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Input Power Measurement System for Driving Motor in Testing Low-Speed Generator

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Abstract

Rapid technological advances are affecting the greater use of electrical energy. One of the devices that can generate electrical energy is a generator. Testing the characteristics of the generator required a drive motor to rotate the generator shaft. This research aims to create a three-phase input power measurement system for driving a motor. The method of measuring input power is by measuring the current and voltage of each phase. The power is obtained from the multiplication between current and voltage. The system consists of current sensors, voltage sensors, a signal conditioning circuit, and an Arduino Mega microcontroller for data processing. The system is equipped with a graphical user interface, data storage, and application. The generator input power measurement system has been created and tested. The measurement system has successfully measured the input power of the generator's driving motor, which in real-time is displayed on the trend graph via the graphical user interface on the laptop. The input power measurement data on the three-phase generator and the time data have been successfully stored inside the micro-SD. The average error of the voltage reading is 2% compared to the measurement of the reference voltmeter. The current reading error was 2% compared to the reference meter ampere measurement.

Keywords: driving motor, generator, microcontroller, power measurement

1 Introduction

One tool to generate electrical energy is a generator. Electric generators work by converting mechanical energy into electrical energy [1]. One type of generator is a permanent magnet generator which is an electric machine that utilizes mechanical energy to produce electricity. This generator utilizes permanent magnets as the rotor[2]. Low-speed permanent magnet generators are generally used to convert the mechanical power output of water turbines [3] and wind turbines [4][5] into electricity. The rotational speed of the generator needed to produce electricity is a minimum of 1500 rotations per minute (rpm) [6]. This study used a generator with a rotation of less than 1500 rpm.

Testing the characteristics of the generator can be done by moving the generator shaft using a driving motor. The generator drive motor requires a tool that can provide power with adjustable frequency and voltage to regulate the rotation of the generator shaft. One of the driving motors that can be adjusted rotational speed is a 3-phase induction motor. So, we need a 3-phase speed driver whose voltage and frequency can be adjusted. To find out the efficiency of the generator, it can be done by measuring the electric power output of the generator and the input power of the driving motor. Therefore, it is necessary to measure the three-phase input power with varying voltages and frequencies. The input electric power of the generator driving motor can be obtained by measuring the motor input voltage and current.

Previously, there was research related to measuring power on generators using voltage sensors and current sensors. The power measurement has be done in research entitled "Rancang Bangun Sistem Proteksi Daya Listrik menggunakan Sensor Arus dan Tegangan berbasis Arduino "[7]. Research on the "Rancang Bangun Sistem Monitoring Tegangan, Arus, dan Frekuensi Keluaran Generator 3 Fasa Pada Modul Mini Power Plant Departemen Teknik Instrumentasi"[8] is concerned with monitoring the output voltage, current, and frequency of a 3-phase generator. In this study, ZMPT101B and ACS712 sensors were used to obtain voltage and current values. In this study, there is also monitoring of the output frequency on the generator. From the sensors used to get the values of voltage, current, and output frequency of the generator, the values from these sensors are then displayed on the LCD and loaded in the Openlogger module. In this research, the method used to measure 3-phase voltage and current is only one phase, so it only uses one voltage sensor and one current sensor.

The research entitled "Perancangan Sistem Monitoring dan Proteksi Daya Balik Untuk Generator 1kW 3 Fasa"[9], monitoring measurements using the ZMPT101B voltage sensor and ACS712-20A current sensor. This monitoring is used as an early indication to prevent damage to the generator. In this research, 3 voltage sensors and 3 current sensors are used to sense each phase. From the sensor, the data is processed to produce a power value. The calculation of the power used is active power. The system is equipped with a monitoring display using a TFT LCD. In addition, the system can control the reverse power protection that occurs. In this system, there is no data storage in memory so the previous data cannot be seen. The measurement system is carried out for power sources with a fixed frequency.

The power measurement system mentioned above is carried out for a power source with a fixed frequency. In testing the low-speed permanent magnet generator, it is necessary to drive a variable rotational speed from a 3-phase power converter with varying frequencies. Therefore this research was made to make a 3-phase electric power meter with an electric power source with varying frequencies originating from the 3-phase converter output used to activate the driving motor. The calculation of the input power to the generator driving motor is obtained by multiplying the voltage and current values for each converter output phase. Therefore a voltage sensor and a current sensor are needed to get the value of the voltage and current. The voltage sensor will sense the voltage by placing the sensors in parallel on each phase. While the current sensor will measure the current by placing the sensor in series on each phase against a given load. The voltage sensor is used to measure the phase voltage. The current sensor is used to measure the phase current. Voltage and current measurements are carried out for the three phases, requiring 3 voltage sensors and 3 current sensors. The processing of the signal from the voltage sensor and current sensor is processed using a microcontroller. The results of voltage, current, and power data are displayed digitally on the LCD and through the GUI in graphical form and can be stored on a micro-SD and can be communicated with other microcontrollers via serial communication.

