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# STABILITY CONTROL OF FREQUENCY AND VOLTAGE IN WIND POWER PLANT USING COMPLEMENTARY LOAD WITH PID CONTROL, PWM AND THINGSPEAK MONITOR

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ABSTRACT

*Utilization of wind energy (wind) that blows from a certain height which is then used to turn wind turbines and converted into electrical energy or so-called wind power plants (PLTB) is one solution to the problem of the energy crisis so far. In addition, voltage stability is very necessary in the continuity of the use of power plants. Unstable voltage and frequency make electrical equipment (load) easily damaged. There are various ways to reduce instability, one of which is using a pseudo/complementary load electronic control circuit. The point is that the generator will be loaded with a total load that is always constant, the load on the consumer plus the complementary (pseudo) load is equal to the nominal capacity of the generator. This research uses a 3 phase generator and a 3 phase induction motor as a driving machine, the main load uses a lamp and the pseudo load uses a heater. The main control uses a Dspic30f4012 microcontroller connected to a voltage sensor. The microcontroller works using PWM with feedback using PID, which then PWM provides pulse information to the load drive circuit. The use of PID in this control system will produce a voltage in the generator at 50 Hz and 220Vac whether there is a load or not. So that the voltage supplied to consumers is stable and does not damage electronic equipment.*

**Keywords**: *dspic30f4012 microcontroller, PLTB, PWM, PID.*

## 1.INTRODUCTION

Energy is a basic human need. Energy sources are now dominated by primary energy sources such as oil, natural gas and coal, even though these primary energy sources are increasingly depleting and non-renewable, therefore alternative energy sources are needed for future life. One of them is a wind power plant (PLTB). The choice of PLTB as a renewable energy source is because Indonesia is rich in wind potential as seen from its geographical location. PLTB is a source of unlimited power generation that utilizes wind gusts at a certain level in areas rich in wind, which are then used to turn a turbine and connected to a generator, so that the generator produces a source of electrical energy that can be utilized for something useful. In the manufacture of PLTB, a design is needed so that the PLTB works optimally, one of which is to regulate the rotation of the generator motor in a fixed state so that the voltage and frequency produced are stable. In research conducted by Inggih Surya Permana, et al (2010). in a paper entitled "Electronic load control design in power plants", said that the level of performance of a power generation system is determined by the output frequency, especially wind power plants. The use of an erratic load will make the frequency change and make the electrical equipment (load) easily damaged, electronic control of the load at this power plant can minimize damage due to the unstable output frequency of the distribution system, the use of electronic load control is cheaper than control using mechanical methods, besides that the dimensions of the area are more concise and practical. To overcome these problems, a solution is needed with various methods. One of the solutions is (Induction Generator Controller) IGC 3 phase induction generator, is a control that regulates the electronic load, the way it works is that the generator will be loaded with a total load that is always constant. The load on the consumer plus the complementary load (pseudo) equals the nominal capacity of the generator. This causes the generator rotation to be constant. So that the resulting voltage and frequency remain at 220V and 50 Hz. The use of PID in the control system is expected to produce output values as expected. The systematics of this writing are: Abstract which contains the essence of the research conducted. Chapter 1 Introduction contains background, literature study and research objectives. Chapter 2

Method contains: overall working diagram, voltage sensor circuit, single phase rectifier circuit, quasi-load drive circuit, microcontroller, programming algorithm and PID tuning. Chapter 3 contains the results and discussion, namely the results of the measurement of the voltage sensor, frequency and PID tuning as well as the display on Thinkspeak. Chapter 4 contains conclusions and bibliography.

### 1.1 Wind Power Plant (PLTB)

One of the efforts to overcome the energy crisis is to reduce dependence on fossil energy sources by utilizing alternative energy sources. One alternative energy that can be used is wind energy (Bayu). Wind power generation is a method for generating electrical energy by turning a wind turbine, which will then be converted to electrical energy. This wind turbine is designed according to the characteristics of the equatorial wind or wind with low speed. The savonius wind turbine is the best wind turbine for low wind speeds. The wind turbine will be connected to a generator, when the rotor rotates, the generator will automatically flow electrical energy,

### 1.2 Monitoring on Thinkspeak

As for how this monitoring system works so that the voltage and frequency can be monitored remotely. First, set the internet network that will be used. Currently, the author is setting up a monitoring system connected to Telkomsel's wifi. Second, the monitoring system is turned on and is directly connected to the internet network. Third, the monitoring system is directly connected to the load. Then, the monitoring system will read the data on the load. The reading results will be sent to the server for viewing. Fourth, log in to the Thingspeak server through the available account and in it you can see the results of sending data from the monitoring system.

