Design of Micro Hydro Power Plant System Prototype with Arduino Uno-Based Dummy Load

Geri Geraldo Salam, Ahmad Raditya Cahya Baswara
Department of Electrical Engineering, Universitas Ahmad Dahlan, Yogyakarta, Indonesia

ARTICLE INFORMATION

Corresponding Author:

Ahmad Raditya Cahya Baswara,
Department of Electrical Engineering,
Universitas Ahmad Dahlan,
Bantul, Yogyakarta, Indonesia.
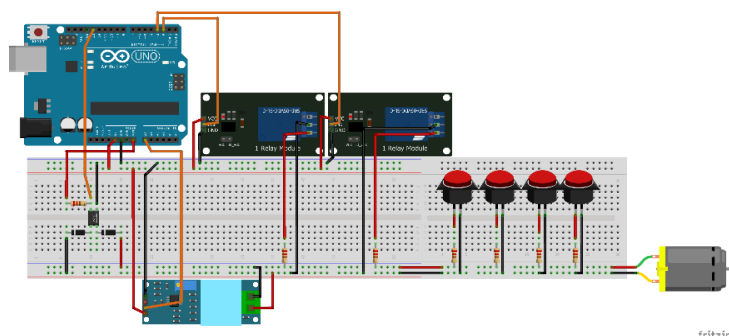Email:
ahmadradityac@ee.uad.ac.id

ABSTRACT

Electricity is a vital need and economic resource that is needed for all communities. One of the electricity technologies that can be generated from water is utilizing water discharge to be converted into electrical energy or called PLTMH (Microhydro Power Plant). This research has been done but still needs to be developed, for example on an automatic loading system. With the help of a 1 channel relay to control the dummy load automatically. This research uses 2 different test simulations and different wiring circuits. The results of this study show that in simulation 2 the dummy load system cannot run at all. Due to the voltage value read is not so stable by the ZMPT101B sensor. The spike of the read voltage value causes it to be difficult for the relay to analyze the voltage value then causes the logic on the relay to be disturbed and an error occurs in the automatic dummy load system. However, in simulation 1 the dummy load system can work properly. For comparison of voltage values between a multimeter with a voltage value of 4.5 V (before adding a load) and on the Arduino IDE with an average of 4.564 V, the average error is -1.42222. For comparison of frequency values between multimeter 47 Hz without load and on Arduino IDE with an average value of 47 Hz with an average error of -0.8, from ac generator rotation with a voltage value of 4.5V.

Document Citation:

1. INTRODUCTION

Droop based controller ensures the parallel operation of power plants in power system. Such controller is also required for Micro hydro power plants to work in interconnected micro hydro power plants [1]. Nevertheless, the results of education and training (Diklat) of Micro Hydro Power Plant (PLTMH) Center for Human Resource Development Electricity, Renewable Energy and Energy Conservation (PPSDM KEBTKE) the last two low force shown by the average value of 67.6 or less satisfactory, while the graduation limit of PLTMH training is 71.0 [2].

Conventional topologies of micro-hydro power are stand-alone operation used in rural electrical network in developing countries [3]. Micro hydro plants ranging from a few hundred Watts for battery charging or food processing application up to 100KW usually provided power for small community or rural industry in remote area away from the grid [4]. Electricity consumption caused by an uncontrolled load is different depending on the number of usage [5].

ZMPT101B voltage sensor module is a voltage sensor made from the ZMPT101B voltage transformer. It has high accuracy, good consistency for voltage and power measurement and it can measure up to 250V AC [6]. In the domestic pipeline the flow of water has enough kinetic energy to rotate the blade of a small hydro turbine which in turn rotates the rotor of a generator to generate electricity in addition to the other routine activities such as laundry, cook and bathe [7].

Hydro power generation can be planned on small-scale on existing small rivers, canals etc. [8]. The design proceed re of micro-hydro power plant was implemented by a MATLAB Simulink computer program to calculate all the design parameters [9]. This paper presents a Fuzzy-based Maximum Power Point Tracking Solar Battery Charge Controller with backup stand-by AC generator. This study is developed to provide a maximum power point tracking battery charge controller using fuzzy logic algorithm for isolated areas that uses solar panels and AC generators [10].

Micro-hydro-electric power is both an efficient and reliable form of clean source of renewable energy. It can be an excellent method of harnessing renewable energy from small rivers and streams [11]. The main source of such generation is a micro hydropower plant. Micro hydro power plants are usually designed up to a capacity of 100 kW [12]. Moreover a controller is needed: for the wind technology to transform AC into DC and protect batteries from overcharges and deep discharges; for the PV technology to protect batteries from overcharges and deep discharges; to transform the 18 V generated current to 12 V current; and also for the micro-hydro technology to adjust the generation to the consumption [13].

Micro-hydro power plants (MHPPs) are emerging as a mature balancing technology and a great alternative to large hydropower plants as they encounter population displacement and many environmental problems [14]. Generally, Electronic Load Control (ELC) used in micro hydro power plant (MHPP) to controls the voltage between consumer load and a dummy load, still detects one parameter voltage or frequency generator only [15]. The importance of the turbine in micro hydro projects with respect to our current energy scenario is also highlighted [16].

Although micro-hydroelectric power plants (MHP) are generally considered a suitable option for rural electrification in remote com- munities, there is a lack of empirical sustainability evaluations to assess the long-term performance of the projects [17]. The prototype is also equipped with a voltage, frequency, and water flow to the generator using Arduino as a signal processing module [18]. Under the ''Private Sector Participation in Micro-Hydro Development Project in Rwanda'', four newly registered Rwandan companies are each constructing a micro-hydroelectricity plant (100–500kW) and building a low-voltage distribution grid [19].

The generator output voltage and current will be read by Arduino as a control center using the ZMPT101B AC voltage sensor and ACS712 current sensor [20]. The basic principle of hydro power is that if water can be channelized from a higher level to a lower level, then the resulting potential energy of water can be used to do work [21]. The use of low-speed generators with permanent magnet excitation for micro-hydroelectric power plants and wind turbines is relevant in terms of providing good weight and size indicators, simplicity of construction, lack of sliding contacts, with the ability to perform a generator of low rotation speeds, which causes low cost and high reliability [22].

Whereas large hydro schemes often involve the construction of major dams and the flooding of whole valleys, micro-hydro is one of the most environmentally benign energy technologies available [23]. As a result of micro-hydro project, electrification of the community center and youth activity center has been done which are now used for many educational and social activities such as recreation of villagers, community development and awareness programs [24]. ELC functions by dumping excess energy into dummy loads when consumers switch off their loads, thereby maintaining the total load on the generator constant [25].

