Design a monitoring system for the output voltage, current, and frequency of a 3-phase generator in a mini power plant module at the instrumentation engineering department

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Abstract— Electrical energy is a requirement in everyday human life. The stability of the electrical energy generation system is something that must be considered, one of the power generation instruments that are often used is a generator, which converts mechanical energy into electrical energy. The generator has physical variables that must be maintained, including voltage, current and frequency. So as to know the amount of voltage and current produced by the generator, a system is made that can measure the amount of current, voltage and frequency produced by the generator with a portable system (plug and play). In this system, the generator output parameters are monitored using various sensors including the ZMPT101B voltage sensor to measure the generator output voltage, the ACS712 sensor to measure the current variable and the zero crossing detector to measure the frequency variable. From the test data of the monitoring system, the results obtained are the ZMPT101B voltage sensor which has an error reading of 0.01 for the ACS712 sensor reading error of 0.09 and for the frequency sensor reading error of 0.01. These three sensors were successfully used in the monitoring system of voltage, current and generator output frequency in the mini power plant module.

Keywords— Generator, ZMPT101B voltage sensor, ACS712 current sensor, zero crossing detector.

1. INTRODUCTION

Generators are important components in the electrical energy generation system that need to be secured against damage. Damage to the generator can disrupt the operation of the power system [1]. Generators are important equipment and their value is also very expensive, so efforts are made to prevent interference. The type of interference in generators that is often encountered occurs overcurrent or voltage drop, this of course can be very detrimental because there can be a fire due to overcurrent, and can damage other electronic equipment and disrupt the operation of the power system [2]. Based on this, it is necessary to make a tool to determine the amount of voltage and current produced by the generator, so a tool is made that can measure

the current, voltage and frequency produced by the generator, namely the monitoring system with portable principles. Monitoring is the process of collecting information based on indicators that have been determined systematically [3]. The monitoring system is included in a measurement system that has input in the form of variable values being measured and output in the form of measured variable values [4]. With this tool, it aims to provide a solution, namely being able to design a monitoring system for voltage, current, and frequency of the 3-phase generator output in the mini power plant module so that changes in physical quantities can be known.

2. PREVIOUS RESEARCHES

In previous research conducted by [5], the energy conversion process in a single-phase induction generator has outputs in the form of voltage, current, and frequency. When the generator is loaded, the output value must be kept stable in accordance with PLN standards, namely a voltage value equal to 220 V and a frequency value equal to 50 Hz [6]. Changing load values can cause unstable voltage and frequency values, so a tool is needed that can monitor the generator while operating [7]. Monitoring system is a system to observe the results of changes in a process variable on the object to be measured, and can be informed in the form of a display [4]. So that users can observe changes in physical quantities easily. For this reason, so that users can find out the information data needed and know the amount of voltage, current and frequency of the generator output, this research will create a monitoring system for voltage, current and frequency of generator output in the mini power plant module. To monitor physical variables in the form of voltage, current and frequency of generator output which can later be informed through the interface. This monitoring system is able to record data from sensor readings as a data logger, and in this monitoring system 4-20mA signal conditioning is carried out as a standard communication signal for instrumentation in the industry regulated in the ANSI/ISA-S50.1-1982 document [8]. And can be connected to the generator control & protection panel (GCPP) or centralised control systems such as DCS and presented in the SCADA system of the generating system.

3. METHOD

3.1. Novelty of Generator Monitoring System Design

In the design of the monitoring system for voltage, current and frequency of the generator output in the mini power plant module, it is designed by analysing the needs of the physical variables in the electrical energy generation system:

- Voltage Sensor ZMPT101B
- ACS712 Current Sensor
- Frequency Sensor
- ATMega32 microcontroller
- LCD 4x20
- Openlogger Module
- Converter 0-5V to 4-20mA.

The variables that will be monitored in this research are the voltage, current and frequency of the generator output in the mini power plant module.

