the voltage in each cycle and measures the produced power to decide the direction of the voltage change or to stop the voltage change when the maximum power is achieved. The algorithm is illustrated in Fig. 2 and described as follows. It starts with the measurement of the voltage ($V(k)$) and the current ($I(k)$), and calculates the power ($P(k)=V(k)\times I(k)$). Then it calculates the change of power ($\Delta P=P(k)-P(k-1)$) and the change of voltage ($\Delta V=V(k)-V(k-1)$). If $\Delta P=0$, the maximum point is achieved, and no voltage change is needed. If $\Delta P>0$ means that the operating point goes to the maximum point, if $\Delta V>0$ then the voltage should be perturbed in the same direction (increases the voltage: $V(k+1)=V(k)+S$), otherwise the voltage should be perturbed in the opposite direction (decreases the voltage: $V(k+1)=V(k)-S$), where S is the step size of perturbation voltage. If $\Delta P<0$ means that the operating point goes away from the maximum point, then the operations are the opposite of the previous ones.

The algorithm may cause the oscillation at the point near to the maximum point, especially when the step size is large. However, when the step size is small, it will reach the maximum point slowly. Thus it leads to the adoption of the variable step size as described in the next section.

B. Variable Step Size Perturb and Observe Method

The variable step size is a common method to improve MPPT efficiency. The method varies the step size according to the position of the operating point from the maximum point. When the operating point is far away from the maximum point, the step size is large, however the step size becomes small when the operating point closes to the maximum point

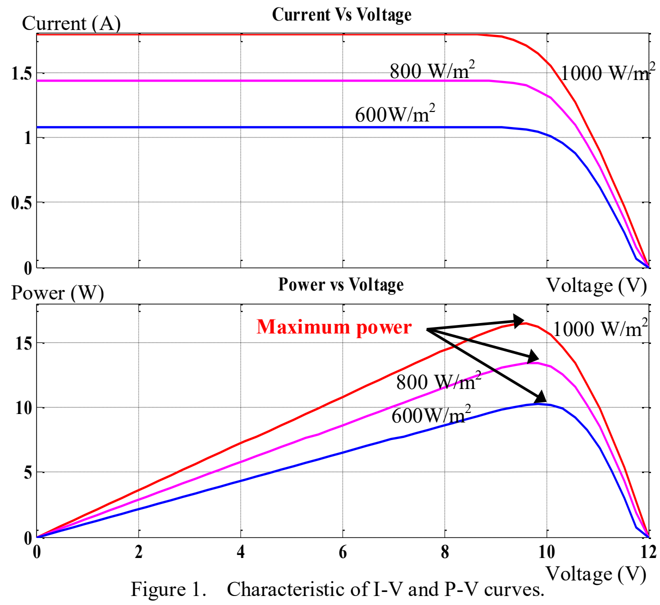

Figure 1. Characteristic of I-V and P-V curves.

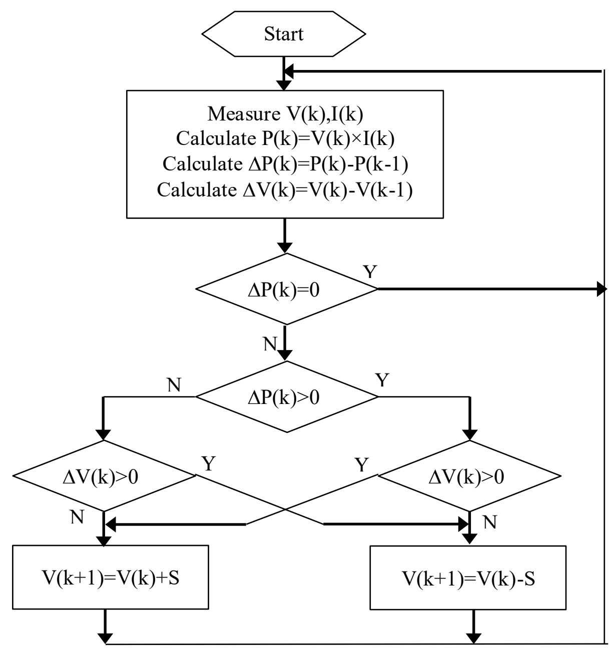

Figure 2. P&O Algorithm

In [5,6] when the change of power is greater than zero ($\Delta P>0$) means it goes to the maximum point, then the step size is multiplied by a constant A, i.e. it is larger. While when the change of power is lower than zero ($\Delta P<0$) means that it goes away from the maximum point, then the step size is divided by a constant A, i.e. it is smaller.