2. METHODS

This research focuses on reading the value of voltage, frequency and automatic control of the dummy load using a 1 channel relay. The object of research studied in this study is to see the load balancing reaction of the dummy load when the voltage value is too high or too low, using an automatic system with 1 channel relay logic as a breaker and connector of the dummy load circuit.

2.1. Flowchart of MHP System with Dummy Load

In this study using 2 simulations and 2 systems. To make an automatic system from a dummy load, a 1 channel relay component is needed which will detect voltage readings using a ZMPT101B sensor, if there is an increase in voltage value, the relay will automatically connect to the dummy load and vice versa if the voltage value decreases, the relay will disconnect the dummy load. In simulation 1 using components 1 switch and 1 relay and simulation 2 using components 4 switches and 2 relays. The measured voltage and frequency values are displayed on the serial monitor on the Arduino IDE which is processed by Arduino UNO. In order for the system of relays to run, it is necessary to program in advance the logic of the 1 channel relay, ZMPT101B sensor. For the frequency reader circuit has no effect on the relay logic system. In simulation 1, if the voltage> = 4 volts, the relay will turn on to connect the dummy load so that the voltage value will drop. In simulation 2, for relay 1 if the voltage> = 3 volts then relay 1 will be connected to connect to the dummy load and reduce the voltage value. For relay 2 if the voltage> = 3.6 volts then relay 2 will be connected to connect to the dummy load. Flowchart simulation 1 can be seen in Figure 1.
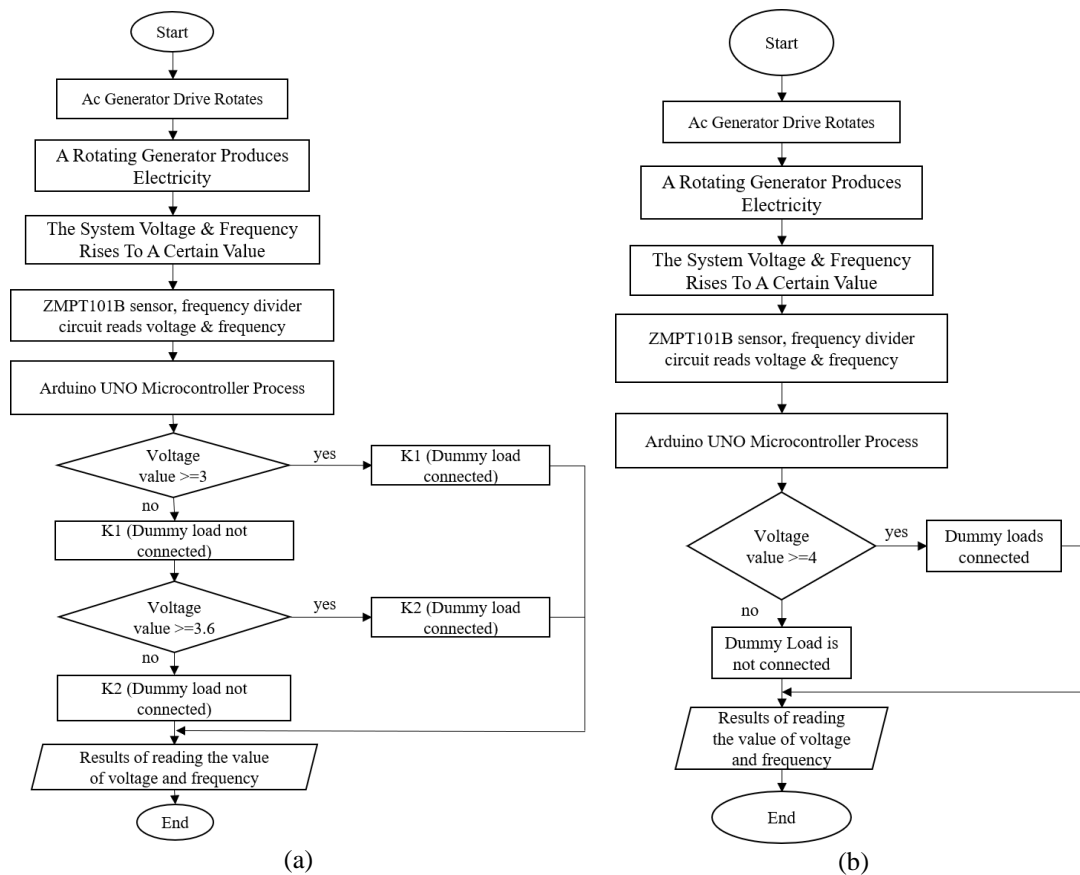

Figure 1. PLTMH System Flowchart Simulation 1 (a) and Simulation 2 (b)

2.2. System Block Diagram

In this study using an automatic switch or switching system from a 1 channel relay to connect and disconnect the dummy load from the original load or actual load switch that is controlled manually using a switch. If the actual load is not connected, the dummy load is connected as a substitute for the lack of load used which is connected to the ac generator. The control of this system works on the reading of the voltage value. Processed using Arduino UNO then transferred to Arduino IDE. The block diagram of the MHP system Simulation 1 and simulation 2 can be seen in Figure 2 and Figure 3. Color description of arrow direction, Green

arrow is the mechanical power arrow, Red arrow is the electric flow arrow and Blue arrow is the information flow arrow.

