Design Maximum Power Point Tracking of Wind Energy Conversion Systems Using P&O and IC Methods

F Ronilaya[1], B Setiawan[1], A A Kusuma[1*], I Mahfudi[1] and D M Yuliawan[2]

[1]Electrical Engineering Departement, State Polytechnic of Malang, Jl. Soekarno-Hatta No. 9, Malang 65141, Indonesia
[2]School of Electrical Engineering and Informatics, Institut Teknologi Bandung. Jl. Ganeca No. 10, Bandung 40132, Indonesia

*arddy_awangga@polinema.ac.id

Abstract. Compare MPPT method between P&O and IC systems. Rapidly growing renewable energy is wind power. The rapid growth is due to the fact that the world has a great resource of wind energy. Wind energy has been estimated to be capable of suppressing up to 10% of the entire world's electrical energy. Availability uncertain winds became the main issue on wind energy. Because wind power systems, power issued on wind power system depends on wind speed. One of the common methods developed researchers is Maximum Power Point Tracking (MPPT) Control. Generally, MPPT methods can be broadly classified into those that do not use sensors and those that do use sensors. The methods without sensors track the MPP by monitoring the power variation. Method use sensors is widely divided into perturbation and observation (P&O) and incremental conductance (IC). The use of the P&O method does not need information and parameters of wind speed wind turbines making it more efficient and has the lowest price. This method has a simple feedback and measurement of some parameters. IC has a performance level close to P&O, but in general the higher implementation cost compared to P&O would not be justified by an improvement in performance. On this paper, researcher mean compare MPPT methode between P&O and IC systems. Researchers intend to want to compare several MPPT methods to find out the type of the MPPT has the best effectiveness. This research resulted that MPPT control type P&O has the results of a greater power output than the type IC. P&O generates its power output value is 1050 Watts while the IC produces a power output is 550 Watts. A comparison between the IC and P&O on the conditions of starting to move torque on the power absorption, P&O results the smallest power absorption than IC that is 25 Nm while the IC of 29 Nm. Whereas in normal conditions, the IC results the smallest power absorption that is IC 3 Nm and P&O of 4.5 Nm.

1. Introduction

Annually renewable energy are expected to experience increased. A variety of renewable power plants that have been present i.e., wind energy, solar energy, wave energy, hydropower and sophistication of the system based on hydrogen. Rapidly growing renewable energy is wind power and has given an important role in reducing energy use emissions worldwide in the Green House Gas [1-2]. The rapid growth is due to the fact that the world has a great resource of wind energy. Wind energy has been estimated to be capable of suppressing up to 10% of all the world's electrical energy [3]. Wind energy has advantages over solar energy i.e. lower installation costs compared with solar energy [4-5].

IOP Conf. Series: Materials Science and Engineering **407** (2018) 012159 doi:10.1088/1757-899X/407/1/012159

Availability uncertain winds became the main issue on wind energy. Because wind power systems, power issued on wind power system depends on wind speed. It makes the researchers feel challenged to look for methods to maximize the efficiency power on wind energy plants. One of the common methods developed researchers is Maximum Power Point Tracking (MPPT) Control. MPPT is a method used to optimize the power output as generation of electricity. MPPT in variable-speed operation systems, like doubly fed induction generator (DFIG) and permanent magnet synchronous generator systems [6].

Wind power system voltage keeps on fluctuating, then needed tracking current and voltage are continuously so that maximum power is obtained by using the MPPT technique. Boost converter used on MPPT technique for tracking maximum power and by extracting maximum power form wind energy system. Using MPPT is able to improve the performance of wind power generation system.

Generally, MPPT methods can be broadly classified into those that do not use sensors and those that do use sensors. The methods without sensors track the MPP by monitoring the power variation. Method use sensors is widely divided into perturbation and observation (P&O) and incremental conductance (IC) [7-9]. The method P&O has a simple algorithm so it is easy to be implemented on a wind turbine system. The use of the P&O method does not need information and parameters of wind speed wind turbines making it more efficient and has the lowest price among the existing methods. This method has a simple feedback and measurement of some parameters. Disadvantages of this method produce oscillations on the conditions of steady state duty cycle changes due to constant [10-11]. IC has a performance level close to P&O, but in general the higher implementation cost compared to P&O would not be justified by an improvement in performance [12] and IC method searches for the peak power [13]. On this paper, researcher mean compare MPPT method between P&O and IC systems. Researchers intend to want to compare several MPPT methods to find out the type of the MPPT has the best effectiveness. This comparison to known performance of the two systems in wind power generation.