2 Methods

At this stage, it is designed to measure the electric power originating from the 3-phase converter which is input to the generator drive motor used in testing the low-speed permanent magnet generator. In this study, the generator used was a low-speed permanent magnet generator with a maximum rotational mechanical rotation of 1395 rpm (rotations per minute). The stage starts with designing the appropriate system block. The next step is to design and implement hardware and software according to the system block. The next stage is to test the system for data collection to see the suitability of the results of the tool with the design, which is then analyzed to get conclusions.

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The input power measurement system for the generator drive motor is part of a system that has several measurements in testing the low-speed permanent magnet generator. This research is focused on measuring the input electric power of the generator drive motor. Electric power is defined as work per unit of time or electrical energy dissipation per unit of time. The unit of power is the watt or joules per second. Measurement of DC power can be done by measuring current and measuring voltage. There are two measurement configurations as shown in Fig. 1 with the symbol E being the voltage source, A being the measured current, and V being the voltage. The electric power P is the product of the current and voltage values.

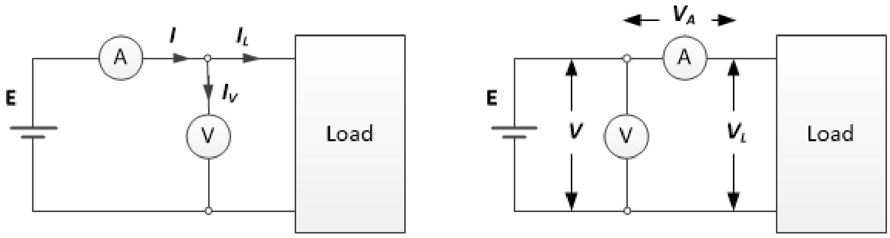

Figure 1. Configuration of power measuring [10]

AC power measurement can be done like DC power measurement, namely through current and voltage measurements. The difference is that for AC voltage, the current and voltage can have different waveforms and different phases. There are several definitions of ac power measurement. Instantaneous power, namely the multiplication of the instantaneous voltage and instantaneous current flowing at the load, is expressed by (1).

$$p(t) = v(t)\ i(t) \tag{1}$$

In an ac circuit with an ac voltage source that is periodic with a period T, the average power or active power (*P*) is defined as stated in (2). Active power is the average power consumed by the load[11].

$$P = \frac{1}{T}\int p(t)\ dt \tag{2}$$

In an ac circuit with a resistive load, the instantaneous power value is expressed in (3), where *V* is the RMS (root-mean-square) voltage, *I* is the RMS current, and *ω* is the corner frequency of the power source. Active power is a multiplication between *V* and *I*.

$$p(t) = VI\,(1 - \cos 2\omega t) \tag{3}$$

For a purely reactive load, the instantaneous power value is expressed as in (4). The active power for a reactive load is zero.

$$p(t) = VI \cos 2\omega t \tag{4}$$

For loads with resistive and reactive components, there is a phase difference between the voltage wave and the current wave which is expressed by the angle φ. The active power P is expressed by (5), where V_L is the rms voltage at the load, I_L is the rms current of the load, and $cos\varphi$ is called the power factor. The multiplication between V_L and I_L is called the apparent power (P_A) or apparent power (S), as shown in (6). Reactive power (Q) is defined as the multiplication between P_A and $sin\varphi$ value as shown in (7).

$$P = V_L I_L \cos\varphi \tag{5}$$

$$P_A = V_L I_L \tag{6}$$

$$Q = V_L I_L \sin\varphi \tag{7}$$

The mathematical relationship between the types of power that exists, namely active power, reactive power, and apparent power uses the principle of trigonometry, as shown by the power triangle in Fig. 2. The relationship between apparent power S, active power P, and with reactive power Q is shown by (8)

$$S = \sqrt{P^2 + Q^2} \tag{8}$$

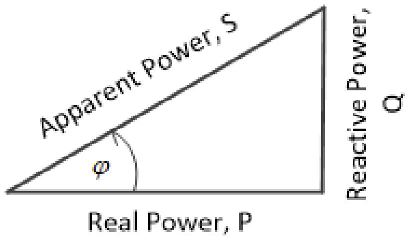

Figure 2. Power triangle.

The input power measurement system in this research is equipped with an LCD viewer and graphic display on a computer, data recording on a micro-SD, and there is an RS485 serial communication facility to communicate with other microcontrollers. Fig. 3 shows a block diagram of the power measurement system design.