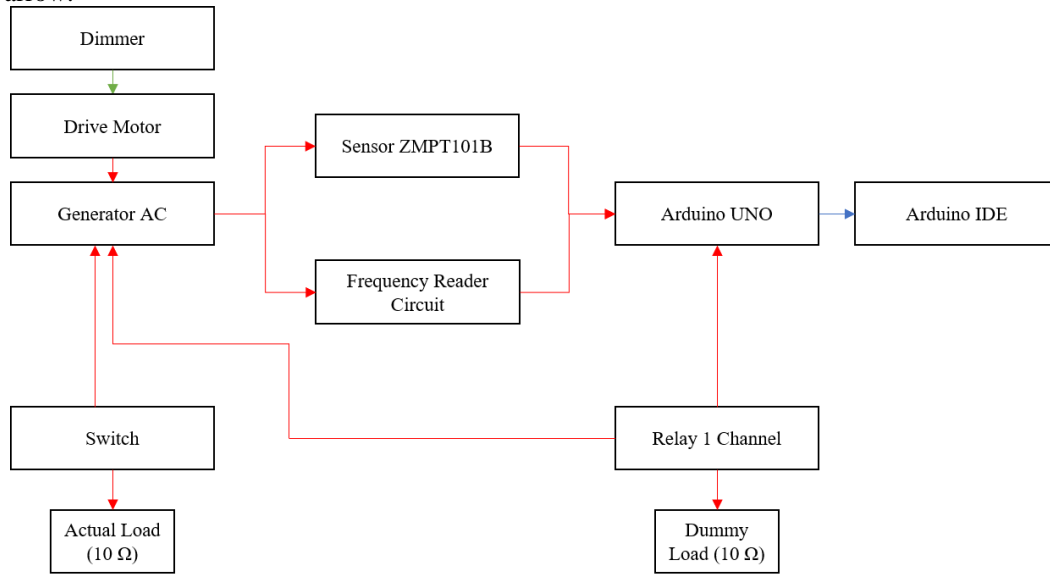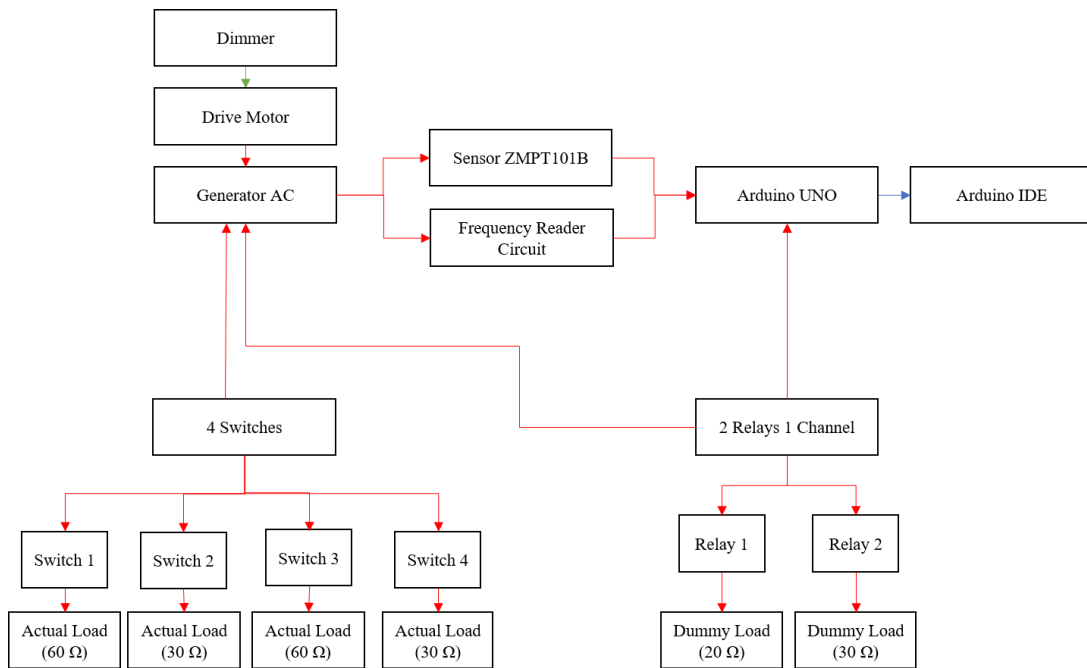**Figure 2.** Simulation 1 MHP system block diagram

Figure 3. Simulation 2 PLTMH system block diagram

2.3. System Wiring Diagram

This research has 3 different circuits because there are 3 test simulations. The dummy load system component used only uses 1 1 channel relay connected to a 10 Ohm resistor. Wiring diagrams or wiring simulation 1 and simulation 2 in this study can be seen in Figure 4 and Figure 5.
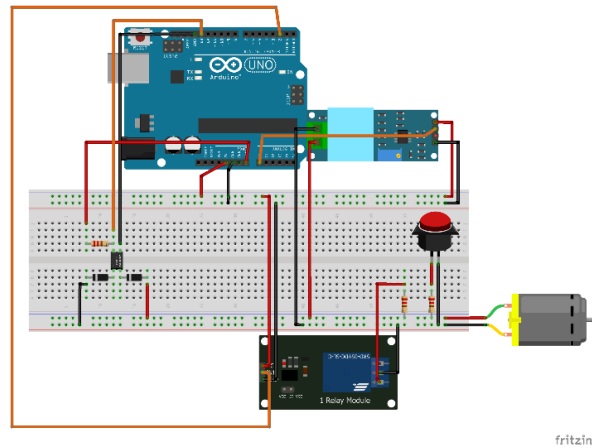
Figure 4. Wiring diagram or wiring simulation 1

The wiring diagram in Figure 4 contains two 1n4007 diodes, one resistor 10k ohm for frequency circuits, one optocoupler pc817, two 10 Ohm resistors for dummy load and actual load, switch on-off, one channel Relay, Sensor ZMPT101B, Arduino UNO R3 and AC Generator. Arduino UNO pins connected to circuits/components can be seen in Table 1.

Table 1. Data output pin table from simulation 1

Arduino Uno Pins	Sensor/Reader Circuit
A0	ZMPT 101B
D13	Frequency reader circuit
D2	Relay 1
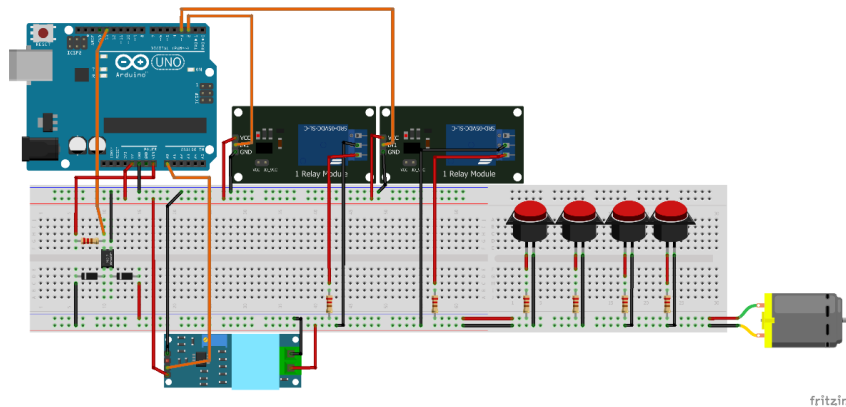
Figure 5. Wiring diagram or wiring simulation 2

The wiring diagram in Figure 5 is two diode 1n4007, one 10k ohm resistor for the frequency circuit, one pc817 optocoupler for frequency circuit, four switch on-off, two resistors 60 Ohm for actual load, two resistor 30 ohm for actual load, one resistor 30 Ohm for dummy load, one resistor 20 Ohm for dummy load, two Relay one channel, one ZMPT101B Sensors, one Arduino UNO R3 and AC Generator. Arduino UNO pins connected to circuits or components can be seen in Table 2.

