Monitoring Design And Power Optimization For Wind Turbine Using Perturb And Observe (P&O) Algorithm Based On Iot

Deta Brian Prayogi, Azmi Saleh, Triwahju Hardianto' Deta Brian Prayogi , Azmi Saleh ,Triwahju Hardianto

Graduate Student, Faculty of Engineering, Department of Electrical Engineering, Universitas Jember
Jalan Kalimantan No 37 Tegal Boto Sumbersari Jember 1st, Indonesia, PH 08566090307
deta.yogik@gmail.com

Lecturer of the Faculty of Engineering, Department of Electrical Engineering, Universitas Jember,
Jalan Kalimantan No 37 Tegal Boto Sumbersari Jember 2nd, Indonesia, PH +6282334136960
azmi.teknik@unej.ac.id

Lecturer of the Faculty of Engineering, Department of Electrical Engineering, Universitas Jember,
Jalan Kalimantan No 37 Tegal Boto Sumbersari Jember 3rd, Indonesia, PH +6282334136960
triwahju.teknik@unej.ac.id

Abstract: Wind energy is one part of renewable energy in which the utilization is used as an alternative to the supply of electrical energy, especially for hard-to-reach areas. The constraints of the wind energy utilization are the monitoring of the energy produced that has been unmonitored quickly, and the results of power output are not yet stable. Therefore, this study proposes the use of TCP/IP network based on Internet of things and an optimization control of the Perturb & Observe algorithm to get a stable power output. The use of this network aims at monitoring the output parameters of wind power plants with the parameters of the wind blowing speed and electricity generated. Moreover, all the data will be stored in the cloud using the internet network, while for the Perturb & Observe (P&O) algorithm as an optimization, it works by searching for the optimal PWM point value. Thus, the power extracted from wind power plants can be channeled to the load optimally.

Keywords: P&O Algorithm, Wind Energy, IoT, PWM.

1. INTRODUCTION

The development of the utilization of wind energy, especially in alternative providers of electrical energy, is growing fast. It can be attributed to the increasing energy needs. Wind energy was chosen because it is environmentally friendly and does not have exhaust emissions such as conventional fuels that can increase CO2 levels in the air. For the use of this wind turbine, it is usually placed near the seashore line or hill which is quite far away and difficult to be reached. Therefore, to carry out the monitoring process to get the latest data from wind turbines, operators must go to different locations. Thus, the operators feel difficult to see the performance of wind turbines that have been operated because the data obtained is limited. Remote monitoring system design is needed to monitor the performance of different wind turbines. This monitoring is designed using TCP / IP network or based on internet of things. It was selected because the internet network provides connectivity with the cloud so that the data obtained can be stored as a database. The potential use of wind energy has an effect on wind speed, the shape of turbines, and generators. The speed of the wind changes every time, giving rise to rotation and output voltage of different wind turbines. (Bayu C.2018). It raises constraints can affecting the supply of electricity to be consumed because the power generated is not maximum. Constraints of varying wind speeds are used based on the algorithm based on perturb & observe methods usually used to search for maximum power points. To implement this algorithm as a maximum power point finder, it is quite easy to implement because it is more efficient and has simple feedback from several measurements. (Dwian A.2016). This study aims to design monitoring and applying perturb & observe algorithms for optimizing IoT-based power. We will later analyze the performance of sending data using TCP/IP communication types and see the performance of the power optimization of perturb & observe algorithm.

2. RESEARCH METHOD

In this study, method employed is action research. It is used because this method refers to studies from journals related to power monitoring and optimization. It used perturb & observe algorithms and analyze the design system that has been applied to the tool.