2. Experimental Method

The acquisition of wind energy, the resulting air pressure from the air flow on the blades and turn it around that produce the kinetic energy of the wind. The energy is contained in the wind, and the rotor blades rotate in wind. Under the effect of aerodynamic force, the vanes generate torque[14]. The power $P_{\omega m}$ generated by wind turbine is expressed as equation(1):

$$P_{\omega m} = \frac{1}{2}\Pi\rho C_p R^2 V_\omega^3 \tag{1}$$

Air density is ρ, blade radius is R, wind speed is V_ω, of wind turbine coefficient of performance is C_p.C_p includes the blade tip speed rati λ. λ is defined as the relationship between blade tip speed and wind speed, expressed as equation (2):

$$\lambda = \frac{T\omega_m}{v_\omega} \tag{2}$$

Blade rotation speed is ω_m. Power characteristic curves at different conditions of speed is shown in (Figure.1).

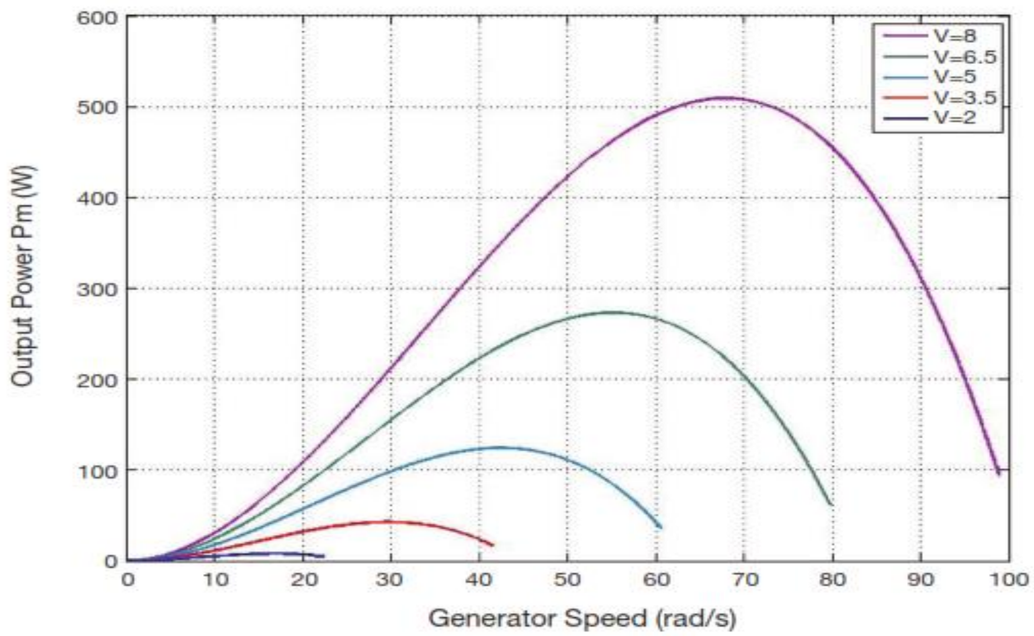


Figure 1. Power characteristic curves[17].

2.1. Wind power system architecture

Figure 2 shows wind power system architecture. Generator used is of permanent magnet synchronous generator (PMSG) type [2][14][16][17]. PMSG is incorporated with wind turbines connected to a set of rectifiers. Rectifier change Generator AC into DC. Signal voltage DC and currents obtained and the signal is connected to the DC-DC boost converter. MPPT function for signal control and adjustment of the cycle switching pulse width modulation (PWM). the DC-DC boost converter is connected to the load, and the system output power is measured[17]. Figure 3 shows basic structure of the boost converter. When the switch is "on", the wind power system charges the inductor via the switch. When the switch is "off", the wind power system releases the inductance energy to the load via diode. The output voltage and current can be changed by different input voltages and currents by adjusting the duty ratio[7] (Figure 2&3).