Table 2. Data output pin table from simulation 2

Arduino Uno Pins	Sensor or Reader Circuit
A0	ZMPT 101B
D13	Frequency reader circuit
D2	Relay 1
D3	Relay 2

The physical appearance of the system wiring circuit of the MHP with the Arduino UNO-based dummy load can be seen in Figure 6. The physical appearance of the MHP circuit in the box can be seen in Figure 7.
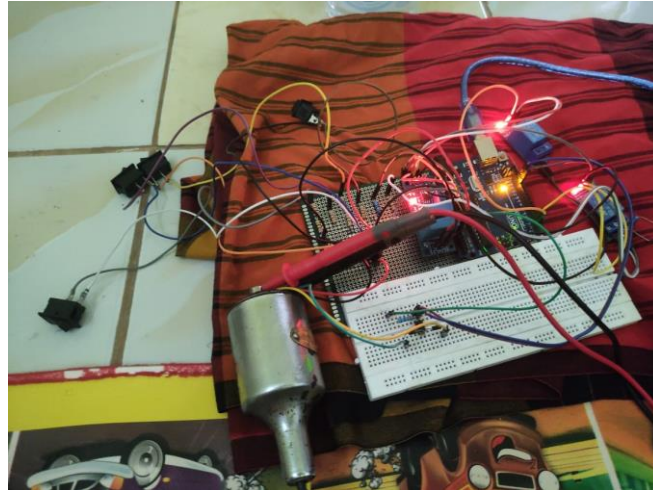
Figure 6. System wiring PLTMH tool series
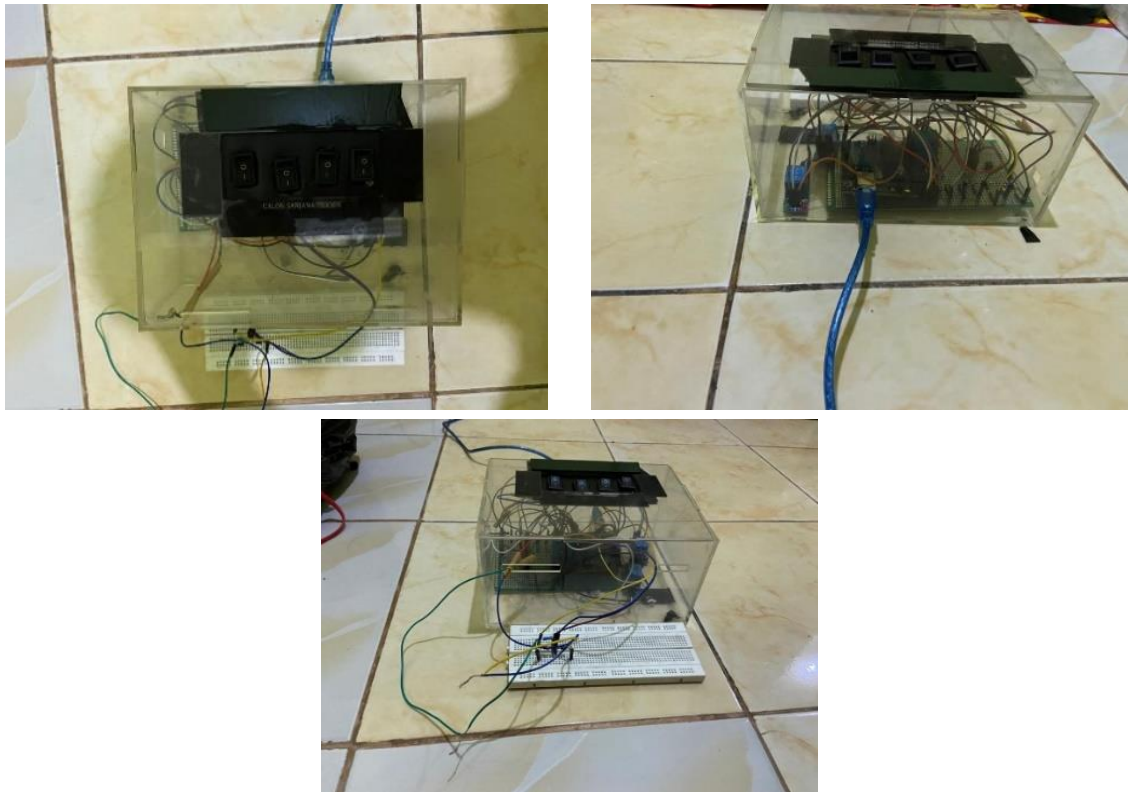
Figure 7. System wiring PLTMH tool kit box

3. RESULT AND DISCUSSION

Testing voltage values on Arduino IDE software after adding actual load and dummy load. In this test, the voltage value is taken by adding actual load and dummy load. But before that, the initial value of the voltage without load is 4.5 V which has been measured using a multimeter first. In this test there are 2 test simulations.

3.1. Testing Using 1 Actual Load and 1 Automatic Relay Dummy load (Simulation 1)

In this test, there are 2 loads including 1 actual load which is controlled using a switch to connect the circuit and 1 dummy load connected to relay input pin 2 on the Arduino UNO, each load has an electrical resistance value of 10 Ohm. In this test, the relay is programmed on the Arduino IDE with logic restrictions (if the voltage value < 2 then the relay will turn off and if the voltage value > = 4 then the relay will turn on). However, to turn on the relay the voltage value must touch the value of 3 V first, if the voltage value has not touched the value of 3 V, for example 2.99 V, then the relay will not respond and remain off. But if the voltage

value is more than 3 V, for example 3.35 V, the relay will turn on and if the voltage value is read above 2 V, the relay will remain on and if it is below the value of 2 V, for example 1.99 V, the relay will turn off.

3.1.1. Switch (R = 10 Ohm)

In this test using a switch as an actual load controller with a resistance value of 10 Ohm load. The test table can be seen in Table 3.