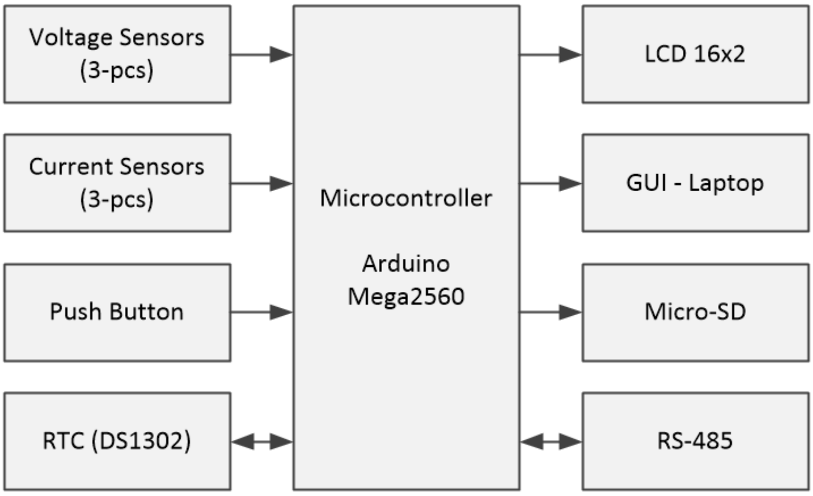

Figure 3. Block diagram of the system

A. Hardware Design

This input power meter consists of three voltage sensors, three current sensors, an RTC module, a push button, a microcontroller, an LCD viewer, a micro-SD memory module, GUI on a laptop, and an RS-485 communication module. Voltage and current measurements are carried out at the output of a 1-phase to 3-phase converter with a load in the form of a generator driving motor. The microcontroller used is Arduino Mega 2560. The data obtained from the measurement results will be displayed on a 16x2 LCD, the GUI is in the form of a trend graph, and the measurement data is stored in a micro-SD.

Based on the system box diagram in Fig. 3, then the wiring between the components or modules used is designed. The wiring diagram is shown in Fig. 4. The output of each voltage sensor and the current sensor is connected to the microcontroller's analog input pin. The 16x2 CD module is used to display the results of measuring the power of each phase and the total power. The DS1302 RTC module is used as a real-time reference for recording data stored on the memory module (micro-SD). The RS485 module is used for communication with other microcontrollers for data collection purposes.

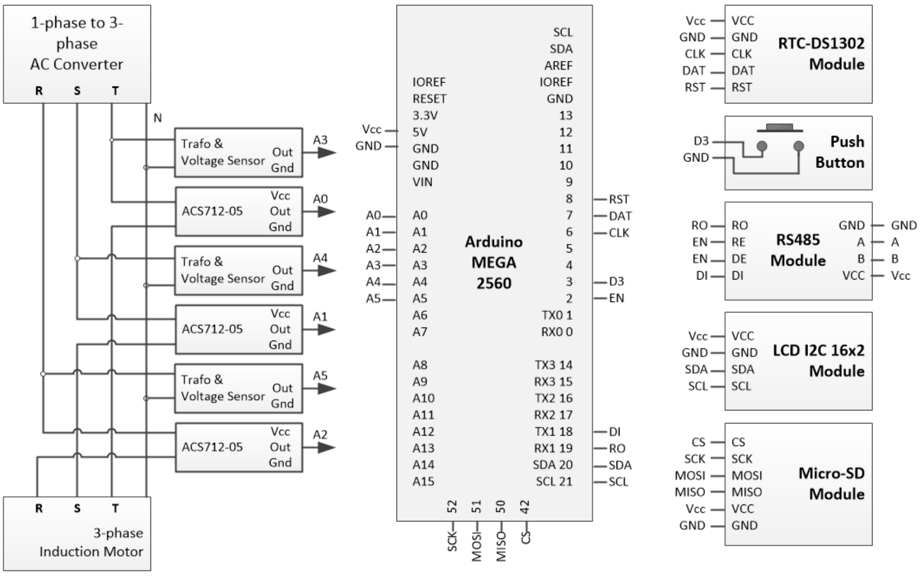

Figure 4. Wiring diagram

The voltage sensor will measure the voltage of each converter output phase, designed to measure voltages up to 250 volts RMS. The voltage sensor used is shown in Fig. 5. The voltage sensor circuit consists of three step-down transformers with a ratio of primary to secondary turns of 220:12. Each transformer's secondary output is connected to a signal conditioning circuit (PS). The signal conditioning circuit consists of a diode bridge, some resistors, and a capacitor. The series of resistors and capacitors function as a filter so that the output voltage of the circuit is even (dc). The characteristics of the sensor are obtained by conducting trials by measuring the converter voltage and the output dc voltage of the sensor, then carrying out the calibration process. Measurements are made for varying converter voltages. The output of each voltage sensor is connected to the microcontroller analog pin.

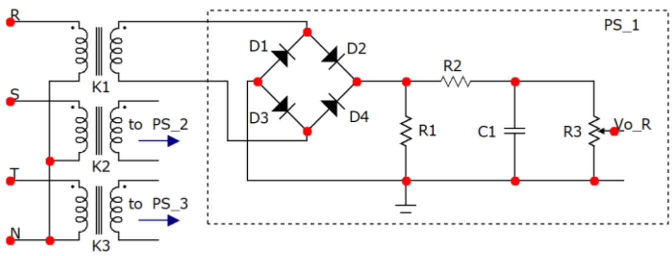

Figure 5. The circuit of the voltage sensor

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Three current sensors that use ACS712-05 which are placed on each phase. The current sensor is designed to measure up to 3.5 A (RMS), or a peak current of 4.949 A. When the sensor detects 0 amperes, the current sensor output will be 2.5 volts. According to the sensitivity of the ACS712-05 sensor, for every 1-ampere increase, the current sensor output will increase by 0.185 volts. When the current is positive at 4.949A, the output voltage of the current sensor will be the same as $VOUT=2.5+(0.185\times4.9497)=3.415V$. Meanwhile, when the current is negative of -4.949A, the sensor output voltage becomes $VOUT = 2.5 + (0.185 \times -4.949) = 1.554V$. This value is used as the maximum output voltage value from the current sensor to be processed by the microcontroller.