## 2. RESEARCH METHOD

To solve the above problems, a hardware and software design is needed. Control IGC (Induction Generator Controller) the main components that must exist are the apparent load (complement) and the control itself. The working block is as follows:

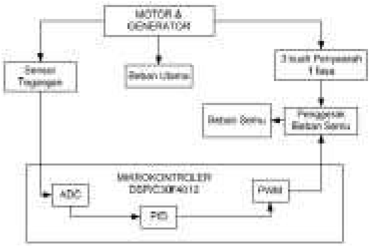



*Figure 1. Work Block Diagram*

In general, the workings of the micro-hydro frequency and voltage stabilizer control system are as follows. When the generator rotates and provides a voltage source to the main load simultaneously the voltage sensor reads and sends it to the microcontroller via the ADC, then the microcontroller activates the PID algorithm and forwards it to PWM, PWM provides a pulse signal to the load drive circuit pseudo (acts as a switch) to turn on/off the pseudo load. The closed loop system is made in order to maintain the value of the generator voltage remains 220 Vac. So when the voltage drops/increases is then read by the sensor and decoded by the microcontroller, the PID starts its action to keep the error value as small as possible and forwards it to PWM, which then PWM gives a signal to the pseudo-load drive circuit to turn on/off the pseudo-load. The apparent load is used as a counterweight to the main load so that the generator works at a voltage of 220 Vac.

### 2.1 Data Collection Method

The series of supports used are:

- **Voltage Sensor Circuit**

The voltage sensor is used to detect the voltage generated by the source. The working principle is that the Vac voltage source from the generator is connected to the primary transformer, while the secondary transformer is connected to the diode bridge. The 220 Vac voltage is converted into a 6Vdc voltage which is then rectified in full wave using a diode bridge. The values of R1 and R2 are used to determine the 220 voltage limit read by the sensor. Value of R1 = 551 and R2 = 389

$$\frac{389}{389 + 551} \times 6 = 2{,}52$$

So that the resulting voltage is 2.52 Vdc when the voltage is 220 Vac. This point will be used as a reference in sensor readings to the microcontroller.

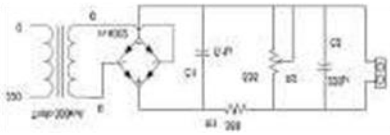


*Figure 2. Voltage Sensor*

- **Phase Rectifier Circuit**

The rectifier circuit used is a single-phase full-wave rectifier, to rectify the Vac source from the generator, using a diode bridge type KBJ508 with a specification of 5 amperes.

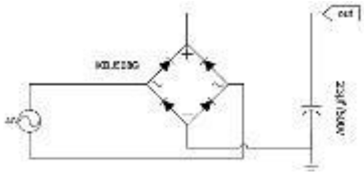


*Figure 3. 1 Phase Rectifier Circuit*

- **Pseudo Load Drive Circuit**

The pseudo-load drive circuit uses a 4n35 optocoupler as a separator between a 5Vdc and 220Vdc current source, and a mosfet as a switch for pseudo-loads, choosing a mosfet as a switch because it can work at high voltages and large power compared to transistors.