Table 3. Voltage value on Arduino IDE 1 actual load

Load (Ω)	Voltage value on Arduino IDE (V)	Voltage value on Multimeter (V)	Switch condition (R)	Relay condition (K)
No-load	4.5	4.5	Off	Off
R (10 ohm)	2.97	2.7	On	Off
R (10 ohm)	2.98	2.7	On	Off
R (10 ohm)	2.93	2.7	On	Off
R (10 ohm)	2.97	2.7	On	Off
R (10 ohm)	2.94	2.7	On	Off
R1 (10 ohm)	2.95	2.7	On	Off
Sensor average		2.956667		

Table 3 shows the results, when the generator is connected to the load, the voltage value will drop. In this test, the switch is carried out in the on condition so that the relay does not meet the requirements to respond to the read voltage value to be able to turn on. So get the average value of ZMPT10B sensor readings connected to 1 actual load, amounting to 2.95 V.

3.1.2. Relay (K = 10 Ohm)

In this test using a relay using an automatic system from the relay that will control the connection and disconnection to the dummy load with a load specification of 10 Ohm resistance value. The test table can be seen in Table 4.

Table 4. The voltage value on Arduino IDE 1 is dummy load

Load (Ω)	Voltage value on Arduino IDE (V)	Voltage value on Multimeter (V)	Switch Condition (R)	Relay Condition (K)
No load	4.5	4.5	Off	Off
K (10 ohm)	2.96	2.9	Off	On
K (10 ohm)	2.91	2.9	Off	On
K (10 ohm)	2.83	2.9	Off	On
K (10 ohm)	2.91	2.9	Off	On
K (10 ohm)	2.79	2.9	Off	On
K (10 ohm)	2.85	2.9	Off	On
Sensor average		2.87		

Table 4 shows the results, when the generator is connected to the load, the voltage value will drop. In this test, the switch is carried out in the off condition so that the relay is qualified to respond to the read voltage value. In this test the relay is in a constant state of turning on, because the read voltage value has touched $\geq$ 4 and the read voltage value does not touch the step < 2 V, according to the Arduino IDE program command. So, get the average value of ZMPT10B sensor readings connected to 1 actual load, amounting to 2.875 V.

3.2. Testing Using 4 Actual loads and 2 Dummy loads (Simulation 2)

In this test, the initial value of the voltage is 4.5 V which is tested on a multimeter first before using the load. This test uses a multimeter measuring instrument and a ZMPT101B sensor for comparison. This test has a load of 6 loads. Among them 4 actual loads and 2 dummy loads are connected. A series of 4 actual loads are connected to 4 switches. Each switch consists of 1 actual load with different resistance values. Switch 1 (R1) is connected to a resistor with a resistance value of 60 Ohms. Switch 2 (R2) is connected to a resistor with a resistance value of 30 Ohms. Switch 3 (R3) is connected to a resistor with a resistance value of 60 Ohms. Switch 4 (R4) is connected to a resistor with a resistance value of 30 Ohms. The dummy load circuit is connected to 2 relays 1 channel. Dummy load relay 1 (K1) uses input pin 2 on Arduino UNO with a resistance value of 20 Ohm and dummy load relay 2 and (K2) uses input pin 3 on Arduino UNO with a resistance value of 30 Ohm. In this test the relay is programmed on the Arduino IDE with the logic limit of the Relay 1 (K1) program = if the voltage value < 2 then relay 1 will turn off, if the voltage value ≥ 3 then relay 1 will turn on. Relay 2 (K2) = if the voltage value < 2.4 then relay 2 will turn off and if the voltage value ≥ 3.6 then relay 2

will turn on. R1 is the Switch 1 (60 Ohm) and K1 is the Relay 1 (20 Ohm), R2 is the Switch 2 (30 Ohm) and K2 = Relay 2 (30 Ohm), R3 is the Switch 3 (60 Ohm), R4 is the Switch 4 (30 Ohm).

3.2.1. Parallel Circuit R1/K1/K2 (60 Ohm/20 Ohm/30 Ohm)

In testing the value of this voltage using 1 switch connected to 1 actual load of 60 Ohm and 2 relays connected automatically to the dummy load with the value of relay 1 resistance of 20 ohms and relay 2 of 30 ohms. The data can be seen in Table 5. Table 5 shows the results, when the generator is connected to the load, the voltage value will drop. In this test, the average value of the sensor is 2.825 V.

Table 5. Voltage value after adding 1 actual load and 2 dummy loads

Load (Ω)	On Arduino IDE (V)	On Multimeter(V)	Switch Condition (R1)	Relay Condition (K1, K2)
No load	4.5	4.5	Off	Off
R1//K1//K2 (60 Ohm//20 Ohm//30 Ohm)	4.24	2.7	R1 On	K1 Off, K2 Off
R1//K1//K2 (60 Ohm//20 Ohm//30 Ohm)	2.71	2.7	R1 On	K1 On, K2 On
R1//K1//K2 (60 Ohm//20 Ohm//30 Ohm)	2.92	2.7	R1 On	K1 On, K2 On
R1//K1//K2 (60 Ohm//20 Ohm//30 Ohm)	2.65	2.7	R1 On	K1 On, K2 On
R1//K1//K2 (60 Ohm//20 Ohm//30 Ohm)	2.94	2.7	R1 On	K1 On, K2 On
R1//K1//K2 (60 Ohm//20 Ohm//30 Ohm)	2.90	2.7	R1 On	K1 On, K2 On
R1//K1//K2 (60 Ohm//20 Ohm//30 Ohm)	2.83	2.7	R1 On	K1 On, K2 On
Sensor average		2.82		

3.2.2. Parallel Circuit R1/R2/K1 (60 Ohm/30 Ohm/20 Ohm)

In testing this voltage value using 2 switches connected to 2 actual loads with a resistance value of switch 1 60 Ohm and switch 2 30 Ohm and 1 relay connected to 1 dummy load automatically with a relay 1 resistance value of 20 ohms. The data can be seen in Table 6. Table 6 shows the results, when the generator is connected to the load, the voltage value will drop. In this test, the average value of the sensor is 2.64 V.