B. Software Design

The working description of the input power measurement system is using three voltage sensors to get the voltage value of each phase, and three current sensors to get the current value of each phase. The voltage value and current value will be processed by the microcontroller to get the power value of each phase. The program first starts with initializing the port used on the Arduino Mega 2560. The port used in the design consists of modules such as RTC, microSD memory module, LCD, push button, and RS485 module as the communication. In addition, there is an analog port initialization that is used to read voltage sensor data and current sensors. When the push button is pressed, the system will start working. The system works by taking voltage and current data for each phase. Retrieval of voltage and current data on each phase using sampling with a certain period. The current and voltage measured by the current and voltage sensors are averaged using the moving average method to remove noise[12]. The flowchart of the measurement system can be seen in Fig. 6.

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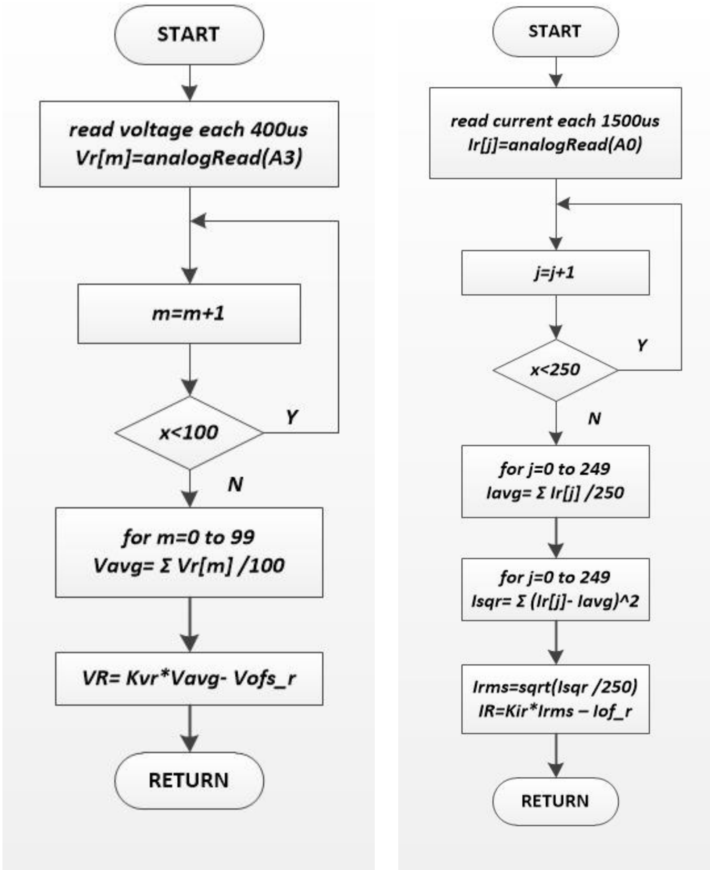

(a) (b)

Figure 6. Flowchart of measurement system (a). Voltage measurement (b). Current measurement

The voltage signal is in the form of a DC wave, while the current signal is in the form of a sinusoidal wave. The data is taken gradually starting from the voltage and then the current. For data collection, the voltage will be sampled every 400us with a total of 100 data so it takes about 40ms in one cycle. For data collection, the current will be sampled every 1.5ms with a total of 250 data, so it takes about 375ms in one cycle. The data collection process is carried out alternately, the first is the voltage on the R phase, the second is the voltage on the S phase, and the third is the voltage on the T phase. The voltage data will use the calibration equation using a true-RMS multimeter, so the data obtained is the processing of RMS voltage data. The calibrated voltage of each phase is calculated using (9) – (11).

$$V_{R\_phase} = (81.425 \times V_{avg} - 97.778) \quad (9)$$

$$V_{S\_phase} = (71.653 \times V_{avg} - 67.291) \quad (10)$$

$$V_{T\_phase} = (88.972 \times V_{avg} - 112.96) \quad (11)$$

The calculation of the current value can be seen in (12) -14).

$$i_{R\_phase} = (0.0275 \times i_{rms} - 0.0146) \quad (12)$$

$$i_{S\_phase} = (0.0264 \times i_{rms} + 0.0034) \quad (13)$$

$$i_{T\_phase} = (0.0274 \times i_{rms} - 0.0105) \quad (14)$$

The rms data stored in a variable will be processed into a per-phase power value. After the per-phase power value is obtained, then the data will be processed by the microcontroller to obtain the total power value. All data processed, both per-phase input data and total input power data, will then be stored on the microSD and the data will be displayed on the LCD.