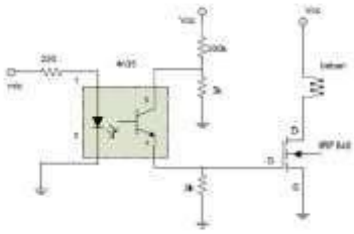


*Figure 4. Pseudo-Load Drive Circuit*

- **Dspic30f4012 Microcontroller**

The dspic 30f4012 microcontroller is the output of the microchip company with a 16bit data type. The main structure of this microcontroller is: CPU core, system integration and support. Inside the CPU core is the CPU itself, data memory, program memory, DSP engine and interrupts. In the minimum system circuit, it is connected to a power supply circuit, a reset circuit and an oscillator circuit, for the oscillator used is 20 MHz. while the micro downloader circuit is only connected to the port as shown in the image below

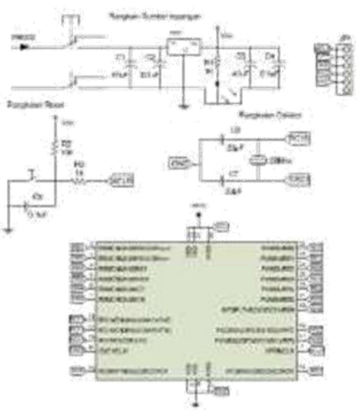


*Figure 5. Microcontroller Minimum System*

- **Programming Algorithm**

The main control in this system uses a dspic 30f4012 microcontroller which has internal PWM features, the programming language used is c language. The flow diagram of the microcontroller programming is as follows:

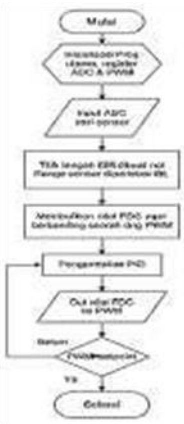


*Figure 6. Microcontroller Programming Flow Chart*

- **PID tuning**

In programming the PID algorithm, parameter values are needed for Kp, Ki and Kd. The method used to determine the PID tuning is the Ziegler Nichols response time and the best performance method. Because this method is easy and can produce the best value.

**<u>Open-loop Response Time Based on Ziegler Nichos Method</u>**

In this method the measurement steps are shown in Figure 7

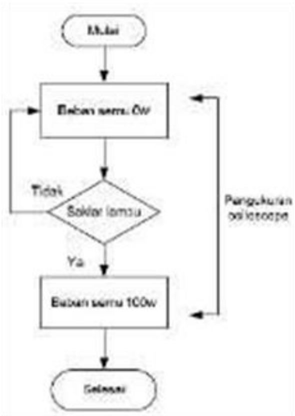



*Figure 7. Flowchart of Data Collection Response Method Time*

1. Measurements are made when the loop is open, not using the algorithm, only ADC and PWM.
2. Measurements are made in the apparent load drive circuit, this is because the circuit is closest to the apparent load, namely the point to be controlled. At the apparent load, measurements cannot be carried out because the apparent load uses a voltage of 220v while the features on the oscilloscope are only able to measure up to 20v.
3. Measurements are made when the main load is 100 watts, because at maximum load the measurement results will be more visible than the 25watt load.

The results of the measurement of the open loop response time method can be seen in Figure 8.

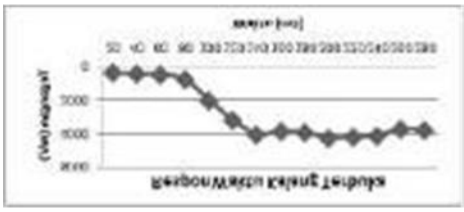


*Figure 8. Open Loop Response Time Measurement Graph*

**Best Performance PID Tuning**
This method is carried out by repeated trials, so that the PID tuning value with the best performance is produced.

## 2.2 Data Analysis Method

In the uning PID method using an open loop response time, the image below is obtained.

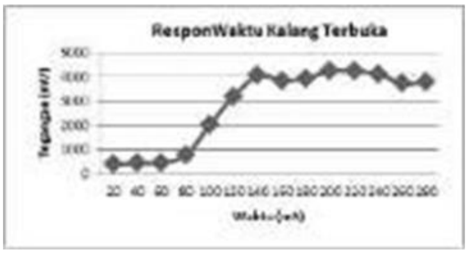



*Figure 9. Open Loop Response Measurement Graph with PID Tuning*

From Figure 9 it can be described for the values obtained, namely:
L = 20 ms= 0.02 s
T = 60 ms = 0.06 s
K= 4

