Modified Maximum Power Point Tracking on Models of a 400 Wp Wind Power Plant

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Abstract—Many papers discuss the Maximum Power Point Tracking (MPPT) control simulation "Perturb and Observe" (P&O), while its realization and practice in control systems remains a major challenge. The purpose of this research to study experimentally by optimizing wind turbines PMSG connected to DC-DC converter (Boost) and resistive load. The proposed MPPT P&O control algorithm modification will be analyzed by comparing with the control method without MPPT P&O at various wind speeds. The 400 WP wind power generation system uses a boost converter simulated in MATLAB/Simulink to analyze the performance of the proposed control algorithm. Modified MPPT P&O control Wind Turbine system with 3 m/s – 7 m/s speed variation at 20 ohm to 60 ohm load, wind turbine power has been successfully improved by an average of 11.868% compared to Wind Turbines that are not installed MPPT P&O. Therefore, MPPT P&O is very suitable to be applied at low average wind speeds.

Keywords—Wind Turbine, Modified MPPT P&O Algorithm, PMSG, Boost Converter

1. Introduction

Currently, the use of electrical energy is increasing exponentially. Meanwhile, sources of electrical energy, namely coal and oil derived from fossils, continue to decline. Fossil energy is predicted to run out in the future if energy use is not diverted to the use of other energy sources. The development of new and renewable energy is a solution to replace dwindling fossil energy. Therefore, new renewable energy sources are very important to be able to become alternative electrical energy that can meet increasing electricity needs and become energy in a sustainable manner. One of the uses of new renewable energy sources is wind energy which is harvested using wind power plants (WPP). To provide an adequate supply of energy sustainable, renewable energy sources seem to be one of the most efficient and effective solutions [1], [2], [3].

Maximum Power Point Tracking (MPPT) based on the (P&O) method that can be used to track the maximum power point with a shorter travel time without studying the characteristics of the turbine and without a wind speed sensor. Maximum power output can be obtained by controlling the duty cycle derived from pulse width modulation (PWM) and then searching by knowing the characteristics of the maximum power point (MPP) curve to get a maximum power output point from the WPP.

The advantage of the (P&O) method in this study is that it will engineer the value of the Duty Cycle (ΔD) change used to optimize the maximum power, namely when the maximum power point has been obtained, the D quantity will)-1 which is proven to produce greater output power than ordinary P&O method [4].

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2. Research Methodology

Wind turbine simulation modelling using permanent magnet synchronous generator (PMSG) on MATLAB R2016b-Simulink. The predetermined average wind speed data will be entered as input to the wind speed of the wind turbine [5]. The wind turbine will be connected to a rectifier and a boost type DC converter which will be connected to a resistive load. The MPPT method with the Perturb and Observe (P&O) algorithm is then used to optimize the maximum power output of the wind turbine.

The variation of wind speed used in this study was 3-7 m/s and was tested on the WPP 400 Wp model [6].

2.1. Wind Turbine Modelling

The wind turbine system used in the simulation consists of variable speed wind turbines, PMSG, and MPPT.

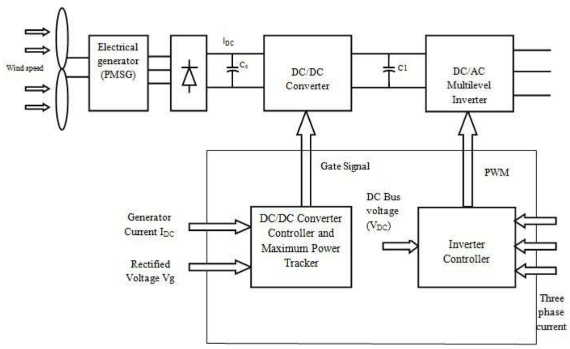

Fig. 1. Wind Turbine Modelling.

The wind turbine parameters used in this simulation are taken from the 400 Wp wind turbine data sheet (Table 1) and PMSG specifications (Table 2).