Table 6. Voltage value after adding 1 actual load and 2 dummy loads

Load (Ω)	On Arduino IDE (V)	On Multimeter(V)	Switch Condition (R1, R2)	Relay Condition (K1)
No Load	4.5	4.5	Off	Off
R1//R2//K1 (60 Ohm//30 Ohm//20 Ohm)	2.73	2.8	R1 On, R2 On	K1 On
R1//R2//K1 (60 Ohm//30 Ohm//20 Ohm)	2.95	2.8	R1 On, R2 On	K1 On
R1//R2//K1 (60 Ohm//30 Ohm//20 Ohm)	2.82	2.8	R1 On, R2 On	K1 On
R1//R2//K1 (60 Ohm//30 Ohm//20 Ohm)	2.50	2.8	R1 On, R2 On	K1 On
R1//R2//K1 (60 Ohm//30 Ohm//20 Ohm)	2.62	2.8	R1 On, R2 On	K1 On
R1//R2//K1 (60 Ohm//30 Ohm//20 Ohm)	2.27	2.8	R1 On, R2 On	K1 On
Sensor average		2.64		

3.2.3. Parallel Circuit R1/R2/R3/K2 (60 Ohm/30 Ohm/60 Ohm/20 Ohm)

In this test using 3 switches with each different load resistance value and relay 2 which has a resistance value of 30 Ohm. However, there is a logic system error that causes relay 1 and relay 2 to collide with each other due to a surge in the voltage value of the ZMPT101B sensor voltage value reading, which should be relay 1 off and relay 2 on. Relay 1 is given a logic limit input if the voltage value read is < 2 V then relay 1 will turn off and if the voltage value read is >= 3 V then relay 1 will turn on. Then the relay 2 is given a logic limit input if the read voltage value < 2.4 V then relay 2 will turn off and if > = 3.6 then relay 2 will turn on as in the first

test that is switch 1 on (R1), relay 1 and relay 2 on (K1 and K2 on). Testing 3 switches and relay 2 can be seen in Table 7.

Table 7. The voltage value is 3 actual loads and 1 dummy load

Load (Ω)	On Arduino IDE (V)	On Multimeter(V)	Switch Condition (R1, R2, R3, R4)	Relay Condition (K1, K2)
No Load	4.5	4.5	Switch Off	Relay off
R1//R2//R3//K2 (60 Ohm//30 Ohm//60 Ohm//20 Ohm)	2.76	2.4	R1 On, R2 On, R3 On	K1 On, K2 On
R1//R2//R3//K2 (60 Ohm//30 Ohm//60 Ohm//20 Ohm)	2.37	2.7	R1 On, R2 On, R3 On	K1 On, K2 On
R1//R2//R3//K2 (60 Ohm//30 Ohm//60 Ohm//20 Ohm)	4.60	4.5	R1 On, R2 On, R3 On	K1 On, K2 Off
R1//R2//R3//K2 (60 Ohm//30 Ohm//60 Ohm//20 Ohm)	3.05	3	R1 On, R2 On, R3 On	K1 On, K2 Off
R1//R2//R3//K2 (60 Ohm//30 Ohm//60 Ohm//20 Ohm)	2.54	2.4	R1 On, R2 On, R3 On	K1 On, K2 On
R1//R2//R3//K2 (60 Ohm//30 Ohm//60 Ohm//20 Ohm)	2.13	2.3	R1 On, R2 On, R3 On	K1 On, K2 On
R1//R2//R3//K2 (60 Ohm//30 Ohm//60 Ohm//20 Ohm)	5.81	4.5	R1 On, R2 On, R3 On	K1 On, K2 Off
R1//R2//R3//K2 (60 Ohm//30 Ohm//60 Ohm//20 Ohm)	2.37	2.4	R1 On, R2 On, R3 On	K1 On, K2 On

When testing, switches 1, 2 and 3 are turned on, the value read is > 3 V on the serial monitor, resulting in relay 1 also responding due to the voltage value read > 3. If the logic limit of relay 1 is increased, for example > = 3.5, then in testing R1 + R2 + K1 the logic of the relay will be disrupted. The voltage value reading from the ZMPT101B sensor is not entirely stable, sometimes experiencing a fairly drastic spike. For example, the voltage measured on a multimeter is 3.5 V, then in the Arduino IDE program using the ZMPT101B sensor the voltage value read can be from 3.01 V to 3.99 V which causes the logic system on relay 1 and relay 2 to be difficult to get the logic limit. And if relay 1 is given a logic limit input < 2.7 which is greater than the logic limit of relay 2, the logic system in the previous test will be disrupted. It can be concluded that testing with 3 switches and using relay 2 there is a system error in the logic of relays 1 and 2 or it can be said that it has not been successful.

3.2.4. Parallel Circuit R1/R2/R3/R4 (60 Ohm/30 Ohm// 60 Ohm/30 Ohm)

In testing this voltage value using 4 switches connected to 4 dummy loads with each resistance value on different loads. In this test, all relays are in a dead condition because the voltage value read does not meet the requirements of relay programs 1 and 2 to respond to turn on. The data can be seen in Table 8. Table 8 shows the results, when the generator is connected to the load, the voltage value will drop. In this test, the average value of the sensor is 2.67 V.

Table 8. Voltage value 4 load actual load

Load (Ω)	On Arduino IDE (V)	On Multimeter(V)	Switch Condition (R1, R2, R3, R4)	Relay Condition (K1, K2)
No Load	4.5	4.5	Off	Off
R1//R2//R3//R4 (60 Ohm//30 Ohm//60 Ohm//30 Ohm)	2.51	2.7	All On	All Off
R1//R2//R3//R4 (60 Ohm//30 Ohm//60 Ohm//30 Ohm)	2.42	2.7	All On	All Off
R1//R2//R3//R4 (60 Ohm//30 Ohm//60 Ohm//30 Ohm)	2.60	2.7	All On	All Off
R1//R2//R3//R4 (60 Ohm//30 Ohm//60 Ohm//30 Ohm)	2.71	2.7	All On	All Off
R1//R2//R3//R4 (60 Ohm//30 Ohm//60 Ohm//30 Ohm)	2.93	2.7	All On	All Off
R1//R2//R3//R4 (60 Ohm//30 Ohm//60 Ohm//30 Ohm)	2.86	2.7	All On	All Off
Average		2.67		

3.2.5. Parallel Circuit K1/K2 (20 Ohm/30 Ohm)

In testing this voltage value, all switches are off. However, the connected load is 2 relay loads connected to the dummy load automatically with the value of relay 1 resistance of 20 ohms and relay 2 30 ohms. Data can be seen in Table 9. From Table 9 shows the results, when the generator is connected to the load, the voltage value will drop. In this test, the average value of the sensor is 3.07 V.