3.1. Plan of System Design

The plan of design for monitoring and optimization of wind turbine power using a P&O algorithm based on IoT, which is in the form of hardware and software. For plan of software as an interface of data appearance, it used a website connected with firbase. Meanwhile, for the plan of hardware, it used Arduino Uno as the processor of the anemometer sensor, voltage, and current to be sent to firbase. Moreover, it is also for generating PWM duty cycle values from perturb & observe algorithm. The process of designing power monitoring and optimization uses perturb & observe algorithms from wind turbines using generators as electricity generators. In addition, the DC boost converter circuit is as a search for the maximum power point to be forwarded to the inverter to be applied to the load. Before heading to the load voltage and current, it will be monitored online from the website interface. Moreover, if there is a decrease in power, it added power optimization that can be controlled remotely.

Figure 1. explains the block diagram of a power monitoring and optimization system for a wind turbine.

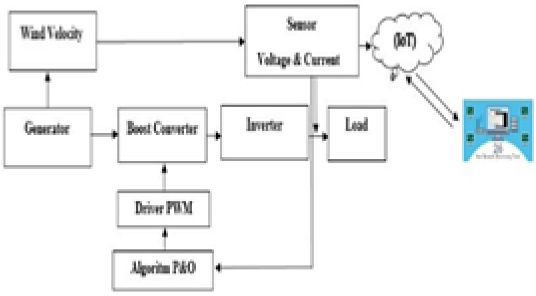

***Figure 1**: Block of monitoring system design for wind turbine power optimization*

3.2. Anemometer sensor

Anemometer sensor uses a bowl type. It is used because the research location is on the beach. The principle of the anemometer sensor is when the wind blows the bowl that is on the sensor in which it will rotate in the direction of the wind. The greater the wind is, the faster the propeller stakes will be. By using the following calculation, an average of the wind speed will be obtained.

$$V = r\omega b \qquad (1)$$

3.3. Voltage Sensor

The voltage sensor used a 500 mA CT transformer, with the principle of input voltage entering through the transformer primary side. Then, the voltage is lowered at the secondary side output, and it passed on the rectifier range to change the AC voltage to DC. Further, a voltage divider is added to be read by the ADC on Arduino Uno. In addition, the range of voltage that can be read is between 0V-5V, using the voltage divider calculation formula as follows:

$$Vout = Vin\frac{(R2)}{(R1+R2)} \qquad (2)$$

$$Vout = 5\,v\frac{(220\ ohm)}{(1000\ ohm + 220\ ohm)} = 4.1\ v$$

3.4. Current sensor

Current sensor uses SCT-013, and it can read current ranges up to 10 A, with the principle of non-contac. This non-contac system is to facilitate the reading of the current. It is without having to cut the wiring, so that it reduces the risk of being stung and safer. This sensor works on a small voltage range for Arduino Uno.

***Figure 2:** Current sensor SCT-013*

3.5. Module NodeMCU ESP8266

NodeMCU is an electronic board chip based on ESP8266 with the ability to run a wifi connection. Moreover, there are a number of I/O pins, thus they can be directly applied as monitoring or projects from IoT.

***Figure 3**. NodeMCU ESP 8266*

3.6. Boost Converter

Boost converter is a series of DC converters in which its duty is to increase the voltage. It is from a small input voltage to a large output voltage, without having to eliminate large power.

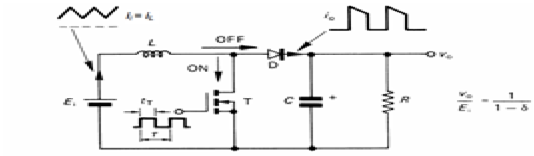

***Figure 4** : Boost converter circuit*

Based on the figure 4., to get the maximum and desired output voltage, calculation of the components that will be used is needed. These include: inductors, capacitors, resistors, and Mosfet channel types. It used the following formula equation.

1. For duty cycle of PWM

$$D = (1 - \frac{Vin-min}{Vout}) \qquad (3)$$

2. For Inductor

$$Lmin = \frac{D(1-)D^2)\,R}{2f} \qquad (4)$$

3. For Resistor

$$R = \frac{Vo}{I} \qquad (5)$$

4. For Capacitor

$$C = \frac{VoD}{R\Delta\,Vof} \qquad (6)$$

3.7. Perturb & Observe Algorithm

It is an algorithm often used to search for optimum power points. Sometimes, it is also called "hill-climbing", and this algorithm is very popular in Maximum Power Point Tracking (MPPT) systems. By using this algorithm, it makes easy to get maximum power, which is enough to do the number of adjustments on the DC converter. By changing the voltage and current values as parameters. Figure 5 shows the flow diagram of the perturb & observe algorithm.