Table 1
Wind Turbine Specifications

Rated Power	400W
Rated AC Voltage	AC 12V / 24V
Rated Rotate Speed	900 rpm
Start-Up wind speed	2.5 m/s
Cut-in wind speed	3.5 m/s
Cut-out wind speed	15 m/s
Rated wind speed	12 m/s
Pole Diameter	48 mm

Table 2
PMSG Specification

Rs (stator resistance)	5,019 Ohm
Ld (d-axis ind.)	0,0082 H
Lq (q-axis ind.)	0,0082 H
No. of poles P	18
Moment of inertia	0.001197 kgm^2

Based on the power coefficient (Cp) which is a nonlinear function of the tip speed ratio (λ) and blade pitch angle (β) then modelled in the form of the Simulink function in Figure (2) below.

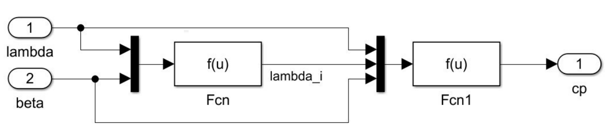

Fig. 2. Power Coefficient Model.

$$C_p(\lambda, \beta) = C_1\left(\frac{C_2}{A_i} - C_3\beta - C_4\right) ei^{-C6} + C6\,\lambda$$

The characteristics of the coefficient values C1 to C6 are [7]: C1 = 0.5176, C2 = 116, C3 = 0.4, C4 = 5, C5 = 21 and C6 = 0.0068. With the wind turbine and PMSG parameters that have been input, the nominal power characteristics (Watts) against the nominal generator speed (pu) will be obtained as shown in Figure 3 [7]below:

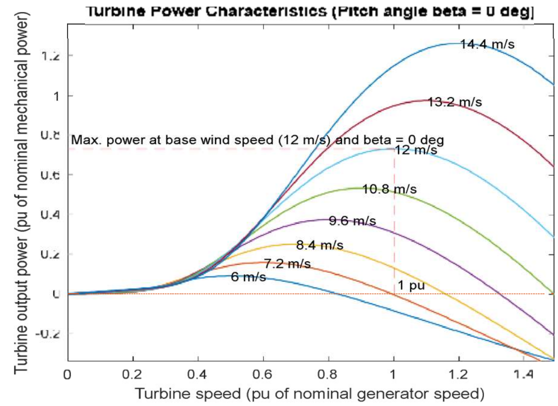

Fig. 3. Power Characteristics

2.2. Boost Converter Modelling

Boost Converter is a DC-DC converter that has a function to increase the input voltage to the output. The boost converter circuit has two operating conditions, namely when the switch is ON and when the switch is OFF. The input voltage from the boost converter is obtained from a 6-pulse uncontrolled rectifier (universal bridge) [8]. By using three pairs of diodes that work alternately, the AC voltage will be converted into a DC voltage which has six wave peaks. Inductor Value (L) The calculation of the inductor value operating in the CCM (continuous conduction mode) state is [8]:

$$L_{min} = \frac{D(1-D)^2 R}{2\,f}$$

Capacitor Value (C) Output capacitor used to reduce the voltage ripple caused by the increase in the load value. Calculation of the appropriate capacitor value is:

$$C_{min} \geq \frac{D}{R\,(V_{ripple)})f}$$

From the calculation results, it is found that the largest capacitor value is 1,956 mF, then the appropriate capacitor value is 10 mF.

2.3. Pulse Width Modulation

PWM is an important parameter so that the boost converter circuit can work according to its function.

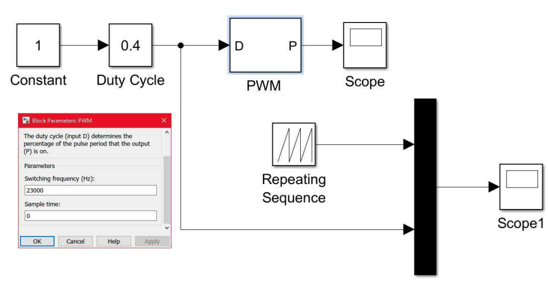

Fig. 4. PWM Circuit.

The triangular wave generated by the repeating sequence has a switching frequency of (f) with an output value of (0 1). When the duty cycle value is greater than the triangular wave output value, it will produce a positive value so that the PWM signal generated is high (ON) and a negative value so that the PWM signal is low (OFF).