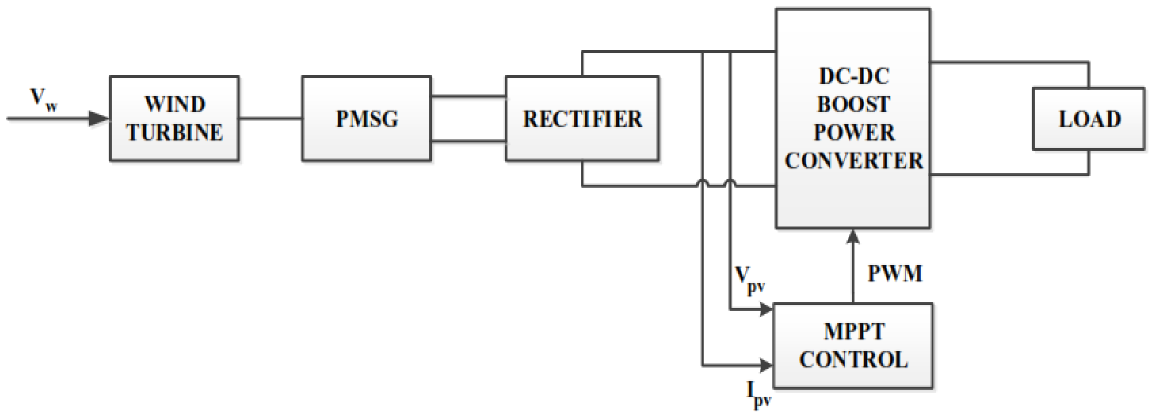


Figure 2. Wind power system architecture.

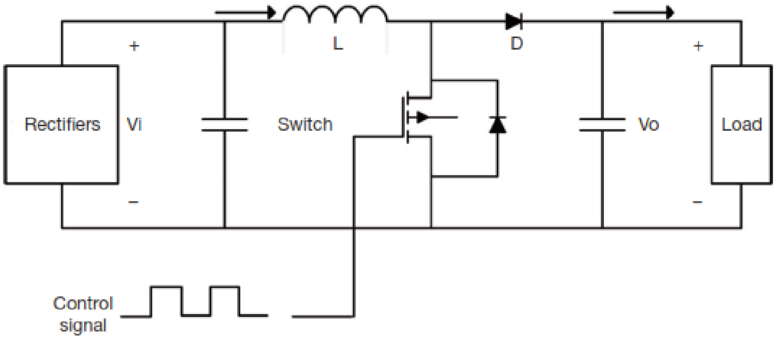


Figure 3. Boost-converter diagram.

Table 1 shows the parameters in the boost converter. The first step is to determine the duty cycle, D which is as follow[18]:

$$\text{Maximum Duty Cycle: } D = \frac{V_{out} x \eta}{V_{in}} \quad (3)$$

Where, - η = efficiency of the converter
- V_{in} = minimum input voltage
- V_{out} = output voltage

Inductor Selection: By selecting appropriate value of inductor current, current ripple can be reduced [18].

$$\text{L} = \frac{V_{in} x (V_{out} V in)}{\Delta I_L x fs x V_{out}} \quad (4)$$

Where, - fs = Frequence switching
- ΔI_L = Inductor ripple
- V_{in} = Input Voltage
- V_{out} = required output voltage.

Capacitor Selection: Equations can be used to adjust the output capacitor values for a desired output voltage ripple[18]:

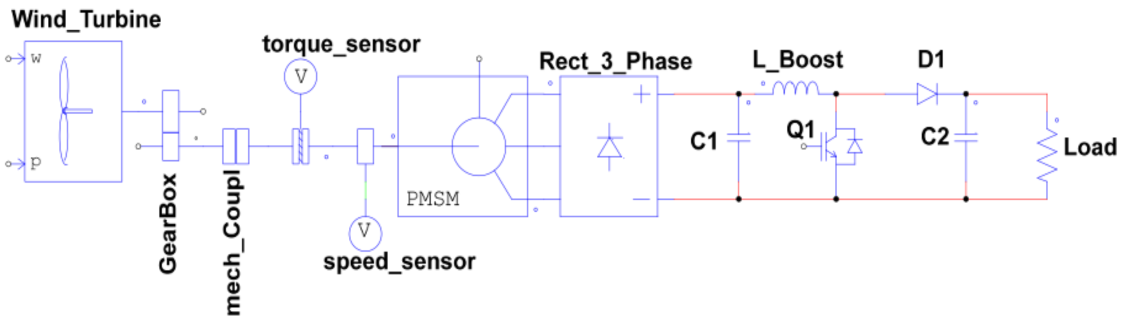
$$C_{out(min)} = \frac{I_{out(max)} x D}{fs x V_{out}}$$

Where, C_{out} = output capacitance.