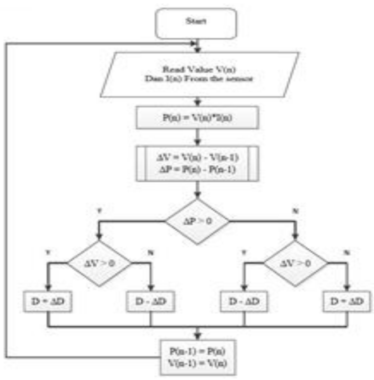

***Figure 5**: Flow chart of perturb & observe algorithm techniques*

This algorithm will observe every change, which changes depend on changes in current power and previous power used as a comparison value, with several parameters as initial price initiation to change the optimal PWM coefficient value.

3.8. Flowchart

Based on the explanation from Figure 6. Overall flowchart system from the initialization of voltage, current and wind speed sensors. After that the data will be processed, and they will be sent to the cloud (temporary storage). After the data is sent, if there is a decrease/change in power, it will do power optimization using the perturb & observe algorithm. It is to conduct an optimal power search point on the DC converter by assigning PWM values to the boost converter.

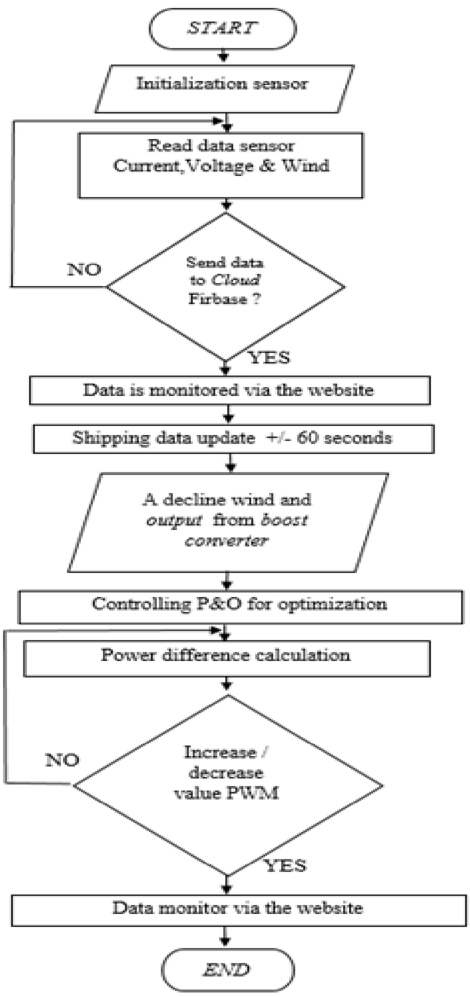

***Figure 6**: Flowchart of power monitoring and optimization.*

3. RESUTS AND DISCUSSIONS

3.1. Sytem Design Results

The design results of a power monitoring and optimization system implemented in the Jember University power system laboratory. The results of the realization of tools and websites that had been made were visualized in Figure 7.

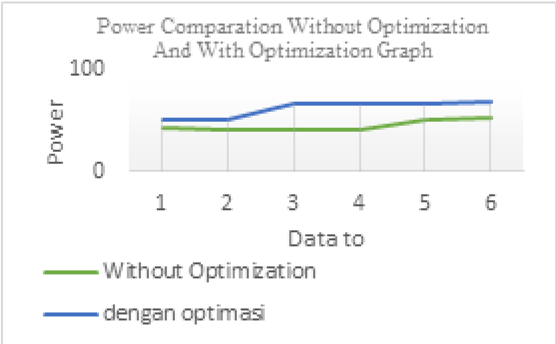

***Figure 7**. Monitoring system tools and website monitoring display*

3.2. Voltage Sensor Testing

The test of the voltage sensor device was conducted by simulating the change in voltage from the variable voltage AC power supply. The voltage varied from 25V to 150V. The results of the voltage sensor test were described in table 1. Based on these test results, the voltage sensor had an average reading error of 0.12%.