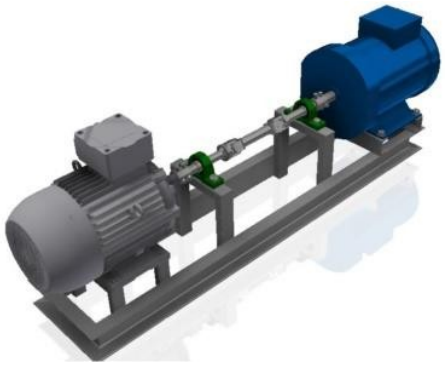

Figure 1 Mini power plant module design

In this stage, the design of the monitoring system is carried out, which includes determining the instruments that will be used to monitor the voltage, current, and frequency of the generator output in the mini power plant module.

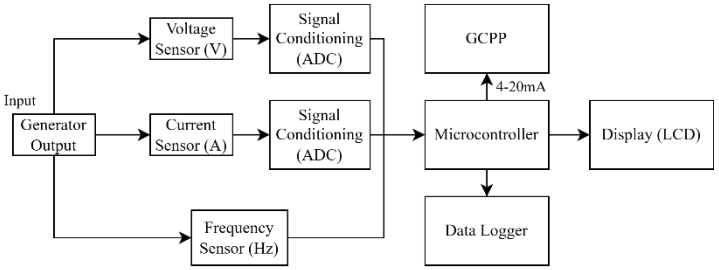

Figure 2 Generator Output Block Diagram

In Figure 2, the block diagram can be seen the physical quantities of generator output voltage, current, and frequency that will be monitored are detected and will be sensed by sensors, namely the voltage, current and frequency of generator output in the mini power plant module.

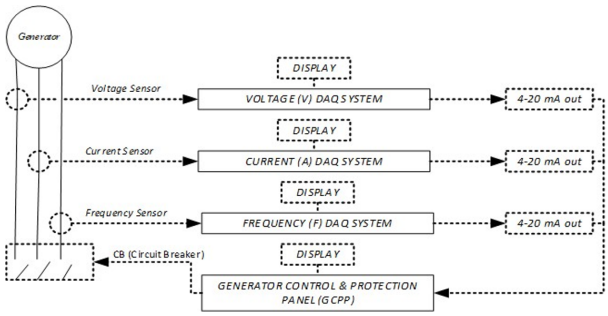

Figure 3 3-phase Generator Output Monitoring System Design

In Figure 3, it can be explained that the real value of a process variable will be the input of the sensor. Then the results of the sensor output will be carried out signal conditioning and signal processing which later the data can be directly transmitted to the microcontroller to be processed and produce outputs that become measured values [9]. Monitoring results can be displayed on the LCD, stored in the data logger, then the 4-20mA signal conditioning results are sent to the GCPP (Generator Control & Protection Panel). As a frequency measuring instrument, this research uses a zero crossing detector circuit which has an input voltage of 220V and is then reduced using a transformer of 6V. The following is a zero crossing detector circuit used as a frequency sensor.

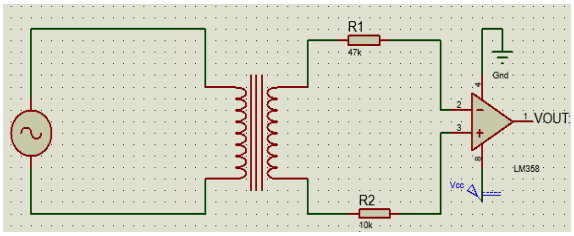

Figure 4 Frequency Sensor Circuit

Transformer for the zero crossing detector circuit which has an input of 220V and an output voltage of 6V. The openlog module is used as a data logger to store data on the results of monitoring the voltage, current and frequency of the generator output in the mini power plant module. Atmega32 as a microcontroller that is used to process data on the monitoring system of voltage, current, and generator output frequency in the mini power plant module. LCD is used as a display to show the monitoring data of ZMPT101B voltage sensor, ACS712 current sensor, and zero crossing detector frequency sensor.

