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

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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 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 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].
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):

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

Air density is $\rho$, blade radius is $R$, wind speed is $V_\omega$, of wind turbine coefficient of performance is $C_p$. $C_p$ includes the blade tip speed rati $\lambda$. $\lambda$ is defined as the relationship between blade tip speed and wind speed, expressed as equation (2):

$$\lambda = \frac{T\omega_m}{V_\omega}$$

Blade rotation speed is $\omega_m$. Power characteristic curves at different conditions of speed is shown in (Figure.1).
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 1. Power characteristic curves[17].

Figure 2. Wind power system architecture.
Table 1 shows the parameters in the boost converter. The first step is to determine the duty cycle, \( D \) which is as follows [18]:

\[
D = \frac{V_{out} \times \eta}{V_{in}}
\]

(3)

Where,
- \( \eta \) = efficiency of the converter
- \( V_{in} \) = minimum input voltage
- \( V_{out} \) = output voltage

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

\[
L = \frac{V_{in} \times (V_{out} / Vin)}{\Delta I_L \times f_s \times V_{out}}
\]

(4)

Where,
- \( f_s \) = Frequency switching
- \( \Delta I_L \) = 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]:

\[
C_{out(min)} = \frac{I_{out(max)} \times \Delta D}{f_s \times V_{out}}
\]

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 \( \mu \)F |
| 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.

![Wind Energy System Architecture](image)

**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. The 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:

$$\frac{dP}{dV} = 0$$ (5)

$$\frac{dl}{dV} = \frac{l - I_o}{V - V_o} = \frac{\Delta I}{\Delta V}$$ (6)
Where $I_0$ and $V_0$ are the current and voltage captured at previous point in time, $\Delta I$ and $\Delta V$ are the variation of current and voltage in unit time. However, when the method processes MPPT, the offset $\Delta V$ 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.
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 specification 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.

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