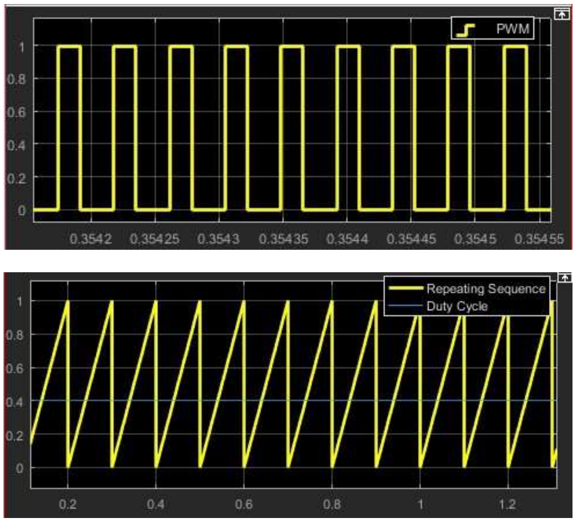

Fig. 5. Pulse Width Modulation.

2.4. Modified MPPT Perturb and Observe (P&O) Method

MPPT control in this simulation uses the *modified Perturb and Observe method* which will use input from the system based on the difference in dc voltage (ΔV_{dc}) and output power (ΔP_o).

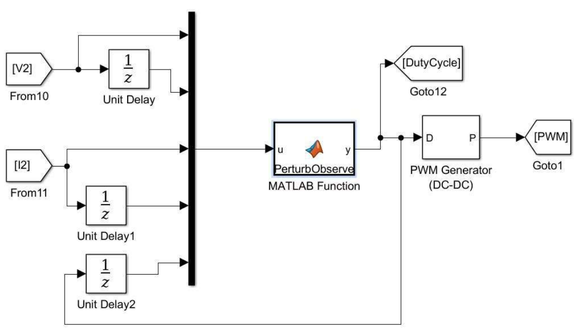

Fig. 6. P&O Circuit.

In Figure 5 there are 5 inputs which will then be controlled by several algorithms using the " if-then " logical operator. Then the MPPT will decide by changing (perturb) the variables that exist in this case, namely the PWM duty cycle ratio to control the boost converter in producing ON or OFF pulse waves so that it affects the rotation of the generator rotor to reach speed. optimal. The P&O algorithm diagram is modified in Figure 7 [9], then the MATLAB-function programming algorithm is made as follows:

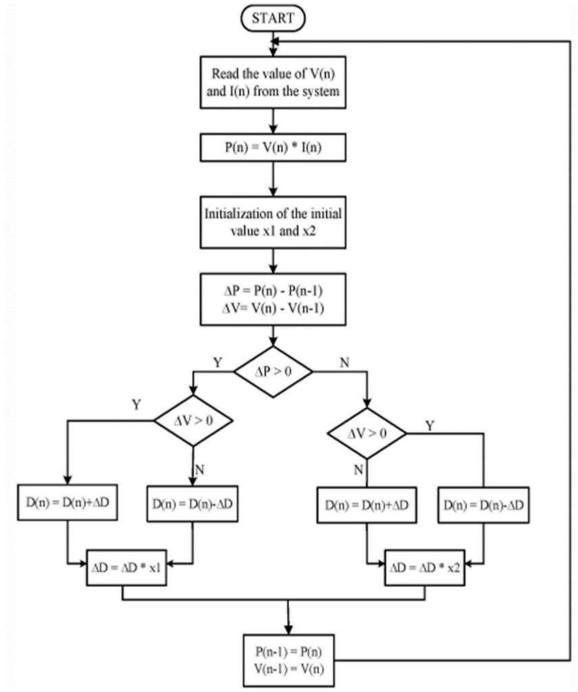

Fig. 7. Modified MPPT P&O Flowchart.

The value of D is multiplied by the value of x1 or x2 as shown in Figure (2.13), where the values of x1 and x1 are between 0 to 1 which aims to provide a better response and can also reduce power ripple when it reaches maximum power.

The results of this study indicate that to extract maximum power from the system using MPPT control by comparing the performance of P&O and modified P&O. The accuracy of performance using modified P&O is better than when using conventional P&O which is 98.176% [9].