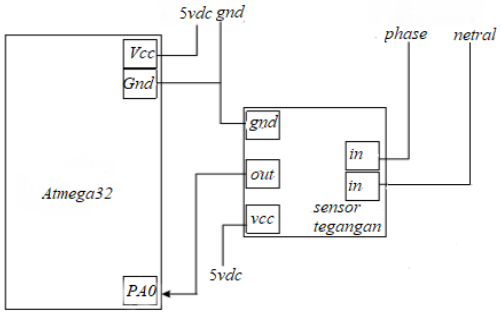

Figure 5 Current sensor wiring schematic

The sensor in this system is used to measure or read the current flowing in the load. The sensor used in this research is a 20A ACS712 sensor that is installed in series with the load. In Figure 6 is a test of the

ACS712 current sensor installed in series with inputs from the generator output, and the load [4]. The ACS712 sensor has 3 main pins namely Vcc, Gnd and Vout pins. The Vcc and Gnd pins are connected to the Vcc and Gnd pins on the Atmega32. While the Vout pin of the sensor is connected to the PA1 pin on the Atmega32.

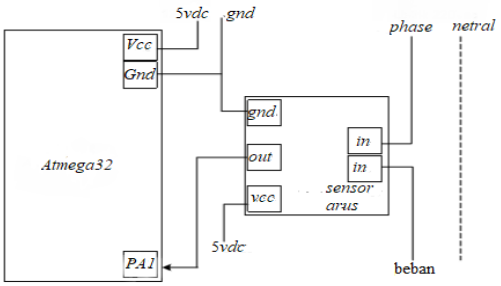

Figure 6 Voltage sensor wiring schematic

In the generator output monitoring system of voltage, current and frequency in the mini power plant module, an indicator is used to determine the presence of electric current generated. The indicator used is a lamp with a voltage of 220-240v, a frequency of 50-60Hz and 1W power as a light medium that will light up if there is electricity generated by the generator output.

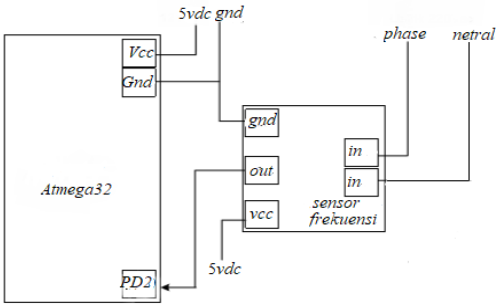

Figure 7 Frequency sensor wiring schematic

Converter testing 0-5V to 4-20mA, In this module there are 2 input pins namely Vin and Gnd which will be installed on Atmega32, there are also 3 output pins namely Vout which must be supplied with a DC voltage of 24V, Out, and Gnd which will be measured by a multimeter. Where in this research using 3 converters which will be used for voltage, current and frequency. The 0-5V to 4-20mA converter used for voltage has a Vin input pin which will be installed on Atmega32, namely pin PA5 and the Gnd pin is installed on the Gnd pin on Atmega32 [10]. In the 0-5V to 4-20mA converter used for current, there is a Vin input pin which will be installed on the Atmega32, namely pin PA6 and the Gnd pin is installed on the Gnd pin on the Atmega32. In the 0-5V to 4-20mA converter used for frequency there is a Vin input pin which will be installed on the Atmega32, namely pin PA7 and the Gnd pin is installed on the Gnd pin on the Atmega32. How to measure the size of the converter with a multimeter is by measuring Vout and Gnd.

4. RESULT AND DISCUSSION

4.1. V,I,F Monitoring

The LCD display of the generator output monitoring system for voltage, current, and frequency in the mini power plant module has some data to be displayed such as:

- On the first line LCD display displays data from the ZMPT101b voltage sensor readings with units of 'V'.
- On the second line LCD display is a display of the results of ACS712 current sensor data readings with units of 'A'.
- On the third line LCD display is the result of reading from the power data with units of 'W'.
- On the fourth line LCD display displays data from the frequency sensor readings with units of 'Hz'.