3 Results and Discussions

The results of the design of the tool that has been made are shown in Fig. 7. The system that has been made is shown at the bottom left which is assembled with a 3-phase converter, a 3-phase induction motor as the drive, and the permanent magnet generator being tested. The generator load is not shown in this figure.

Figure 7. Result of the design

The procedure for using the tool is as follows: First, when the system is supplied with power, a description of the measuring instrument and a description of the date, month and year will be displayed on the LCD. Then the LCD will display a description of the condition of the SD Card storage. The push button is used to activate and stop the measurement process. As an indicator, a description will appear on the LCD. When the push button is pressed for the first time it will activate the measurement system. When the push button is pressed a second time it will stop the measurement system. The description of the measurement results will be displayed on the LCD directly. The memory module will automatically store data after the user activates the measurement system.

The measurement data results will be stored in real-time with the timing data obtained via the RTC DS1302. RTC DS1302 is used for recording the time, day, and date of measurement. Data is stored in micro-SD memory with the .csv extension format. This is to make it easier to process data. The stored data will be delimited by commas so that the data obtained is easy to classify. The process of storing data in the SD card begins when the system is ready to start measuring. When the system detects the SD card, the system will be ready to start measuring. Data storage will take place every 1 second starting after the measurement system starts. When the measurement system stops or is inactive, the process of saving data to the SD card will stop.

Power measurement data can be seen on the 16x2 LCD, as shown in Fig. 8. After the push button is pressed, the system will start measuring power. The LCD displays R phase power (Pr), S phase power (Ps), T phase power (Pt), and total power (PT). In addition, voltage measurement data, current measurement data, and power calculation results can be monitored through the 'serial monitor' contained in the Arduino software.

Figure 8. LCD of power per phase and total power.

Testing of the measurement system is carried out by connecting the hardware (results of the measuring instrument design) to the converter and the driving motor as the load. As a reference measuring device for current measurement, 3 multimeters are used as shown in Fig. 9, multimeter numbers 1 to 3. Meanwhile, multimeter numbers 4 to 5 are used as a reference measuring instrument for measuring voltage. As a load from the generator, several lamps are used which can be varied. In addition to variations in the load on the generator, tests were also carried out using a variety of converter indicators. The converter indicator is a description of the numbers printed on the converter LCD. The converter indicator is a sinusoidal frequency setting to adjust the rotational speed of the driving motor. The variation used is from 3 Hz to 13 Hz.

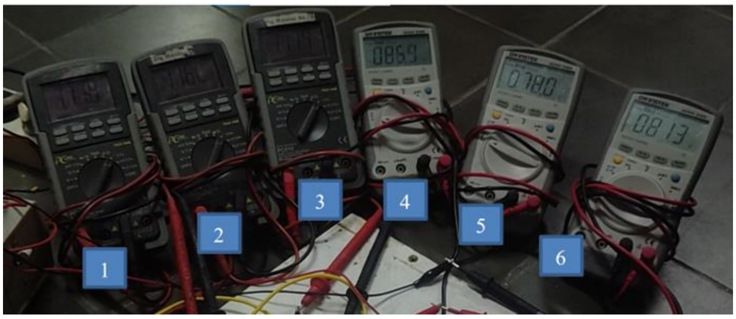

Figure 9. Multimeter as a reference for measuring voltage and current

A. Voltage meter testing

The voltage measurement test uses a generator load of six lamps of 25 watts each and a variation of the converter indicator. The test is carried out alternately the first voltage sensor will measure the voltage on the R phase, the second voltage sensor will measure the voltage on the S phase, and the third voltage sensor will measure the voltage on the T phase. This voltage sensor test is carried out after going through the calibration process. The test results are shown in Table 1 for measuring the R phase voltage, Table 2 for measuring the S phase voltage, and Table 3 for measuring the T phase voltage.

Based on Table 1, Table 2, and Table 3, it can be seen that the value of the voltage measurement on the sensor is not much different from the reference multimeter value. The average error on the first sensor test for phase R is 1.77% with reading ability. The average error on the second sensor test for phase S is 1.08%. The average error in the third sensor test for phase T is 0.61%. The results of the three sensors show that the three voltage sensors can work well, which have an error of less than 2%, for measurements using a reference multimeter.