In [7.8], the variable step size v_{step} is expressed as

$$v_{step} = M \times \left| \frac{dP}{dV} \right| \quad (1)$$

where M is a scaling factor which is defined empirically, $|dP/dV|$ is the slope of the P-V curve. It is clear from (1) that the step size is proportional to the power slope, i.e. when the slope is larger, means that the operating point is far from the maximum point, then the step size is larger and vice versa.

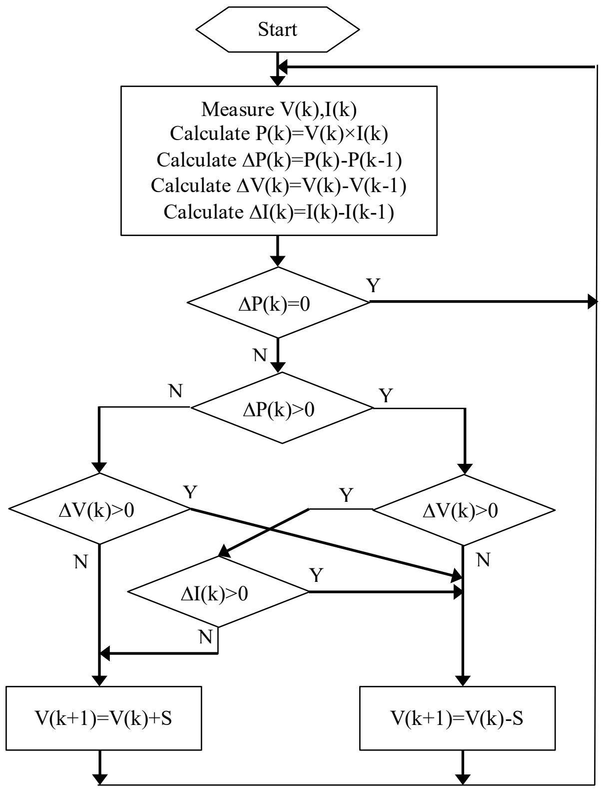

Figure 3. Drift-free P&O Algorithm [8]

C. *Drift-free Perturb and Observe Method*

Drift problem occurs when the irradiation change and the MPPT could not recognize the change of power whether it is caused by the perturbation or irradiation changes. One method to overcome the drift is by detecting the irradiation change and adjusting the perturbation direction accordingly as proposed in [8].

It is observed from Fig. 1 that at the same irradiation level, the sign of change in the current (ΔI) is the opposite from the sign of change in the voltage (ΔV). Therefore this property could be used to detect the irradiation change [8]. The flowchart of Drift-free P&O algorithm proposed by [8] is depicted in Fig. 3. As shown in the figure, the ΔI is calculated to check the irradiation change and correct the perturbation direction.

III. PROPOSED METHOD

Our proposed variable step size is illustrated in Fig 4. It uses three variations of step size:

- Large step size (CS1);
- Medium step size (CS2);
- Small step size (CS3).