***Table 1** : Voltage sensor testing*

AC variable regulator (v)	Multimeter (v)	Voltage sensor (v)	Error (%)
25	26.2	26.8	0.6
50	50.8	50.8	0
75	75.5	75.6	-0.1
100	100.6	100.8	-0.2
125	125.6	125.8	0.2
150	150.2	150.6	0.4

3.3. Anemometer Sensor Testing

Wing speed sensor testing was done by comparing the value displayed on the digital anemometer and the value of the reading results from the anemometer sensor. Anemometer sensor test results were listed in table 2. The results presented above indicate that the anemometer sensor had an average reading error of 0.11%.

***Table 2** :Anemometer sensor testing*

Digital anemometer (m/s)	Sensor anemometer (m/s)	Error (%)
1.4	1.3	-0.1
1.8	1.9	-0.1
2.1	2.2	1
2.2	2.2	0
2.6	2.5	-0.1
3.0	3.0	0

3.4. SCT-013 Current Sensor Testing

The SCT-013 current sensor test included testing the reading of the SCT-013 current sensors by providing incandescent lamps loads that varied from 40W to 140W. The sensor test results were presented in table 3. The results above indicate that the average reading error was 0.032%. Thus, it can be concluded that the current sensor reading worked well.

***Table 3** : SCT-013 current sensor testing*

Load (W)	Amperemeter (A)	Current sensor (A)	Error (%)
40	0.11	0	-0.11
65	0.2	0.2	0
100	0.40	0.4	0
125	0.51	0.5	0.01
140	0.54	0.5	0.04

3.5. Power Monitoring and Optimization Testing Using the P&O Algorithm

The tests of all monitoring and optimization of power using the P&O algorithm included the performance of sending sensor reading data on Arduino and NodeMCU ESP8266 to Google Firbase and remote control to optimize the power output from wind turbines. The results of the power optimization test can be seen in the following table 4 while the data transmission test can be seen in table 5.

***Table 4** : System monitoring and power optimization testing*

Wind speed (m/s)	V	A	P	PWM	optimization
Without optimization					
1.0	220	0.2	42.3	0	off
1.3	219	0.2	40.5	0	off
1.6	223	0.2	41.9	0	off
1.4	221	0.2	41.0	0	off
1.1	218	0.3	50.5	0	off
1.3	216	0.2	50.3	0	off
With optimization					
2.0	219	0.3	50.7	192	on
2.1	218	0.3	51.2	200	on
2.2	214	0.3	66.8	201	on
2.2	215	0.3	66.4	210	on
2.3	214	0.3	65.6	209	on
2.2	218	0.3	67.7	210	on

***Table 5** : Data delivery testing*

ID	Firbase data record	Time sent
08062029012020	08:06: 20 29/01/2020	08:06: 20
08063429012020	08:06: 34 29/01/2020	08:06: 34
08064629012020	08:06: 46 29/01/2020	08:06: 46
08065729012020	08:06: 57 29/01/2020	08:06: 57
08070929012020	08:07: 09 29/01/2020	08:07: 09
08072229012020	08:07: 22 29/01/2020	08:07: 22
08073529012020	08:07: 35 29/01/2020	08:07: 35
08074629012020	08:07: 46 29/01/2020	08:07: 46
08085029012020	08:08: 50 29/01/2020	08:08: 50
08090029012020	08:09: 00 29/01/2020	08:09: 00