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Table 1. Data of R-phase voltage sensor

No	Voltage (V)		Error (%)	Converter Indicator (Hz)
	Voltage Sensor	Voltage Sensor		
1	67,63	68,90	1,84	3
2	72,68	72,40	0,39	4
3	79,15	77,20	2,53	5
4	84,26	81,90	2,88	6
5	89,16	86,50	3,08	7
6	93,27	90,80	2,72	8
7	97,31	94,90	2,54	9
8	101,37	99,00	2,39	10
9	104,45	103,20	1,21	11
10	107,90	106,40	1,41	12
11	111,28	110,40	0,80	13
12	114,10	114,00	0,09	14
13	117,11	117,50	0,33	15
average	95,36	94,08	1,71	-

Table 2. Data of S-phase voltage sensor

No	Voltage (V)		Error (%)	Converter Indicator (Hz)
	Voltage Sensor	Multimeter Reference		
1	65,17	66,30	1,70	3
2	70,55	72,00	2,01	4
3	76,35	77,20	1,10	5
4	81,45	81,40	0,06	6
5	86,25	86,00	0,29	7
6	90,27	90,20	0,08	8
7	94,19	94,40	0,22	9
8	97,75	98,40	0,66	10
9	101,32	102,00	0,67	11
10	104,80	105,80	0,95	12
11	108,28	109,90	1,47	13
12	111,04	113,50	2,17	14
13	114,07	117,20	2,67	15
average	92,42	93,41	1,08	-

Table 3. Data of T-phase voltage sensor

No	Voltage (V)		Error (%)	Converter Indicator (Hz)
	Voltage Sensor	Voltage Sensor		
1	66,44	67,20	1,13	3
2	71,90	72,50	0,83	4
3	77,65	77,80	0,19	5
4	83,05	82,30	0,91	6
5	87,94	87,10	0,96	7
6	92,33	91,30	1,13	8
7	96,45	95,50	0,99	9
8	100,11	99,40	0,71	10
9	104,03	103,50	0,51	11
10	107,41	107,40	0,01	12
11	111,34	111,20	0,13	13
12	115,15	115,10	0,04	14
13	118,30	118,80	0,42	15
average	94,78	94,55	0,61	-

B. Current meter testing

Before being used for testing in a measuring system, the current sensor has gone through a calibration process. The calibration process is carried out by measuring current with a voltage source using a TDGC2-0.5kVA AC variable transformer with a load of several lamps that can be varied, as well as measuring using a reference multimeter. This calibration process is to determine the actual characteristics of the current sensor. Each sensor has different characteristics. Calibration process by taking data with variations in load and voltage. Voltage variations are taken for every 25 V to 125 V increase. Meanwhile, load variations are up to four lamps with 100 Watts for each lamp. This calibration process is carried out on the three sensors used. The data taken is then searched for the linearity equation.

Current meter testing is carried out by applying a lamp load to the generator. The light load used is 6 lamps of 25 watts each and a variation of the converter indicator. The test is carried out by alternating current sensor 1 will measure the current in phase R, current sensor 2 will measure the current in phase S, and current sensor 3 will measure the current in phase T. The test results of the current sensor are shown in Table 4 for measuring phase current R, Table 5 for the measurement of the S-phase current, and Table 6 for the measurement of the T-phase current.

Table 4. Data of R-phase current sensor

No	Current (A)		Error (%)	Converter Indicator (Hz)
	Current Sensor	Multimeter Reference		
1	1,23	1,25	1,60	3
2	1,25	1,26	0,79	4
3	1,31	1,31	0,00	5
4	1,36	1,35	0,74	6
5	1,36	1,36	0,00	7
6	1,37	1,36	0,74	8
7	1,34	1,33	0,75	9
8	1,29	1,31	1,53	10
9	1,29	1,28	0,78	11
10	1,26	1,26	0,00	12
11	1,25	1,24	0,81	13
12	1,22	1,22	0,00	14
13	1,19	1,20	0,83	15
average	1,29	1,29	0,66	-

Table 5. Data of S-phase current sensor

No	Current (A)		Error (%)	Converter Indicator (Hz)
	Current Sensor	Multimeter Reference		
1	1,19	1,19	0,00	3
2	1,25	1,25	0,00	4
3	1,33	1,32	0,76	5
4	1,36	1,36	0,00	6
5	1,39	1,39	0,00	7
6	1,37	1,38	0,72	8
7	1,35	1,36	0,74	9
8	1,32	1,33	0,75	10
9	1,31	1,31	0,00	11
10	1,28	1,28	0,00	12
11	1,25	1,26	0,79	13
12	1,24	1,24	0,00	14
13	1,22	1,22	0,00	15
rerata	1,30	1,30	0,29	-

Table 6. Data of T-phase current sensor

No	Current (A)		Error (%)	Converter Indicator (Hz)
	Current Sensor	Multimeter Reference		
1	1,25	1,25	0,00	3
2	1,29	1,29	0,00	4
3	1,34	1,34	0,00	5
4	1,38	1,38	0,00	6
5	1,39	1,40	0,71	7
6	1,38	1,38	0,00	8
7	1,36	1,36	0,00	9
8	1,33	1,34	0,75	10
9	1,31	1,32	0,76	11
10	1,30	1,29	0,78	12
11	1,27	1,27	0,00	13
12	1,24	1,25	0,80	14
13	1,23	1,23	0,00	15
average	1,31	1,32	0,29	-

In Tables 3, 4, and 5, it can be seen that the value of the current measurement on the sensor is not much different from the value shown by the multimeter. The average error in testing sensor 1 in phase R is 0.66%. The average error in sensor 2 testing in phase S is 0.29%. The average error on the 3-sensors test in the S phase is 0.29%. The results of the three sensors show that the three current measurements can work properly, with an error of less than 1% compared to the reference multimeter.