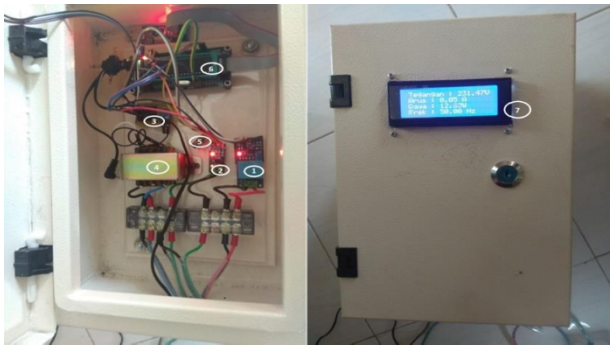

Figure 8 3-phase portable generator monitoring system

The process variable detected and sensed by the ZMPT101B voltage sensor is the voltage output produced by the generator. The output data from this sensor is analogue data in the form of voltage which will be processed first on the ADC microcontroller [11], so that it can be transmitted to Atmega32 for processing, then the data will appear in the form of numbers with units of 'V'. Testing the voltage sensor is done by measuring the changing voltage. This ZMPT101B sensor is a voltage sensor that uses a step down transformer as a medium to convert voltage parameters that will be read by Atmega32 [4].

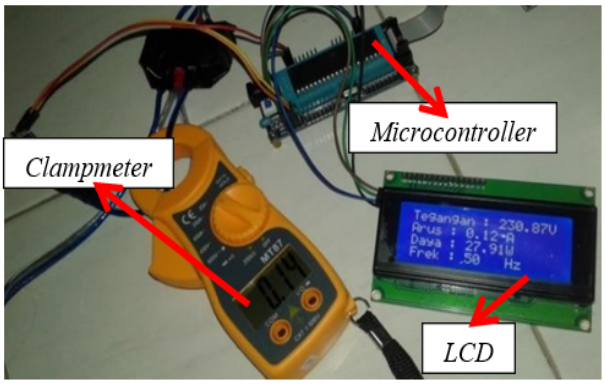

Figure 9 ZMPT201B Sensor Test

Current sensor testing is done by measuring the current with a load. In testing this sensor is done using a load of electronic equipment that works at a voltage of 1 phase 220V, in this measurement is done with a laptop charger load. In system measurements compared with a clampmeter to find out whether the ACS712 sensor has a value that matches the standard measuring instrument [12]. In Figure 4.11 testing the ACS712 sensor in this test 10 experimental samples were taken for data collection. Electrical power is defined as the rate of delivery of electrical energy in an electrical circuit. The SI unit of electrical power is watts which expresses the amount of electrical power flowing per unit of time (joules/second) [13].

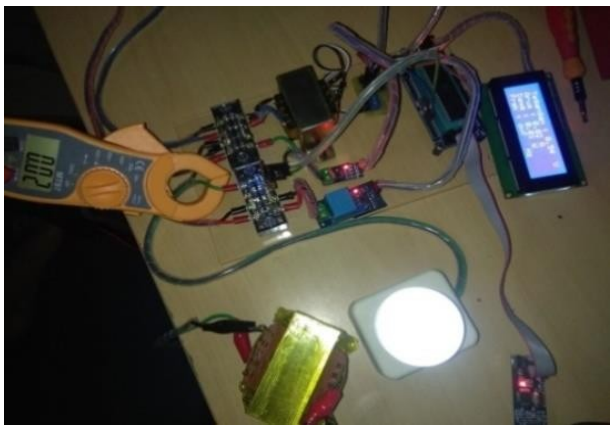

Figure 10 ZMPT201B Sensor Test

Electrical power is denoted by the letter P. The amount of electrical energy is proportional to the amount of power used in electrical equipment.Table 1 is the result of power monitoring.

Table 1 Power monitoring testing

Time Minute to	Sensor ZMPT101	Sensor ACS712	Power
1 minute	230V	0.06A	13.8W
2 minute	230V	0.05A	11.5W
3 minute	231V	0.06A	13.8W
4 minute	232V	0.05A	11.6W
5 minute	231V	0.05A	11,5W
6 minute	230V	0.06A	13.8W
7 minute	230V	0.05A	11.5W
8 minute	230V	0.06A	13.8W
9 minute	232V	0.06A	13.9W
10 minute	232V	0.05A	11.6W

The wave generated by the zero crossing detector circuit is as shown in Figure 11 which is the 220 volt 50 Hz voltage input signal.