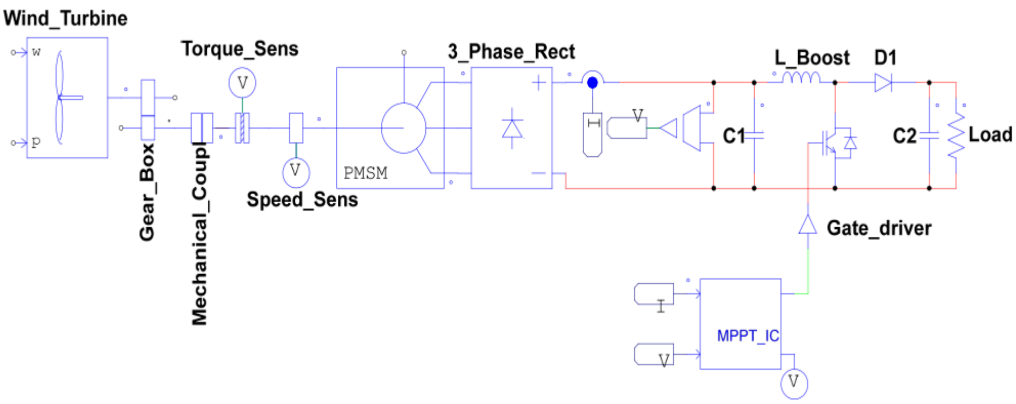
Table 1. Parameters of Boost Converter.

Parameter	Value
Input Voltage (Vin)	8.74 V
Output Voltage (Vout)	151 V
Output Capacitor (Cout)	400 µF
Inductor (L)	700 mH
Switching Frequency (fs)	5 kHz

Design of MPPT technique is proposed for this research using PSIM 9.0 Software. The simulation is compared the Non-MPPT, INC and P&O proposed in this paper at constant wind speed and variable wind speed. Fig. 4. show the schematic of the wind energy system is proposed.



(a)



(b)

Figure 4. Wind energy system architecture (a) Design Non-MPPT Controller (b) Design P&O and IC Controller.

2.2 Perturbation and Observation (P&O)
Application of the P&O method is so widely used in the last few years. P&O has a simple architecture. Another advantage of this type of MPPT is a bit parameter requirements. he P&O MPPT technique algorithm calculates the power P(t) by measuring the instant voltage V(t) and current I(t) and then compares it with last calculated power P(t-1). The algorithm continuously perturbs the system if the operating point variation is positive; otherwise the direction of perturbation is changed if the operating point variation is positive [17]. The algorithm of P&O technique is shown in Figure 5 and design of simulated P&O in PSIM software shown in Figure 6.

2.3 Incremental Conductance (IC)
IC has been proposed as a solution to overcome some limitations of the P&O method, such as convergence speed and steady-state error [17]. Use The IC is based on power-voltage (P – V), equations (7) or (8) must be met at maximum power point:

$$\frac{dP}{dV} = 0 \tag{5}$$

$$\frac{dI}{dV} \approx \frac{I - I_0}{V - V_0} = \frac{\Delta I}{\Delta V} \tag{6}$$

Where I_0 and V_0 are the current and voltage captured at previous point in time, ΔI and ΔV are the variation of current and voltage in unit time. However, when the method processes MPPT, the offset ΔV determines the speed of reaching the MPP and the perturbation after the MPP is reached. The decision must be made by the user. The algorithm of IC technique is shown in Figure 7 and design of the simulation of IC on PSIM software shown in (Figure 5).

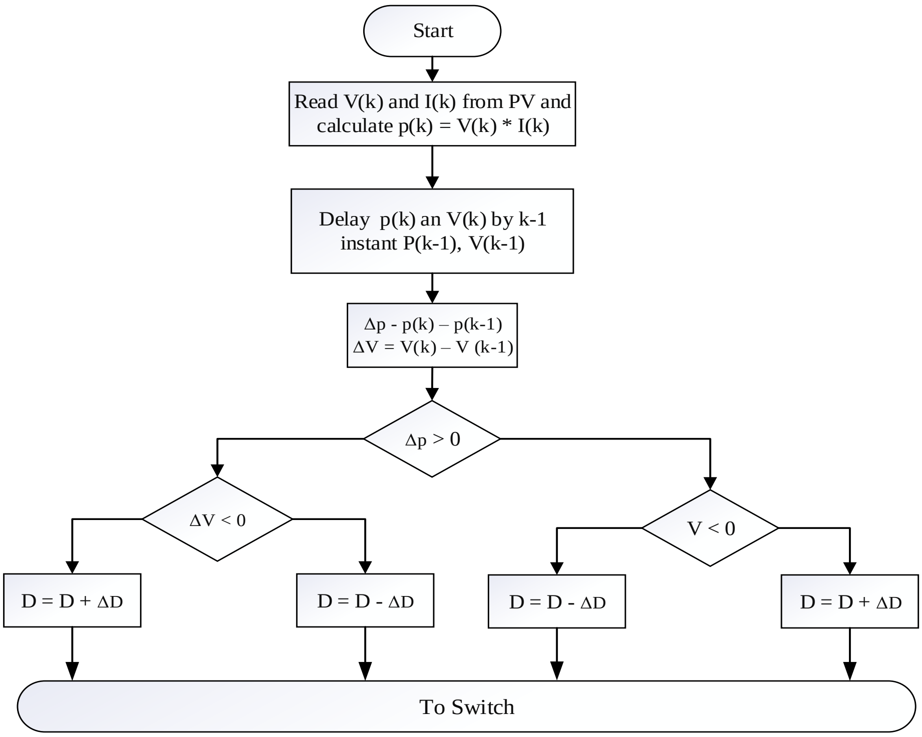


Figure 5. Flowchart of P&O Method.