Table 9. Voltage value 2 load dummy load

Load (Ω)	On Arduino IDE (V)	On Multimeter(V)	Switch Condition (R1, R2, R3, R4)	Relay Condition (K1, K2)
No Load	4.5	4.5	Off	Off
K1//K2 (20 Ohm//30 Ohm)	3.18	3	All Off	K1 On, K2 On
K1//K2 (20 Ohm//30 Ohm)	2.95	3	All Off	K1 On, K2 On
K1//K2 (20 Ohm//30 Ohm)	2.92	3	All Off	K1 On, K2 On
K1//K2 (20 Ohm//30 Ohm)	3.05	3	All Off	K1 On, K2 On
K1//K2 (20 Ohm//30 Ohm)	3.19	3	All Off	K1 On, K2 On
K1//K2 (20 Ohm//30 Ohm)	3.15	3	All Off	K1 On, K2 On
Average			3.07	

3.3. Frequency value reader component circuit testing

Next, testing the frequency value reader component circuit of 2 diode components, optocoupler, and 10k ohm resistor. This circuit is tested on the Arduino IDE software which is transferred by Arduino Uno to display the frequency value of the ac generator. Frequency value testing and comparison of standard multimeter measuring instruments before being connected to the load and after being connected to the load can be seen in Table 10.

Table 10. The frequency value on the multimeter and Arduino IDE after and before being connected to the load

Load	Frequency (Hz)	Multimeter (V)	Difference	Error
R1 (60 Ω)	47	47	0	0
R1//R2 (60 Ω//30 Ω)	47	46	-1	-2
R1//R2//R3 (60 Ω//30 Ω//60 Ω)	46	45	-1	-2
R1//R2//R3//R4 (60 Ω//30 Ω//60 Ω//30 Ω)	45	45	0	0
No Load	47	47	0	0
Average Error Value				-0.8

In testing the frequency value above is from the voltage value of 4.5 V. When testing, the ac generator is connected to the load and not connected to the load, the frequency value read only has a difference of 1 difference and the highest is only 2 and the average frequency value reading from the Arduino IDE and multimeter is almost the same, because the ac generator from the MHP of this study is rotated using a drill where the rotation of the drill is stronger and faster even though it is given a load, only the voltage value drops.

4.   CONCLUSION

In the 1st simulation based on the test results in table 4.7 with an initial voltage value of 4.5 V after being connected to an actual load of 10 Ohm getting an average voltage value of 2.956667 V. Furthermore, after the switch connected to the actual load is turned off, the ac generator is automatically connected to the dummy load controlled by a relay that has been programmed on the Arduino IDE, with a resistance value of 10 Ohm. In the test results in table 4.8 with an initial voltage value of 4.5 V after being connected to the dummy load, the average voltage value that has been averaged is 2.875 V. Then the difference in the voltage value of the ac generator when connected to the actual load then the load reaches the dummy load on the Arduino UNO, the actual load voltage value minus the dummy load voltage value of 0.081667. Because the logic system of the relay runs well, it can be concluded that this 1st simulation can be said to be successful. In the 2nd simulation, the 3rd experiment testing the voltage value with 4 actual loads and 2 dummy loads experienced an error in the relay system 1 and 2, namely in the parallel circuit experiment R1 / R2 / R3 / K2, could not run according to

the desired command, namely when switches 1, 2, and 3 are turned on, relay 2 should respond to turn on (constant / relay does not experience repeated off and on). Relay 2 is connected to a 30 Ohm dummy load, and relay 1 should be off and not respond to the voltage value. Due to the voltage sensor that is used to take readings, there are ups and downs that are far away and result in system errors from controlling 2 relays or resulting in errors in relay systems 1 and 2. Due to errors in the logic system of relays 1 and 2, the 2nd simulation did not all go well and in the 2nd simulation which was successful only in experiments 1, 2, 4 and 5, it is said that the 2nd simulation has not been successful.

ACKNOWLEDGMENTS

REFERENCES

[1] X. Meng, J. Liu and Z. Liu, "A Generalized Droop Control for Grid-Supporting Inverter Based on Comparison Between Traditional Droop Control and Virtual Synchronous Generator Control," in *IEEE Transactions on Power Electronics*, vol. 34, no. 6, pp. 5416-5438, June 2019, https://doi.org/10.1109/TPEL.2018.2868722.

[2] P. Albus, A. Vogt, and T. Seufert, "Signaling in virtual reality influences learning outcome and cognitive load," *Computers & Education*, vol. 166, p. 104154, 2021, https://doi.org/10.1016/j.compedu.2021.104154.

[3] I. Sami, N. Ullah, S. M. Muyeen, K. Techato, M. S. Chowdhury and J. -S. Ro, "Control Methods for Standalone and Grid Connected Micro-Hydro Power Plants With Synthetic Inertia Frequency Support: A Comprehensive Review," in *IEEE Access*, vol. 8, pp. 176313-176329, 2020, https://doi.org/10.1109/ACCESS.2020.3026492.

[4] S. Hoseinzadeh, M. H. Ghasemi, and S. Heyns, "Application of hybrid systems in solution of low power generation at hot seasons for micro hydro systems," *Renewable Energy*, vol. 160, pp. 323-332, 2020, https://doi.org/10.1016/j.renene.2020.06.149.

[5] S. Ginting, J. W. Simatupang, I. Bukhori and E. R. Kaburuan, "Monitoring of Electrical Output Power-Based Internet of Things for Micro-Hydro Power Plant," *2018 International Conference on Orange Technologies (ICOT)*, pp. 1-7, 2018, https://doi.org/10.1109/ICOT.2018.8705786.

[6] B. Septian, P. Rakesh and S. R. Dhora, "IoT Based Power Monitoring System for Diesel Generator," *2020 5th IEEE International Conference on Recent Advances and Innovations in Engineering (ICRAIE)*, pp. 1-4, 2020, https://doi.org/10.1109/ICRAIE51050.2020.9358316.

[7] F. C. Dime and J. P. Rogelio, "Pico-Hydro Turbine and Pump for Small Scale Agricultural Electrification and Irrigation: A Review of Similar Ventures," *2022 IEEE 14th International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment, and Management (HNICEM)*, pp. 1-6, 2020, https://doi.org/10.1109/HNICEM57413.2022.10109601.

[8] X. Lu *et al.*, "Detection of Micro Solder Balls Using Active Thermography Technology and K-Means Algorithm," in *IEEE Transactions on Industrial Informatics*, vol. 14, no. 12, pp. 5620-5628, 2018, https://doi.org/10.1109/TII.2018.2839614.