2.5. Network Verification

Comparison of results based on Syahputra's research [7], with a model that has been designed with a 50-ohm load, is as follows:

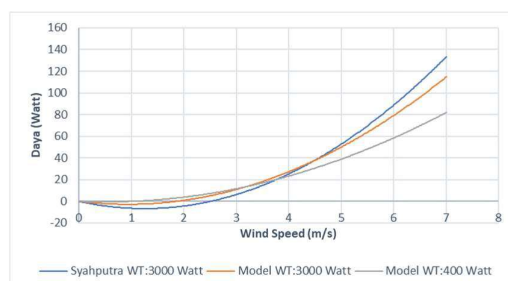

Fig. 8. Model Verification Circuit.

Based on Figure 7 above, from the three circuits, the 3000-Watt Wind Turbine design model has characteristics that are almost close to the Syahputra [10], circuit with 3000-Watt power. After that the 400-Watt Wind Turbine circuit can be assembled with the characteristics of results power which different. therefore, the circuit that has been designed can made ingredient for simulation on the writing this.

3. Result and Discussion

The actual data test aims to determine the characteristics of the 400 WP wind turbine at the previously obtained average wind speed. In this test, the rotational speed of the rotor, the voltage and the output power produced by the PMSG wind turbine will be calculated at the rectifier output. mounted on the load. As for the output power generated calculated based on the voltage and current values that are read on the voltmeter and ammeter. Then the product of our voltage and current plot in a graph showing the characteristics of the effect of stress as well as velocity rotor turbine wind to output power system.

3.1. Maximum Power Test Results

From actual test results without MPPT P&O at high wind speeds variable, based on the results obtained, at every certain average wind speed there is a point in the rotor speed and the DC output voltage from the turbine. wind on score burden certain which produces the greatest output power.

Table 3
Actual Maximum Power Test

v (m/s)	R (ohms)	V a (V)	I a (A)	P a (w)	RPM
3	60	12.5	0.24	3	343
4	60	16.5	0.54	8,91	412
5	30	16.5	0.54	8,91	479
6	20	15	0.7	10.5	568
7	20	16	0.76	12.16	682

3.2. Modified MPPT P&O Wind Turbine Performance

Based on the simulation that has been carried out in section 4.3, it is obtained that results which will be analysed to determine the effect of performance after the addition of MPPT P&O Modified.

Table 4
Modified P&O Simulation Result

V (m/s)	R (Ohm)	With MPPT		
		Power	RPM	t(s)
3	60	4.459	183	0.28
4	60	16.03	262	0.247
5	30	21.6	270	0.133
6	20	30.93	278	0.127
7	20	55.97	376	0.153
Average				0.188

Table 5
Without MPPT Simulation Result

With MPPT			ΔP (%)
Power	t(s)	RPM	
4.059	0.32	156	9.85
14.41	0.327	308	11.24
18.9	0.216	236	14.28
27.35	0.141	244	13.08
50.47	0.167	337	10.89
	0.2342		11.868

From table 4, the simulation results of power with respect to wind speed and load, the power graph in Figure 9 below is obtained as following:

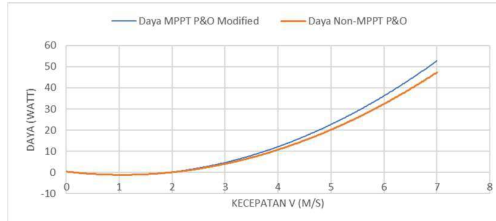

Fig. 9. P&O MPPT Power Graph.

The power generated in the wind turbine reaches a stable maximum value with an average time (t) of 0.2342 s and when MPPT P&O is installed, the average output power that can be produced by the wind turbine increases with an average increase of 11,868% with a relatively short average time (t) of 0.188 s.

3.3. Power Characteristics against Rotor Speed

The following graph of Rotor Speed characteristics on efficiency after installation of the Modified P&O MPPT can be seen in the picture following:

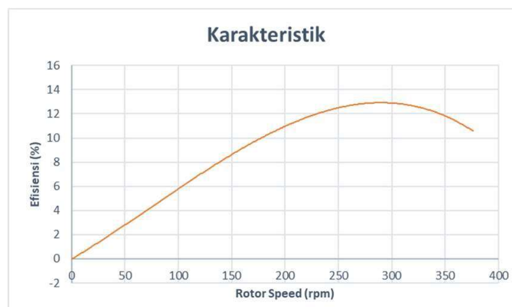

Fig. 10. Speed Characteristics.