In accordance with the results above, we enter into the following equation, it becomes

$$G(s) = \frac{4\,e^{-0.02s}}{1+0.06s}$$

*Table 1. Tuning Parameters for The Open Loop Time Response Method*

| | P | PI | PID |
|---|---|---|---|
| Kp | T/KL | 0.9 T/KL | 1.2T/KL |
| Ti | 0 | 3.3T | 2L |
| Td | 0 | 0 | 0.5L |

Then the value for the PID is

$$Kp = 1.2\,\frac{T}{K.L}\;1.2\,\frac{0.06}{4x0.02} = 0.9$$

$$Ki = \frac{1}{Ti} = \frac{1}{2L} = \frac{1}{2.0.02} = \frac{1}{0.04} = 25$$

$$Kd = Td = 0.5\ L = 0.5\ x\ 0.02 = 0.001$$

The ideal control equation

$$G(s) = 0.9\ (1 + \frac{1}{0.04\ s} + 0.001s)$$

From the equation in table 1, the values obtained are Kp=0.9 Ki=25 and Kd=0.001. The next step is to enter the tuning value into the PID algorithm.

## 3. RESULT AND DISCUSSION

### 3.1 Voltage and Frequency Sensor

The first step in programming this algorithm is to take measurements at the voltage sensor, this process is carried out when the system is still open without PID control, while the measurement results are in table 2.

*Table 2. Voltage Sensor Measurement Results*

| Burden Main (Watt) | Burden Pseudo (Watt) | Teg Input (Vac) | Teg Output (vdc) | freq (Hz) |
|---|---|---|---|---|
| 0 | 100 | 296 | 3.54 | 56.9 |
| 25 | 75 | 282 | 3.35 | 55.6 |
| 50 | 50 | 260 | 3.17 | 53.5 |
| 75 | 25 | 237 | 2.83 | 51.2 |
| 100 | 0 | 221 | 2.6 | 50 |

### 3.2 Results of Ziegler Nichols . Open-Cound PID Response Time Measurement Results

From the results of PID tuning with parameter values Kp=0.9 Ki=25 and Kd=0.001, it is

- **When the apparent load is 100 Watt**

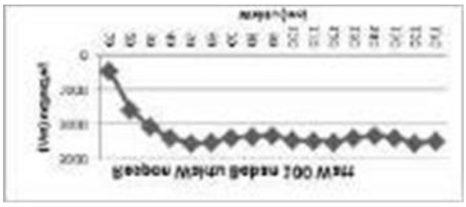


*Figure 10. Graph of Response Time at 100 W . Load*

- **When the apparent load is 75 Watt**


*Figure 11. Graph of Response Time at 75W . Load*

- **At 50 Watt apparent load**

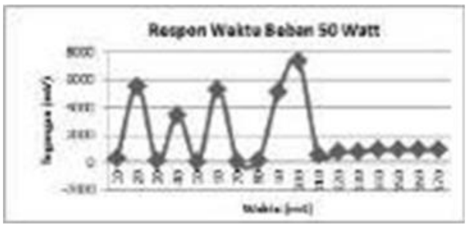



*Figure 12. Graph of Response Time at 50 W . Load*

- **When the apparent load is 25 Watt**


*Figure 13. Graph of Response Time at 25W . Load*

*Table 3. Measurement Results*

| Main (Watt) | Pseudo (Watt) | Generator (Vac) | (Hz) |
|---|---|---|---|
| 0 | 100 | 235 | 53 |
| 25 | 75 | 226 | 51.3 |
| 50 | 50 | 222.5 | 50.5 |
| 75 | 25 | 218 | 49.8 |
| 100 | 0 | 214 | 48.9 |

**3.3 Best Perfomance PID Tuning**

In the experimental step of determining the PID tuning with the best performance, repeated trials are carried out, as for the steps in Figure 14, are:

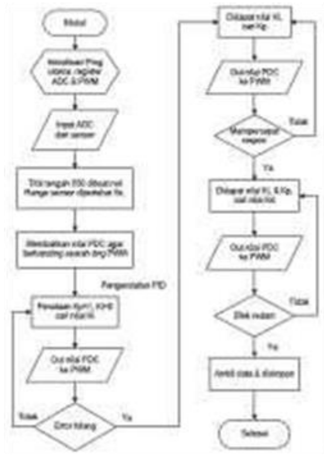


*Figure 14. Best Performance PID Tuning Flowchart*

First setting Kp = 1, Kd = 0, then the value of Ki is increased and decreased, when Ki is given a value oscillation occurs even though the value given is very small, it is decided that Ki = 0. Both Kp settings with Ki = 0 and Kd = 0, the value of Kp is increased and decreased so that the maximum result is Kp = 5. The three Kd settings with Kp=5 and ki=0. The value of Kp is increased and decreased to get the best response, namely the value of Kd = 3

From the above test, the value of Kp = 5, Ki = 0, Kd = 3.
The measurement results are:

- **When the apparent load is 100 Watt**

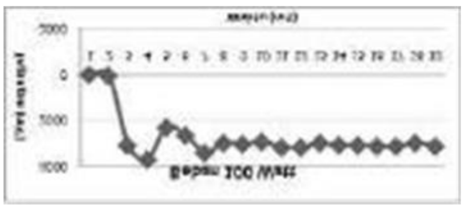


*Figure 15. 100w .Load Best Performance Graph*

- **When the apparent load is 75 Watt**

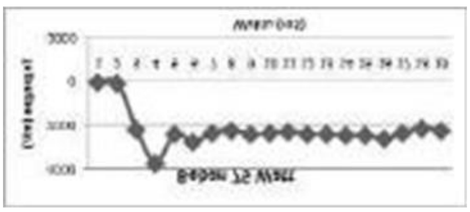


*Figure 16. 75w . Load Best Performance Graph*

- **At 50 Watt apparent load**

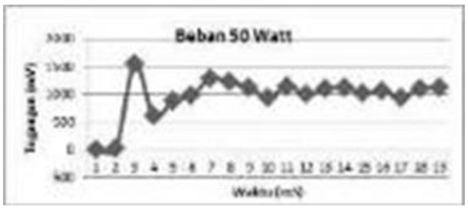



*Figure 17. 50w . Load Best Performance Graph*

- **When the apparent load is 25 Watt**

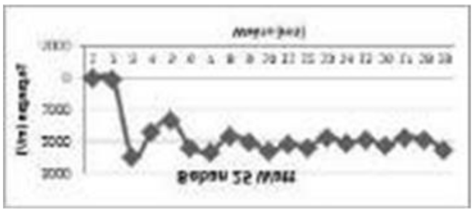


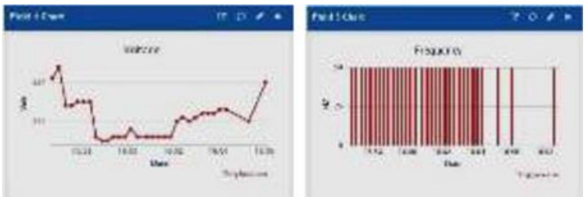
*Figure 18. 25w . Load Best Performance Graph*

The results of measuring the voltage at the generator are shown in table 4.

*Table 4. Measurement Results in Generator*

| No | Beban semu (Watt) | Teg Generator (Vac) | Frekuensi (Hz) |
|---|---|---|---|
| 1 | 0 | 220 | 50 |
| 2 | 25 | 220 | 50 |
| 3 | 75 | 220 | 50 |
| 4 | 100 | 220 | 50 |

#### 3.4 Display of Voltage and Frequency Test Results on Thinkspeak



## 4. CONCLUSION

1.With the use of IGC control (Induction Generator Controller) can be generated control generator automatically.
2.The use of the Dspic 30f4012 microcontroller makes it easy to use both programming and hardware design.
3. The process of determining PID tuning using the response time method has not shown maximum results, because the voltage in the generator cannot be constant at 220Vac.
4. Determination of PID tuning to find the best performance produces a fixed generator output voltage at 220 Vac and 50 Hz both when there is a load or full load.
5. The internet of things (IoT) system that integrates the web and Thingspeak can display and provide notifications of real electricity conditions anytime and anywhere.

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