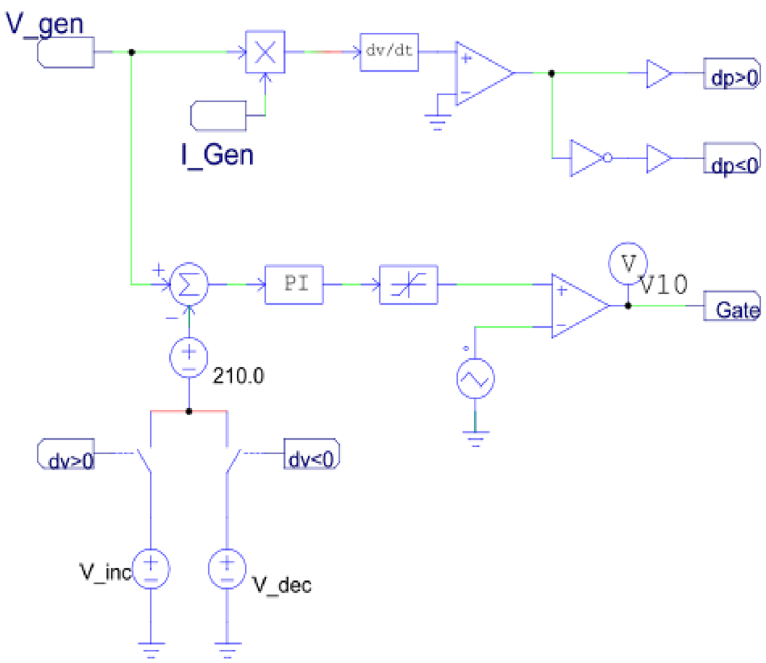


Figure 6. Design of simulation of P&O on PSIM Software.

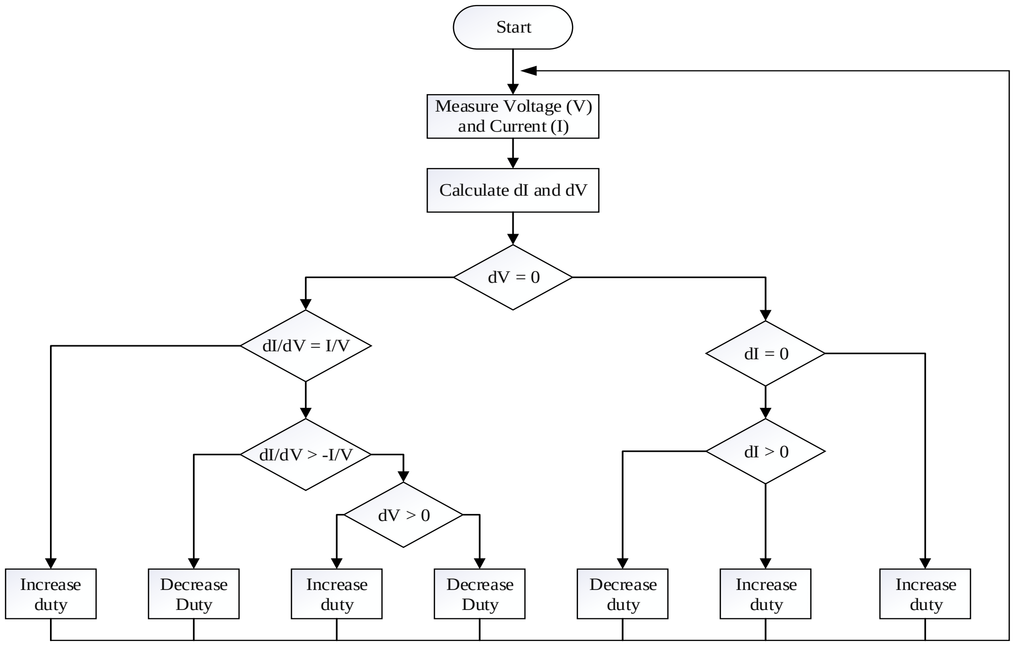


Figure 7. Flowchart of IC Method.