In Figure 10 the P&O MPPT has the same efficiency characteristics as the power efficiency characteristics of wind speed. This is because the mechanical energy of the wind will be directly proportional to the rotation of the turbine rotor. From optimal power generated occurs when the rotor speed reaches 250-300 rpm.

4. Conclusion

From the research that has been done then it can be concluded as following:

1. The control system design that is applied to increase the Maximum Power Point (MPP) is the installation of a converter with MPPT using a modified P&O algorithm (P&O Modified) with converter modeling in the form of an Inductor (L) value of 100 H , a Capacitor

(C) value of 10 mF , and the Switching Frequency is 23 kHz.
2. The addition of MPPT P&O Modified to a series of wind turbine systems with variations in speed of 3 m/s – 7 m/s at a load of 20 ohms to 60 ohms, wind turbine power has been successfully increased by an average of 11.868 % compared to wind turbines that are not installed MPPT P&O.
3. The addition of the Modified MPPT P&O also increases the response time (t) of stability at its maximum value which is faster where before the MPPT P&O was installed the time it reached stability (t) of 0.2342 seconds but after addition of MPPT P&O time response stability (t) is relatively shorter, which is 0.188 seconds.
4. The optimal power generated occurs when the rotor speed reaches 250-300 rpm, after that the efficiency has decreased again. This decrease is caused by the algorithm applied to the MPPT that has worked to reach the maximum point of the system.

References

[1] O. Erdinc and M. Uzunoglu, "Optimum design of hybrid renewable energy systems: Overview of different approaches," *Renew. Sustain. Energy Rev.*, vol. 16, no. 3, pp. 1412–1425, 2012, doi: 10.1016/j.rser.2011.11.011.

[2] B. W. Dionova and Irianto, "Rancang Bangun Suplai Hybrid Energy Dengan Auto Selection Switching Untuk Beban Charger Battery Pada Laptop Dan Cooling Pad," *Pros. Semin. Nas. NCIET*, vol. 1, no. 1, pp. 1–12, 2020, doi: 10.32497/nciet.v1i1.8.

[3] E. Muljadi, C. P. Butterfield, J. Chacon, and H. Romanowitz, "Power quality aspects in a wind power plant," 2006, doi: 10.1109/pes.2006.1709244.

[4] D. A. Ernadi and M. Pujiantara, "Desain Maximum Power Point Tracking Untuk Turbin Angin Menggunakan Modified Perturb & Observe (P&O) Berdasarkan Prediksi Kecepatan Angin," *J. Tek. ITS*, vol. 5, no. 2, 2016, doi: 10.12962/j23373539.v5i2.16170.

[5] P. Li, W. Hu, R. Hu, Q. Huang, J. Yao, and Z. Chen, "Strategy for wind power plant contribution to frequency control under variable wind speed," *Renew. Energy*, vol. 130, pp. 1226–1236, 2019, doi: 10.1016/j.renene.2017.12.046.

[6] K. Angin, M. Bulan, and S. Klimatologi, "Wind Velocity By Months at Semarang Climatology Staon,." .

[7] A. Jain, S. Shankar, and V. Vanitha, "Power generation using Permanent Magnet Synchronous Generator (PMSG) based variable speed wind energy conversion system (WECS): An overview," *J. Green Eng.*, vol. 7, no. 4, pp. 477–504, 2018, doi: 10.13052/jge1904-4720.742.

[8] S. Kasbi, E. Rijanto, and R. bin Abd Ghani, "Design and Implementation of Controller for Boost DC-DC Converter Using PI-LPF Based on Small Signal Model," *J. Mechatronics, Electr. Power, Veh. Technol.*, vol. 6, no. 2, pp. 105–112, 2015, doi: 10.14203/j.mev.2015.v6.105-112.

[9] R. P. Eviningsih, R. I. Putri, M. Pujiantara, A. Priyadi, and M. H. Purnomo, "Controlled bidirectional converter using PID for charging battery in the stand-alone wind turbine system with Modified P&O to obtain MPPT," *Proc. 2017 Int. Conf. Green Energy Appl. ICGEA 2017*, no. 4, pp. 69–73, 2017, doi: 10.1109/ICGEA.2017.7925457.

[10] R. Syahputra and I. Soesanti, "Performance improvement for small-scale wind turbine system based on maximum power point tracking control," *Energies*, vol. 12, no. 20, 2019, doi: 10.3390/en12203938.

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