[9] Y. Triasdian, H. Pamingotan, B. Triatmodjo, R. Sriwijaya, M. Mahardika and M. A. Muflikhun, "A Study Analysis of Micro-Hydro Powerplant (MHPP) Potential from Cooling of Steam Turbine," *2020 International Conference on Technology and Policy in Energy and Electric Power (ICT-PEP)*, pp. 33-37, 2020, https://doi.org/10.1109/ICT-PEP50916.2020.9249919.

[10] R. K. Rai and O. P. Rahi, "Fuzzy Logic based Control Technique using MPPT for Solar PV System," *2022 First International Conference on Electrical, Electronics, Information and Communication Technologies (ICEEICT)*, pp. 01-05, 2022, https://doi.org/10.1109/ICEEICT53079.2022.9768650.

[11] R. D. Sudiro, B. M. Arthaya and L. Halim, "Design of Propeller Turbine for Micro-Hydro-Electric Power Plant at Cikapundung River - Bandung," *2019 International Conference on Mechatronics, Robotics and Systems Engineering (MoRSE)*, pp. 122-127, 2019, https://doi.org/10.1109/MoRSE48060.2019.8998683.

[12] A. B. Timilsina, S. Mulligan, and T. R. Bajracharya, "Water vortex hydropower technology: a state-of-the-art review of developmental trends," *Clean Technologies and Environmental Policy*, vol. 20, pp. 1737-1760, 2018, https://doi.org/10.1007/s10098-018-1589-0.

[13] A. Hirsch, Y. Parag, and J. Guerrero, "Microgrids: A review of technologies, key drivers, and outstanding issues," *Renewable and sustainable Energy reviews*, vol. 90, pp. 402-411, 2018, https://doi.org/10.1016/j.rser.2018.03.040.

[14] I. Sami, N. Ullah, S. M. Muyeen, K. Techato, S. Chowdhury, and J. S. Ro, "Control Methods for Standalone and Grid Connected Micro-Hydro Power Plants with Synthetic Inertia Frequency Support: A Comprehensive Review," *IEEE Access*, vol. 8, pp. 176313–176329, 2020, https://doi.org/10.1109/ACCESS.2020.3026492.

[15] Z. Has, A. Z. Rosyidi, I. Pakaya, N. A. Mardiyah, N. Nurhadi and M. Effendy, "Integrated Frequency Control of Microhydro Power Plant Based Flow Valve Control and Electronic Load Controller," *2018 IEEE Conference on Systems, Process and Control (ICSPC)*, pp. 244-249, 2018, https://doi.org/10.1109/SPC.2018.8704153.

[16] A. Kuriqi, A. N. Pinheiro, A. Sordo-Ward, M. D. Bejarano, and L. Garrote, "Ecological impacts of run-of-river hydropower plants—Current status and future prospects on the brink of energy transition," *Renewable and Sustainable Energy Reviews*, vol. 142, p. 110833, 2021, https://doi.org/10.1016/j.rser.2021.110833.

[17] A. López-González, L. Ferrer-Martí, and B. Domenech, "Long-term sustainability assessment of micro-hydro projects: Case studies from Venezuela," *Energy Policy*, vol. 131, pp. 120–130, 2019,

https://doi.org/10.1016/j.enpol.2019.04.030.

[18] Y. Z. Arief, M. F. A. Rahim, N. Mubarakah, M. H. I. Saad and H. Eteruddin, "Development of Micro Hydro Power Plant Prototype as A Field Laboratory for Educational and Research Purposes," *2021 5th International Conference on Electrical, Telecommunication and Computer Engineering (ELTICOM)*, pp. 15-18, 2021, https://doi.org/10.1109/ELTICOM53303.2021.9590111.

[19] M. C. Mukeshimana, Z. Y. Zhao, and J. P. Nshimiyimana, "Evaluating strategies for renewable energy development in Rwanda: An integrated SWOT–ISM analysis," *Renewable Energy*, vol. 176, p. 402-414, 2021, https://doi.org/10.1016/j.renene.2021.05.104.

[20] Y. Xu, C. Li, Z. Wang, N. Zhang and B. Peng, "Load Frequency Control of a Novel Renewable Energy Integrated Micro-Grid Containing Pumped Hydropower Energy Storage," in *IEEE Access*, vol. 6, pp. 29067-29077, 2018, https://doi.org/10.1109/ACCESS.2018.2826015.

[21] A. Chel and G. Kaushik, "Renewable energy technologies for sustainable development of energy efficient building," *Alexandria engineering journal*, vol. 57, no. 2, pp. 655-669, 2018, https://doi.org/10.1016/j.aej.2017.02.027.

[22] L. Wei, T. Nakamura, and K. Imai, "Development and optimization of low-speed and high-efficiency permanent magnet generator for micro hydro-electrical generation system," *Renewable Energy*, vol. 147, pp. 1653-1662, 2020, https://doi.org/10.1016/j.renene.2019.09.049.

[23] I. Ihsanullah, A. Jamal, M. Ilyas, M. Zubair, G. Khan, and M. A. Atieh, "Bioremediation of dyes: Current status and prospects," *Journal of Water Process Engineering*, vol. 38, p. 101680, 2020, https://doi.org/10.1016/j.jwpe.2020.101680.

[24] V. Ganesh *et al*., "Technology for Addressing Income Insufficiency in Rural India," *2020 IEEE 8th R10 Humanitarian Technology Conference (R10-HTC)*, 2020, pp. 1-6, 2020, https://doi.org/10.1109/R10-HTC49770.2020.9356975.

[25] R. A. Ofosu, E. Normanyo, K. K. Kaberere, S. I. Kamau, and E. K. Otu, "Design of an electronic load controller for micro hydro power plant using Fuzzy-PI controller," *Cogent Engineering*, vol. 9, no. 1, p. 2057115, 2022, https://doi.org/10.1080/23311916.2022.2057115.

AUTHOR BIOGRAPHY

Geri Geraldo Salam is a student of the Electrical Engineering Study Program, Faculty of Industrial Technology, Ahmad Dahlan University, Yogyakarta.

Ahmad Raditya Cahya Baswara is a Lecturer in the Electrical Engineering Study Program, Faculty of Industrial Technology, Ahmad Dahlan University, Yogyakarta. S1 : Electrical Engineering, Gadjah Mada University – Yogyakarta, S2 : Electrical Engineering, Gadjah Mada University – Yogyakarta, Electrical Power Energy, Wireless Power Transfers & Renewable Energy