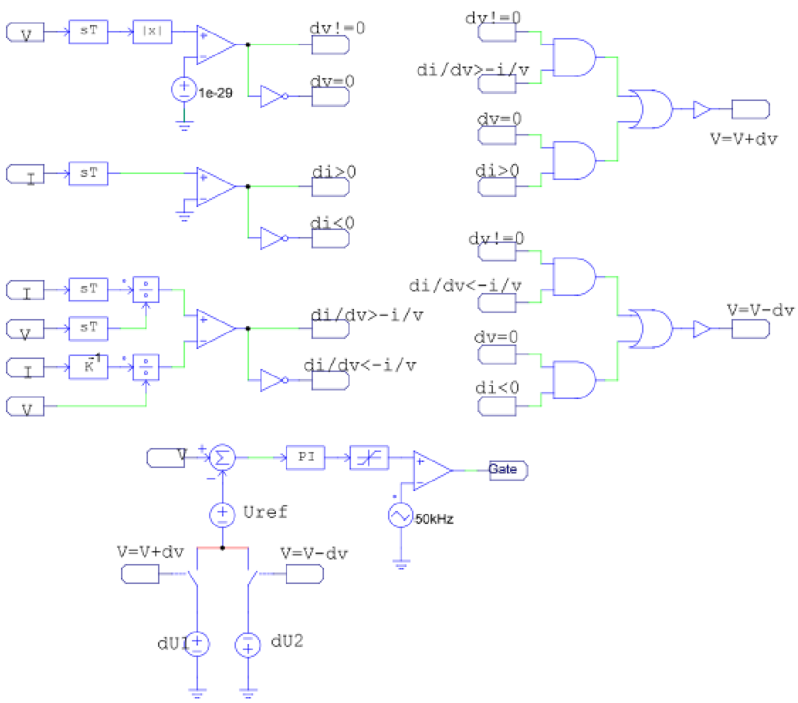


Figure 8. Design of simulation of IC on PSIM Software.

3. Results and Analysis

This research used PSIM 9.0 Software to build the model and controller of wind power system. The simulation compared the Non MPPT, P&O and IC. First test with constant speed customize is at 12.2 m/s. next do a comparison between Non-MPPT, IC and P&O. The results of this testing is shown in Fig. 9. This testing is done to analyze and compare the third method in the same wind speed conditions. The spesification of design proposed is shown on Table 2.

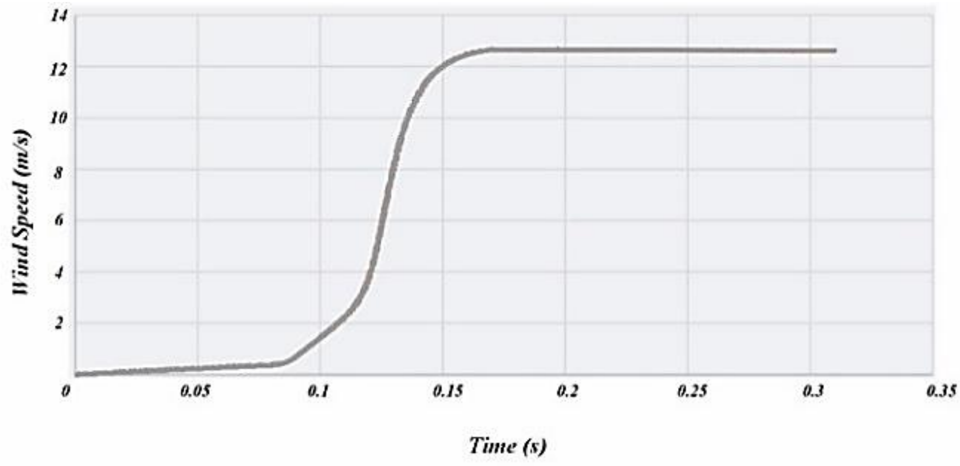


Figure 9. Comparison between Non MPPT, IC and P&O with the speed constant at 12.2 m/s.

Table 2. Parameters of Wind Energy System[10].

Wind Generator		***Wind Turbine***	
Parameters	Value	Parameters	Value
Power Rating	30 kW	Power rating	28 Kw
Poles	8	Radius	1 m
Rs	56 mΩ	Gear Ratio	1:1
Ls	1.6 mH	Base rotational speed	180 rpm
Ld	1.6 mH	P	1.205 kg/ m^2
Moment of inertia	0.02 kg.m^2	Moment of inertia	0.025 kg. m^2

Figure 10 shows the characteristics of the rotor starting torques at Non MPPT, IC and P&O. IC absorbs power most high upon starting condition than P&O. But at a time when the nominal conditions, IC fewest absorb of power than P&O. Whereas on P&O at the time of starting condition process of absorbing is fewest power however, at nominal conditions P&O most high absorbing power.