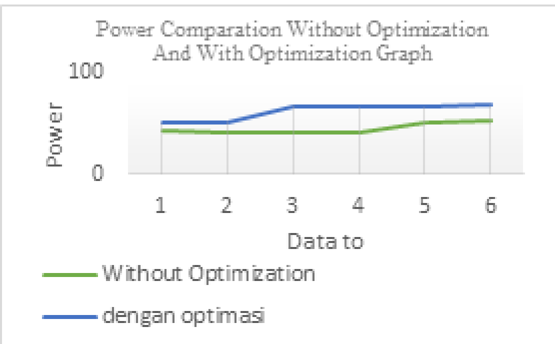

***Figure 8**. Maximum power comparison graph*

4. ANALYSIS AND DISCUSSION

The overall design of power monitoring and optimization was implemented in the Jember University power system laboratory. Observation data was carried out for 3 hours on January 29, 2019. Table 4 presents the data taken with wind speeds ranging from 1 m/s to 2.2 m/s. Data displayed on the website in the form of voltage, current, power, wind speed, and PWM. The value of power using optimization can be more optimal because of the PWM value sent to the boost converter which was an ideal value. As for the process of sending data from the sensor to the website, data transmission was updated every 12 seconds. Meanwhile, the average delivery time on firbase was 2 seconds. The test results indicate that the system was capable of sending monitoring data reliably. The following figure 9 and figure 10 were monitoring the display of current, voltage, power, and wind speed.

***Figure 9**. Display of current and voltage monitoring*

***Figure 10**. Display of power and wind monitoring*

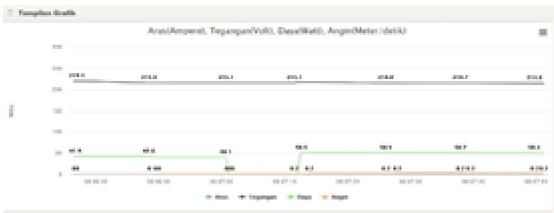

***Figure 11**. P&O power monitoring and optimization graph*

5. CONCLUSIONS

This study presents an IoT-based monitoring design to monitor the performance of wind tubing. The design included hardware for sending data to software as a monitoring display interface. This design plan was implemented in the Jember University power system laboratory. Based on the results of tests conducted, the average error reading scores were obtained as follows: a voltage sensor of 0.12%, anemometer sensor of 0.11%, and a current sensor of 0.032%. Whereas, the power optimization test showed the optimum power of 67.7 W with a PWM value of 210. Moreover, the average data transmission in Firbase was 2 seconds with the Firbase performing data displayed on the website for 12 seconds from the sensor to the NodeMCU.

REFERENCES

[1]. Bayu chaniago dan Amir Hamzah, (2018) [Analisa dan Desain Monitoring Pembangkit Listrik Tenaga Angin Dengan Menggunakan Web dan Arduino].Jurnal Jom FTEKNIK Vol.5 Edisi 2.

[2]. Dwi Anugrah Ernadi, Margo Pujiantara dan Mauridhi Heri Purnomo, (2016) [Desain Maksimum Power Point Tracking Untuk Turbin Angin Menggunakan Modified Perturb Observe P&O Berdasarkan Prediksi Kecepatan Angin].Jurnal Teknik ITS Vo. 5 No.2.

[3]. Helmi Cahyo Prasetyo dan Edriansyah, (2018) [Optimalisasi Daya pembangkit Listrik tenaga Angin Menggunakan Maximum Power Point Tracker MPPT Dengan Metode Perturb and Observe]. Jurnal Teknik Elektro Unesa Vol.7 No.2.

[4]. Machmud Effendi, Nur Alif dan Khusnul Hidayat, (2017) [Implemntasi Maximum Power Tracking Pada Photovoltage Berbasis P&O-Fuzzy]. Jurnal JNTETI Vol. 6 No 1.

[5]. Dimas Juniyanto, Tatyantoro Andrasto dan Suryono, (2018) [Optimalisasi Stand-Alone Photovoltage System Dengan Algoritma P&O-Fuzzy MPPT]. Jurnal Teknik Elektro Unes Vol.10 No 1.

[6]. Barry W William. (2006) [Power Electronics] University of Strathclyde. Glasgow.