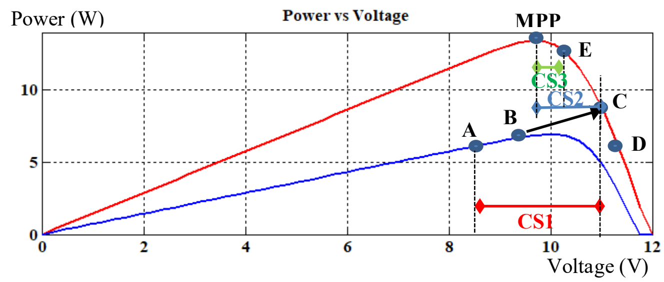

Figure 4. Illustration of proposed variable step size

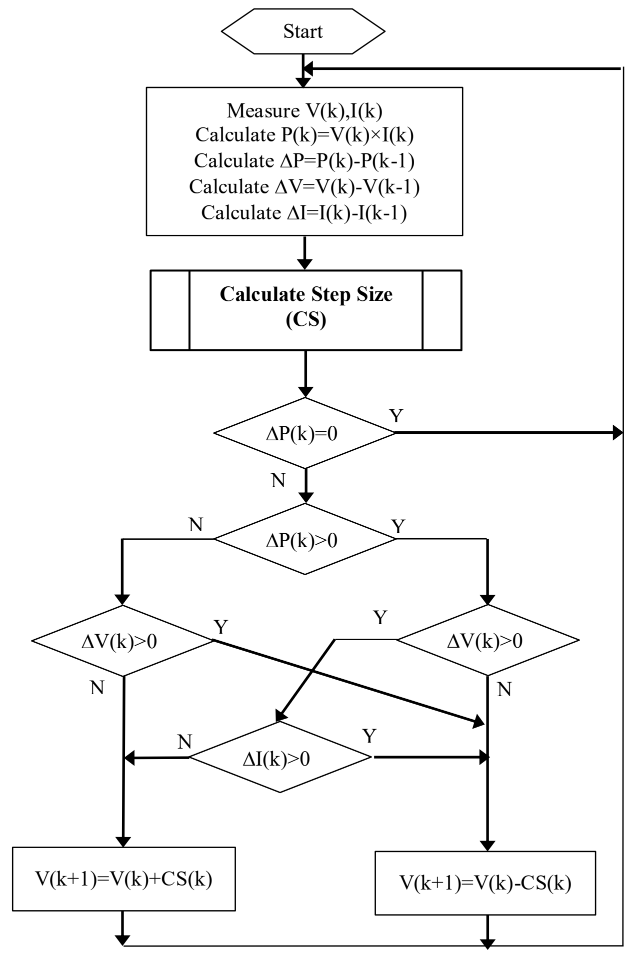

Figure 5. Proposed Algorithm

It is noted here that CS1, CS2, CS3 shown in the figure are not the voltage differences, but they are the duty cycles of the DC-DC converter that correspond to the voltage changes. The interval shown in the figure is just to simplify the explanation.

The CS1 is adopted when there is an irradiation change as described in the following. Suppose that the current operating point is at point B (the previous position is at point A). When the irradiation changes, the operating point will be shifted, for instance, to point C. As shown in the figure, shifting the position from point B to point C (from point A previously) requires a large step size. Further, it leads to the drift condition, i.e. since $\Delta P>0$ and $\Delta V>0$ then it will perturb the voltage to the right (point D). Thus it moves to the wrong detection. Therefore the drift detection method should be adopted as shown in Fig. 3 and Fig. 5.

The CS1, CS2, and CS3 are defined using the following formula

$$CS(k)=\begin{cases} CS1(k)=\alpha\times|\Delta P(k)|, & if\,(\Delta V(k)\times\Delta I(k))>0 \\ CS2=0.05, & if\left(\left|\dfrac{\Delta P(k)}{\Delta V(k)}\right|\right)\geq\beta \\ CS3=0.002, & otherwise \end{cases} \quad (2)$$

where α and β are the constants which are defined empirically, and the condition $(\Delta V(k)\times\Delta I(k))>0$ is used to ensure that the $CS1$ is only applied when the irradiation changes. The CS2 is a step size which is used to move the operating point from point C to point E. While CS3 is a step size which is used to move the operating point from point E to point MPP (Maximum Power Point). As illustrated in the figure, the CS3 should be small to avoid the high oscillation, and the CS2 should be a large value to speed up the response time. Instead of using the variable values as the CS1, we choose the fix values for CS2 and CS3.

The flowchart of our proposed algorithm is depicted in Fig. 5. As shown in the figure, the algorithm is almost similar to [8], except that we introduce the new method to calculate the step size CS as expressed by (2).

IV. Simulation Results

We verify our proposed method by the simulation using Matlab/Simulink. We employ the PV and the DC-DC converter (Buck-Boost converter) models from [23]. The specification of the PV model, the PV temperature and the profile of sun irradiation used in the simulation are given in Table 1.

We compare our proposed method (**Prop**) with the existing methods as follows: a) Fixed step size = 0.05, drift checking (**FD-05**); b) Fixed step size = 0.01, drift checking (**FD-01**); c) Fixed step size = 0.002, drift checking (**FD-002**); d) Fixed step size = 0.05, no drift checking (**FND-05**); e) Fixed step size = 0.01, no drift checking (**FND-01**); f) Fixed step size =0.002, no drift checking (**FND-002**).

TABLE I. Specification of PV Model

Parameter	Value
Maximum power (Pmax)	281 W
Voltage at Pmax (Vmp)	34 V
Current at Pmax (Imp)	8.26 A
Open circuit voltage (Voc)	37.51 V
Short circuit current (Isc)	8.63 A
Total cells in series (Ns)	10
Total cells in parallel (Np)	6
PV temperature	25 ^{0}C
Sun irradiation	1000 W/m^2 (0-1 s); 300 W/m^2 (1.01-2 s); 1000 W/m^2 (2.01-3 s)

TABLE II. Comparison Results of Generated Power

Method Name	Generated Power
Prop	63.16 KW
FD-05	62.78 KW
FD-01	56.46 KW
FD-002	46.32 KW
FND-05	62.50 KW
FND-01	56.08 KW
FND-002	45.96 KW

The simulation results are depicted in Fig. 6 and Fig. 7. Fig. 6 shows the curves of generated power of **Prop**, **FD-05**, **FD-01**, **FD-002**. While Fig. 7 shows the curves of generated power of **Prop**, **FND-05**, **FND-01**, **FND-002**. It is clearly shown from the figures that our proposed method (**Prop**) achieves the highest performance among the others, especially it has no oscillation in the steady state. The response time of our proposed method is also fast, it is almost the same as the fixed step size of 0.05 (**FD-05** and **FND-05**). However, the **FD-05** and **FND-05** exhibit the oscillations in the steady state.