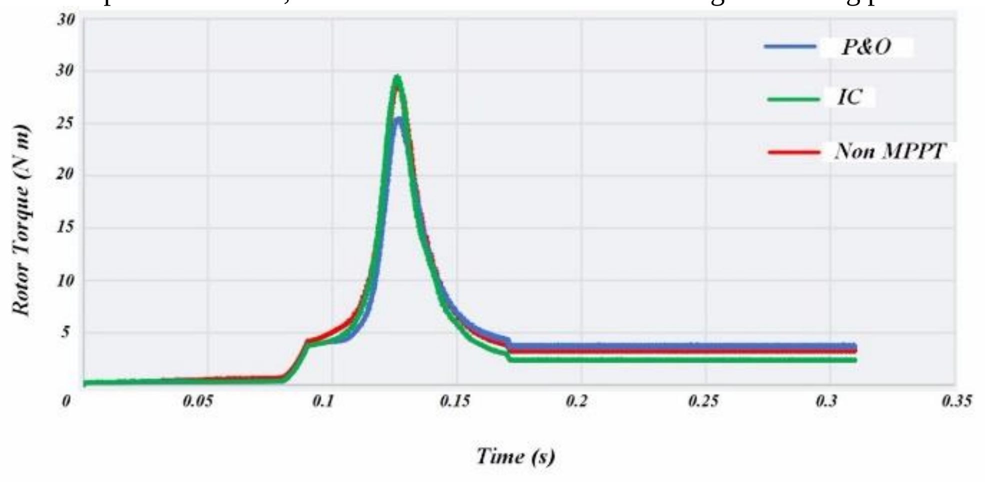


Figure 10. Characteristics of the rotor starting torques at Non MPPT, IC and P&O.

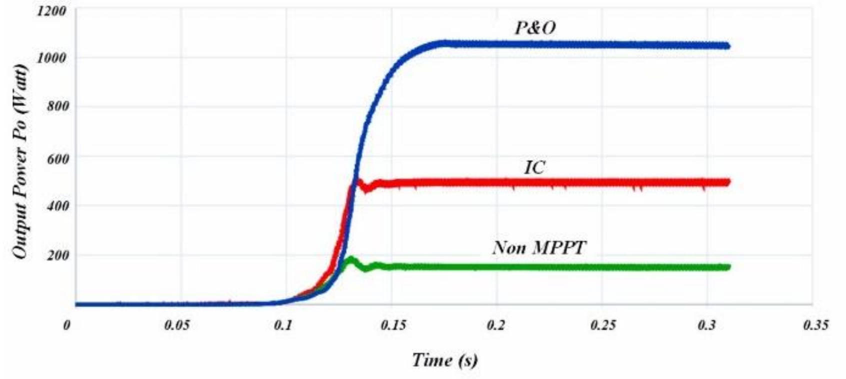


Figure 11. Comparison of the results of the output NON MPPT, IC and P&O on wind power system.

The output from the P&O largest compared IC and NON MPPT. Recorded approaching 1050 Watts. This value is the greatest power output. While the output of approaching the value of 500 Watts. so the power output from the turbine system output using NON MPPT, IC and P&O obtained that the P&O value is the highest output power. On non MPPT generated value approaching 200 watts. Non MPPT has the smallest value than P&O and IC methods.

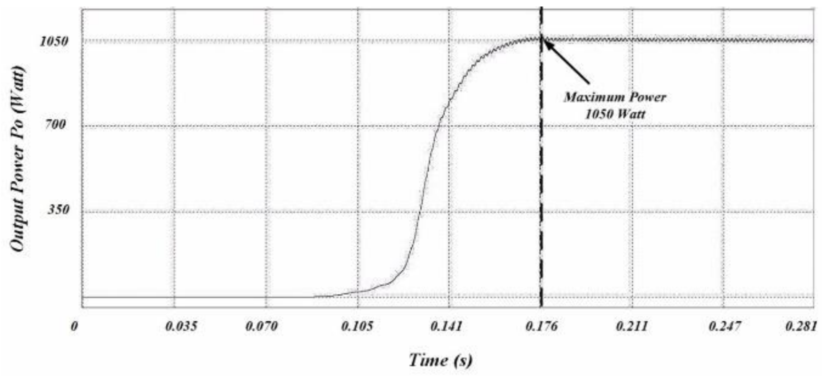


Figure 12. Maximum power point tracking of P&O method in wind power system.