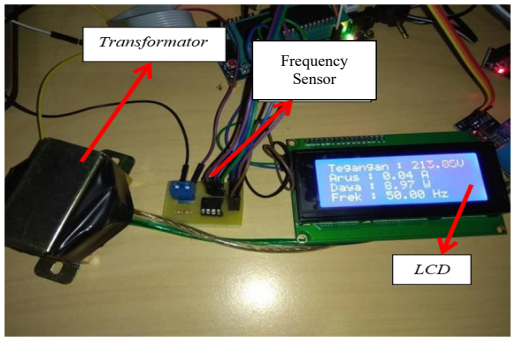

Figure 11 Frequency sensor circuit waveform results

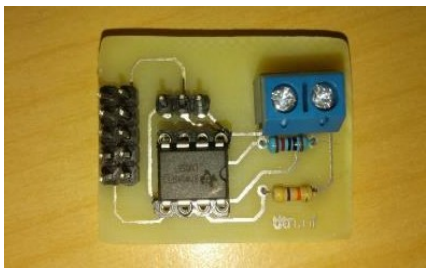

Figure 12 Zero crossing detector frequency sensor circuit results

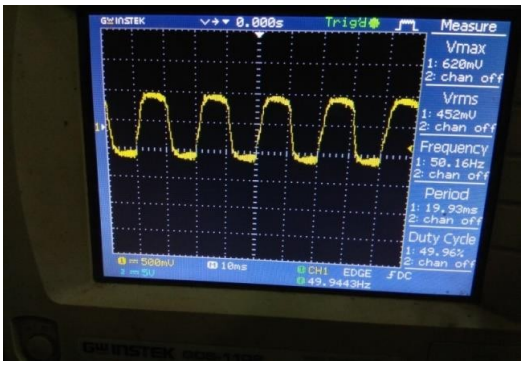

Figure 13 Zero crossing detector frequency sensor test results

In Figure 13, it can be seen that the process variable detected and will be sensed by the frequency sensor is the frequency output produced by the generator. The output data from this sensor is digital data so that it can be transmitted to Atmega32 for direct processing, then the data will appear in the form of numbers with units of Hz.

4.2. 4-20mA Signal Conditioning

The test results of the 0-5V to 4-20mA converter used to measure the voltage value of 0-250V aim to facilitate this monitoring system to be connected to the PLC & DCS system in centralised and distributed control. So that this monitoring system can be used in industrial standards, namely 4-20mA signals [10] [8]. This signal conditioning is a change in V to I, with the method of conditioning the voltage value of 0, the converter is 4mA, and when the voltage value reaches 250V, the converter is 20mA. Figure 13 shows the

reading of the converter from a voltage value of 214V, which is 18.5mA.

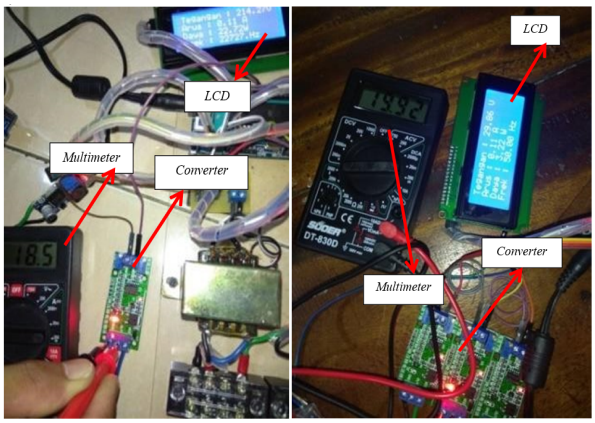

Figure 14 Signal conditioning results V,I,F to 4-20mA

Test of the 0-5V to 4-20mA converter used to measure the current value of 0-20A. So that when the current value is 0A, the converter is 4mA, and when the current value reaches 20A, the converter is 20mA.