The figures also show the typical problem of the fixed step size of P&O, i.e. the small step size yields the smaller oscillation but slower response, the large step size yields the larger oscillation but faster response.

The effect of drift could be examined from the time of 2.01 seconds, i.e. when the irradiation changes from 0.3 W/m^2 to 1 W/m^2. The upper figures in Fig. 6 and Fig. 7 are the curves of generated power from 2 to 2.05 s. From the figures we can see that starting from 2.01 s, the curves of **FD-05** and **FD-01** differ from **FND-05** and **FND-01**. It is caused by the irradiation change at 2.01 s that leads to the wrong perturbation direction (drift problem). Thus it changes or shifts the curve of generated power. Since the step sizes of **FD-002** and **FND-002** are very small, the difference in the curve is not significant.

The comparison results of generated power for all seven methods are given in Table 2, when the generated power is accumulated power during 3 seconds of the simulation. From the table, it is clearly shown that our proposed method (**Prop**) achieves the highest generated power, followed by the **FD-05** and **FND-01**. The results show that the smaller step size reduces the generated power as confirmed by Fig. 6 and Fig. 7. The results also show that the fixed methods with drift checking (**FD-05**, **FD-01**, **FD-002**) yield the higher generated power than the methods without drift checking (**FND-05**, **FND-01**, **FND-002**).

V. Conclusion

The method to adjust the step size of the P&O algorithm is presented. The step size is calculated based on two parameters, namely the irradiation change, and the slope of the P-V curve. It yields a variable step size which is appropriate to cope with the typical problems of the P&O algorithm such as the response time, the oscillation in the steady state, and the drift. The proposed method is simulated using the Matlab/Simulink environment and shows superiority compared to the existing techniques.

In future, we will implement our method on the embedded system. Further, the combination with other advanced techniques will be conducted.

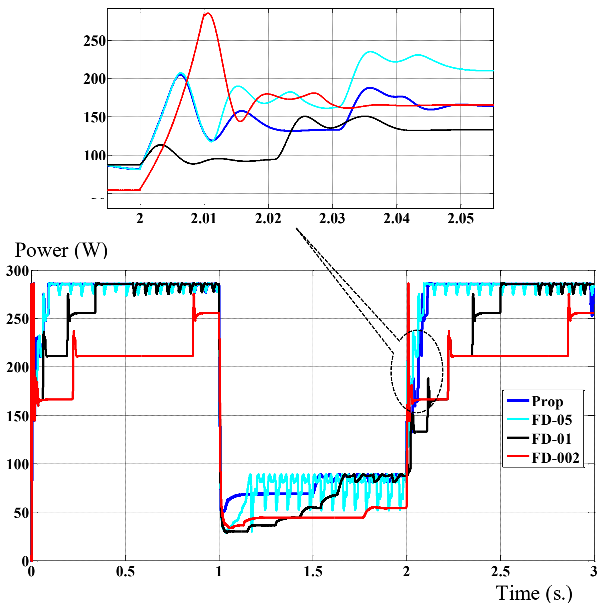

Figure 6. Curves of generated power: Prop, FD-05, FD-01, FD-002

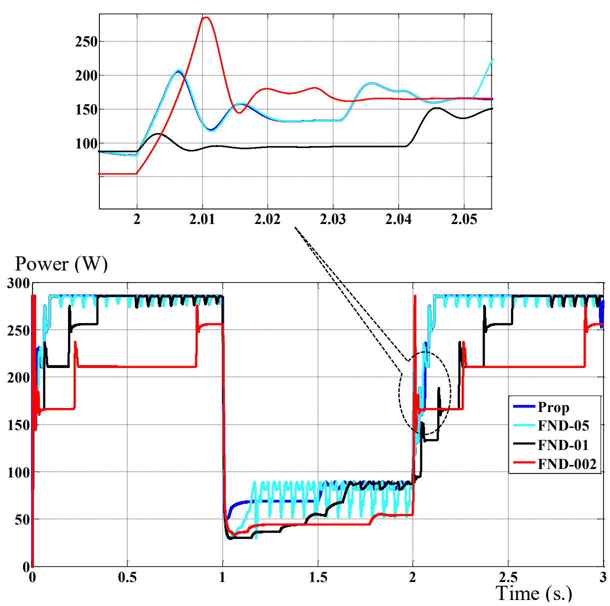

Figure 7. Curves of generated power: Prop versus FND-05, FND-01, FND-002

ACKNOWLEDGMENT

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