Figure 12 shows the performance of boost converter with P&O method. This figure shows MPPT tracking to maximum power point is started at time 0 until 281 ms and resulted track the maximum power point is 1050 W at the time 176 ms.

4. Conclusions

In this research it can be concluded that MPPT control type P&O has the results of a greater power output than the type IC. P&O generates its power output value is 1050 Watts while the IC produces a power output is 550 Watts. A comparison between the IC and P&O on the conditions of starting to move torque on the power absorption, P&O results the smallest power absorption than IC that is 25 Nm while the IC of 29 Nm. Whereas in normal conditions, the IC results the smallest power absorption that is IC 3 Nm and P&O of 4.5 Nm.

Acknowledgment

The Authors would like to thank to The State Polytechnic of Malang for supporting to attend this conference.

References

[1] J Zhou *Status and Trends Of New Power Generation Technology*
[2] F Ronilaya and T State 2014 *Distribution Systems and Dispersed Generation - CIGRE SC C6 COLLOQUIUM Yokohama 2013 Frequency and Voltage Droop*

[3] E Adzic, Z Ivanovic, M Adzic and V Katic 2009 Maximum power search in wind turbine based on fuzzy logic control *Acta Polytech. Hungarica* **6** 1 pp. 131–149
[4] E Koutroulis and K Kalaitzakis 2006 Design of a maximum power tracking system for wind-energy-conversion applications *IEEE Trans. Ind. Electron*. **53** 2 pp. 486–494
[5] F Valenciaga, S Member, P F Puleston and P E Battaiotto 2003 Power control of a solar / wind generation system without wind measurement : A passivity / sliding mode approach *IEEE Trans. Energy Convers.* **18** 4 pp. 501–507
[6] K Vigneswaran and P S Kumar 2016 *Maximum Power Point Tracking (MPPT) Method in Wind Power System* pp 680–687
[7] K Shah, V Gaur, S Joshi and N Patel 2015 *Maximum Power Point Tracking Methods for Wind and Solar Conversion Systems for Standalone Generation PSIM based Perturb and Observe Method* pp. 46–54
[8] S M R Kazmi, H Goto, H J Guo and O Ichinokura 2011 A Novel Algorithm for Fast and Efficient Speed-Sensorless Maximum Power Point Tracking in Wind Energy Conversion Systems *Ind. Electron. IEEE Trans.* **58** 1 pp. 29–36
[9] D P Hohm and M E Ropp 2000 Comparative study of maximum power point tracking algorithms using an experimental, programmable, maximum power point tracking test bed *Photovolt. Spec. Conf. 2000. Conf. Rec. Twenty-Eighth IEEE* pp. 1699–1702
[10] Z M Dalala, Z U Zahid, W Yu, Y Cho and J S Lai 2013 Design and analysis of an MPPT technique for small-scale wind energy conversion systems *IEEE Trans. Energy Convers.* **28** 3 pp. 756–767
[11] T Lei, X Wei, Z Chengbi, L Jinhu and H Jinwei 2012 One novel variable step-size MPPT algorithm for photovoltaic power generation *IECON 2012 - 38th Annu. Conf. IEEE Ind. Electron. Soc.* pp. 5750–5755
[12] Y Huang, M Shen, S Member, F Z Peng and J Wang 2006 Z -Source Inverter for Residential Photovoltaic Systems *IEEE Trans. Power Electron.* **21** 6 pp. 1776–1782
[13] T Salma and R Yokeeswaran 2014 Incremental Conductance Technique for a Hybrid Wind - Solar Energy System **3** 5 pp. 2012–2015
[14] T Nakamura, S Morimoto, M Sanada, Y Takeda and E Systems 2002 Optimum Control of IPMSG for Wind Generation System pp. 1435–1440
[15] E Hau 2005 Wind Turbines: Fundamentals, Technologies, Application, Economics. *Berlin, Ger. Springer.* p. 48
[16] F Ronilaya and H Miyauchi 2015 A new implementation of PID-type fuzzy controller for a battery grid-supporting inverter in an autonomous distributed variable-speed wind turbine *IEEE J Trans. Electr. Electron. Eng.* **10** 2 pp. 134–143
[17] K N Yu and C K Liao 2015 Applying novel fractional order incremental conductance algorithm to design and study the maximum power tracking of small wind power systems *J. Appl. Res. Technol.* **13** 2 pp. 238–244
[18] B Hauke 2009 Basic Calculation of a Boost Converter's Power Stage *Texas Instruments, Appl. Rep. Novemb.* pp. 1–9