C. Power meter testing

The power measurement results are obtained when measuring voltage and current. The power measurement data is obtained from recording on the serial monitor from the Arduino software. Tests are carried out using variations when the generator is without load and also when the generator is loaded. The generator when loaded consists of 1 lamp load to 6 lamp loads. In addition, the tests carried out have a variety of indicators from the converter with an indicator range of 3 to 13. The measurement results for a generator load of 6 lamps are shown in Figs 10-12. The 'Measure' curve is the result of a power measurement processed by the microcontroller. While the 'Calculate' curve is the power value obtained from multiplying the voltage and current by the multimeter measurement results. With each increase in the frequency of the converter, the power will increase, indicating that the generator power will increase with an increase in generator shaft rotation. Based on the test results data used to make the graph, the error value has been calculated between the measurement results and the calculation results. The average error of the R phase power is 2%, the average S phase error is 1.26% and the average T phase error is 0.75%. The average error for all tests is 1.4%. Based on the average error value which is less than 2%, it can be said that the power measurement system (VA) can work properly.

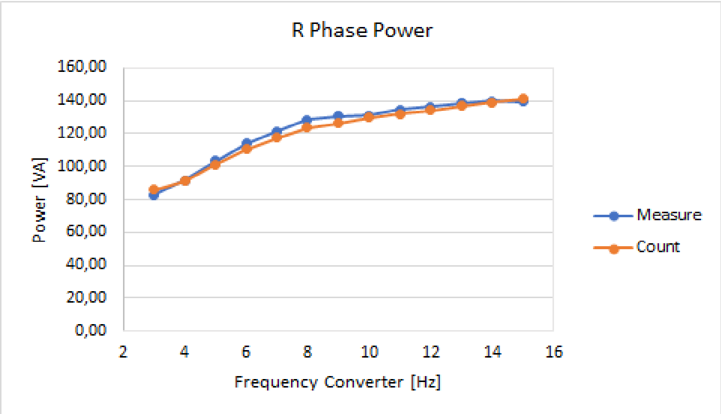

Figure 10. Results of measuring the R phase power and calculating the power based on a multimeter with variations in the frequency converter.

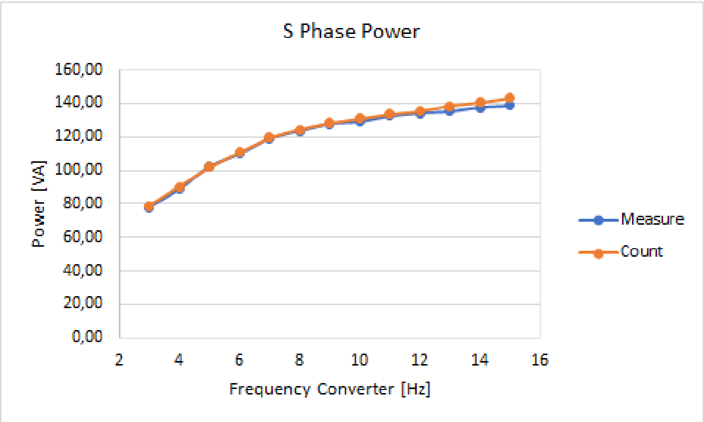

Figure 11. Results of S-phase power measurements and power calculations based on a multimeter with frequency converter variations.

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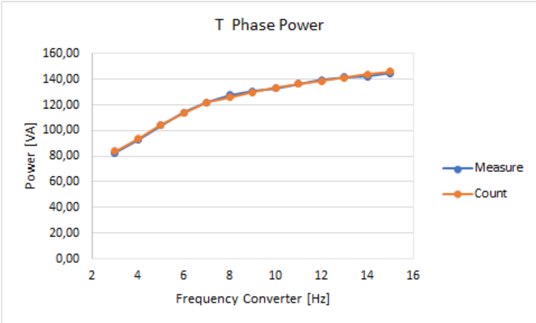

Figure 12. Results of measuring phase T power and calculating power based on a multimeter with variations in frequency converters

D. Communication with GUI and other Microcontrollers

After the device is connected to a computer/laptop, the user can activate the device by pressing the push button, data will be sent using serial communication. Data from the serial is then read in a GUI application program created using Python which is then plotted as a trend graph in the GUI. The GUI display can be seen in Fig. 13. The power value of each phase and the total power can be displayed numerically and graphically. The horizontal axis shows the measurement time in seconds, and the vertical axis is the power measured in VA units. One window is displayed for every 10 data points, when the curve reaches the right boundary of the graph, then the next time curve will be displayed starting from the left again.