The results of testing the current value using a lamp load show the results of the converter reading of the current value using a 0.12A lamp load of 4.16mA. Furthermore, testing the 0-5V to 4-20mA converter is used to measure the frequency value of 0-60Hz. So that when the frequency value is 0A, the large converter is 4mA, and when the frequency value reaches 60Hz, the large converter is 20mA. In Figure 4.24 is the frequency value that shows the reading of the converter from the 50Hz frequency value of 19.92mA.

5. CONCLUSION

Based on the problems and results of the research design of the generator output monitoring system for voltage, current and frequency in the mini power plant module, it can be concluded that a generator output voltage monitoring system has been designed in the mini power plant module using ZMPT101B voltage sensors, ACS712 current sensors, and frequency sensors with 4-20mA signal conditioning facilities with a portable system. The monitoring results are stored in the data logger in .txt format.

- ZMPT101B voltage sensor at PLN voltage obtained an average error reading of 0.01 at 6V voltage obtained an average error reading of 0.05 at 12V voltage obtained an average error reading of 0.04 at 15V voltage obtained an average error reading of 0.06 and at 20V voltage obtained an average error reading of 0.03.
- The ACS712 current sensor obtained an average error reading of the charger load and the lamp load obtained an average error of 0.1.
- The frequency sensor obtained an average error reading of 0.01.

REFERENCES

[1] M. Kabalan, D. Tamir, and P. Singh, ‘Electrical load controller for rural micro-hydroelectric systems using a programmable logic controller’, in *2015 IEEE Canada International Humanitarian Technology Conference (IHTC2015)*, IEEE, 2015, pp. 1–4.

[2] J. A. Buck *et al.*, ‘Pulsed eddy current inspection of support structures in steam generators’, *IEEE Sens J*, vol. 15, no. 8, pp. 4305–4312, 2015.

[3] M. W. Ahmad, N. Agarwal, and S. Anand, ‘Online Monitoring Technique for Aluminum Electrolytic Capacitor in Solar PV-Based DC System’, *IEEE Transactions on Industrial Electronics*, pp. 7059–7066, 2016.

[4] B. Raafiu and P. A. Darwito, ‘Smart Monitoring of Solar Panel System in Saving of the Electrical Power with Internet of Things’, *Proceedings Book*, 2018.

[5] M. Arfianto, S. Bachri, and B. Kaloko, ‘Desain sistem monitoring pada generator induksi satu fasa’, pp. 13–16, 2016.

[6] F. Afrizal, K. Endah, and G. Herri, ‘Rancang bangun alat monitoring arus dan tegangan berbasis mikrokontroler dengan SMS gateway’, *Electrician–Jurnal Rekayasa dan Teknologi Elektro*, vol. 10, no. 2, pp. 87–98, 2016.

[7] Z. Alex, M. Ali, and R. Brian, ‘Speed control of single phase ac motor on cocoa beans fermentation process using pid controller’, in *Proceedings of the 8th Annual Basic Science International Conference, Malang, Indonesia*, 2018, pp. 6–7.

[8] I. S. America, 'Compatibility of Analog Signals for Electronic Industrial Process Instruments (American Standard)', *ANSI/ISA - S50.1 - 1982*, 1992.
[9] A. Namin, E. Chaidee, T. Sriprom, and P. Bencha, 'Performance of inductive wireless power transfer between using pure sine wave and square wave inverters', in *2018 IEEE Transportation Electrification Conference and Expo, Asia-Pacific (ITEC Asia-Pacific)*, IEEE, 2018, pp. 1–5.
[10] D. Kusanto and K. Indriawati, 'Perancangan Sistem Akuisisi Data sebagai Alternatif Modul DAQ menggunakan Mikrokontroler Atmega8535', pp. 1–10, 2016.
[11] G. Floor, ' AC voltage sensor (ZMPT101B)', vol. 4578, pp. 1–5, 2010.
[12] A. Microsystems, 'ACS712', pp. 1–16, 2017.
[13] E. M. Leny, 'Sistem Current Limitter dan Monitoring Arus serta Tegangan. ', pp. 39–46, 2009.