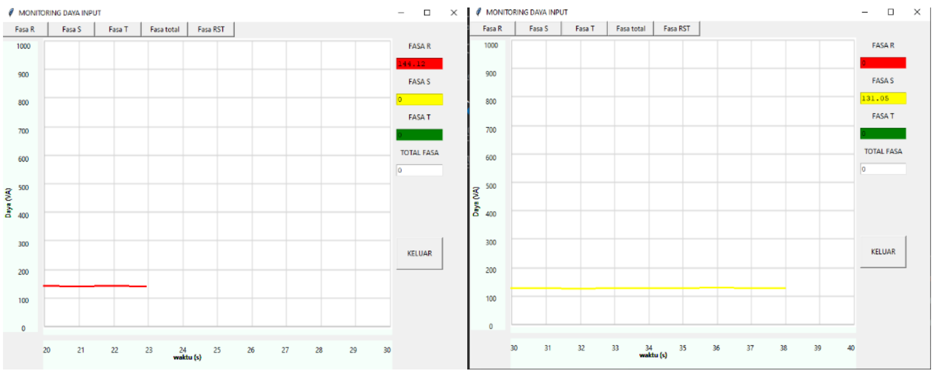

Figure 13. The results of displaying graphical trends in the GUI application.

Communication between the system and another microcontroller (master) is designed using the RS-485 serial communication module. The data communication process will take place when the measuring system is active. If the measurement system

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is not active there will be no communication. The communication process uses the RS485 module through two lanes A and B. This communication will start when the master sends data in the form of an encoded address desired by the master. Each measurement system on a low-speed permanent magnet generator has its own mutually agreed-upon coding address. For input power measurement coding address is #I$. When the slave gets data that matches the coding address, the slave will immediately send measurement data. The format of data transmission carried out by the slave is as follows "#i, total power, $". Fig. x is the result of communication between two slave and master microcontrollers.

4 Conclusions

Based on the design and implementation as well as testing of the input power measurement system for the driving motor, it can be concluded as follows. The measurement system has succeeded in measuring the voltage, current, and apparent power of each phase, as well as the total input power of the generator drive motor. Real-time measurements are monitored and displayed on an LCD viewer and graphs via the GUI on the laptop. Instantaneous measurement data can also be displayed on the LCD. The voltage and current sensors used can be used to measure the input power per phase of the generator with a value close to the multimeter reference. Input power measurement data and time data have been successfully stored in the micro SD. There is an average voltage reading error of 2% against the reference voltmeter. The current reading error is 1% against the reference ammeter. The average power measurement error is 2% against a reference multimeter.

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References

[1] M. H. Rashid, Electric Renewable Energy System. London: Elsevier Ltd, (2016).

[2] T. Yee Heng, T. Jian Ding, C. Choe Wei Chang, T. Jian Ping, H. Choon Yian, and M. Dahari, Permanent Magnet Synchronous Generator design optimization for

wind energy conversion system: A review, Energy Reports, 8 (2022) 277–282.

[3] K. I. Liangliang Wei, Taketsune Nakamura, Development and optimization of low-speed and high-efficiency permanent magnet generator for micro hydro-electrical generation system, Renew. Energy, 147 (1) (2020) 1653–1662.

[4] H. Q. and P. J. Wang Fengxiang, Bai Jianlong, Design features of low speed permanent magnet generator direct driven by wind turbine, in International Conference on Electrical Machines and Systems, Nanjing, China, (2005) 1017–1020.

[5] S. D. Zevalukito, Y. Lukiyanto, and F. R. Prayogo, The Experiment of Wind Electric Water Pumping for Salt Farmers in Remote Area of Demak-Indonesia, Int. J. Appl. Sci. Smart Technol., 4 (2) (2022) 185–194.

[6] P. Ristianto, Generator Ganda Pada Pembangkit Listrik Mikrohidro Dengan Turbin Tunggal, Avitec, 1 (1) (2019) 65–70.

[7] Syafruddin, G. Devira ramady, and R. Ristiadi Hudaya, Rancang Bangun Sistem Proteksi Daya Listrik menggunakan Sensor Arus dan Tegangan berbasis Arduino, Isu Teknol. Stt Mandala, 16 (1) (2021) 36–43.

[8] F. Adi Iskandarianto et al., Rancang Bangun Sistem Monitoring Tegangan, Arus, dan Frekuensi Keluaran Generator 3 Fasa Pada Modul Mini Power Plant Departemen Teknik Instrumentasi, J. AMORI, 1 (2020).

[9] I. M. A. N. and S. M. U. Azmi, Perancangan Sistem Monitoring dan Proteksi Daya Balik untuk Generator 1 kW 3 Fase.

[10] W. S., Teknik Ukur dan Peranti Ukur Elektronik. Jakarta, Gramedia, (1988).

[11] von M. A., Electric Power System. Canada: John Wiley & Sons, Inc., (2006).

[12] Bernadeta Wuri Harini, Martanto, and Tjendro, Comparison of Two DC Motor Speed Observers on Sensorless Speed Control Systems, J. Nas. Tek. Elektro dan Teknol. Inf., 11 (4) (2022) 267–273.