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Utilization of Heat from Geothermal Well Pipes as Electricity for Road Lighting Based on The Internet of Things

Rizani Firdaus, Muhamad Ariandi*

Department of Electrical Engineering, Faculty of Science and Technology, Universitas Bina Darma, Jl. Jenderal Ahmad Yani No.3, South Sumatra 30264, Indonesia

*muhamad_ariandi@binadarma.ac.id

Abstract. PT. Pertamina Geothermal Energy Area Lumut Balai has a very extreme work location with various contours, safety factors and lack of access to electricity for street lighting are things that need attention given the importance of street lighting in the company's operations. Street lighting is an important element that supports the comfort and safety of road users in their activities at night. The research objective is to design an IoT (Internet Of Things) system that can monitor the utilization of pipe heat into electrical energy for street lighting and provide street lighting needs around geothermal well pipes. In this study used thermoelectric as a tool to generate electrical energy from available heat. The IoT system is used to read data parameters as a tool to display temperature, voltage and current values on the LCD (Liquid Crystal Display) and the Thingspeak website. The temperature value is read by the MAX6675 thermocouple sensor while the INA219 sensor is used to read the voltage and current values. The focus of this research is to heat the thermoelectric so that it can produce electrical energy to turn on the lights as lighting and can monitor parameter data directly. The highest thermoelectric electrical energy output is at a temperature of 75.1˚C. Where at this temperature a voltage of 2.32 V is generated and a current of 0.03 A. The lamp will turn on if the thermoelectric heat is fulfilled. The light turns on when the environment is dark and the light turns off when the environment is bright.

Keywords: Street Lighting, Internet of things, Thermoelectric, MAX6675, INA219, Lights

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1. Introduction

Street lighting is an important element that supports the comfort and safety of road users in their activities at night [1]. Street lighting can provide lighting that resembles conditions during the day so that activities at night can be more effective [2]. Street lighting is a facility that must exist in the business activities of a company [3]. Regional owned enterprises (BUMD) and State-owned enterprises (BUMN) are business entities that need street lighting for each of their activities, especially at night [4]. One of the BUMN that requires street lighting for its activities is PT. Pertamina Geothermal Energy [5].

PT. Pertamina Geothermal Energy is a company that produces electricity from geothermal energy. One of the working areas of PT. Pertamina Geothermal Energy is located in the Lumut Balai Area which has been operating to generate electricity commercially since 2020 [6]. In the operation of a geothermal plant, the fluid used to generate electrical energy is in the form of steam (steam) or water (brine) which will be flowed through a pipeline network along the 9 km which are interconnected between production wells, reinjection wells, and generators [7]. The fluid flowing through the pipes has wasted heat that is not utilized. The pipes used are relatively long and laid along the road between the wells [8]. PT. Pertamina Geothermal Energy Area Lumut Balai has a very extreme work location with various contours [9]. Safety factors and the lack of access to electricity for street lighting are things that need attention given the importance of street lighting in the company's operations [10].

Based on research previously conducted by Dodit Arditama, et al (2021) with the title "Utilization of Thermal Energy from Smokeless Burning of Garbage as an Alternative to Small-Scale Power Generation Using Thermoelectrics". The result of this research is that the heat from combustion can generate an electric voltage so that it can light up a light bulb [11]. In a journal entitled "Utilization of Rice Husk Briquettes as a Heat Producer in a Thermoelectric Generator Stove for Street Lighting" research results by Suliono, et al (2019). The results of research in this journal can be concluded that electrical energy with the highest output is generated by using 6 thermoelectric pieces arranged in series which are capable of turning on 1 lighting lamp and 1 fan for cooling [12].

The purpose of this research is to use geothermal well pipe heat to design an Internet of Things system that can monitor the utilization of pipe heat into electrical energy for street lighting and provide street lighting needs around geothermal well pipes. This is very useful where apart from safety and comfort factors, street lighting can also streamline the process of monitoring pipes along the PLTP.

2. Methods

The preparation of this scientific work is based on several studies related to the utilization of heat in electrical energy. These studies inspired the authors to utilize heat from geothermal good pipes to turn into electrical energy for street lighting.

2.1 Tool Planning

Planning is the initial stage in designing a tool [13]. Planning is a stage that has an important role in completing the manufacture of a tool. In the planning process, there is a design and manufacture that will be taken in several steps, including the selection of a component that adapts to the needs of a tool. The process carried out in planning this tool has all stages that are interconnected with a series, namely Hardware planning and Software planning (programming language).

2.2 Tool Design

This tool, which is made for the utilization of pipe heat into electrical energy, has three stages, namely input, then process, and finally output. These stages have an important role in each other. The stages are described in the block diagram as follows:

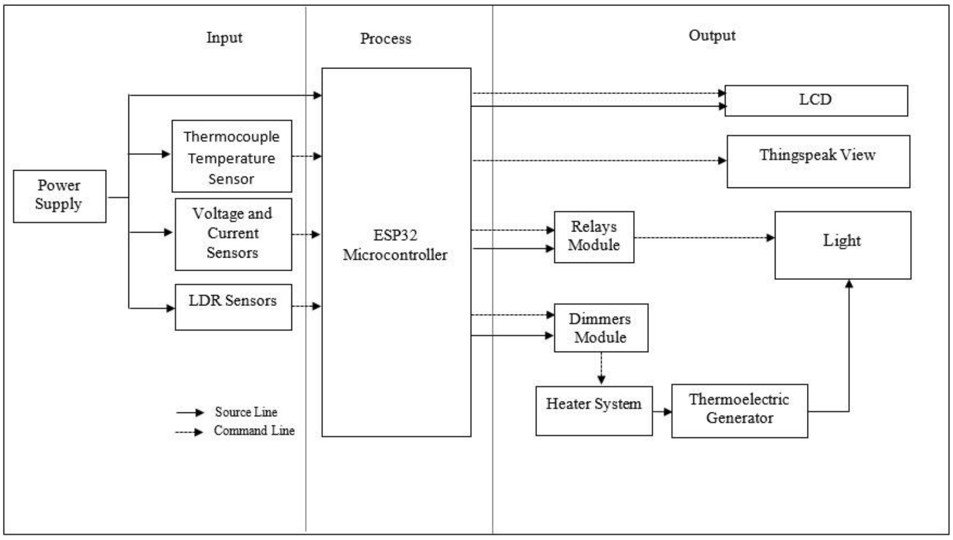

Figure 1. System Block Diagram

2.2.1 Tools Testing

Tool testing is done by collecting data directly on the components that have been installed. Testing is done by measuring components such as power supplies, microcontrollers and sensors. Schematic of a series of pipe heat utilization into electrical energy can be seen in the following figure:

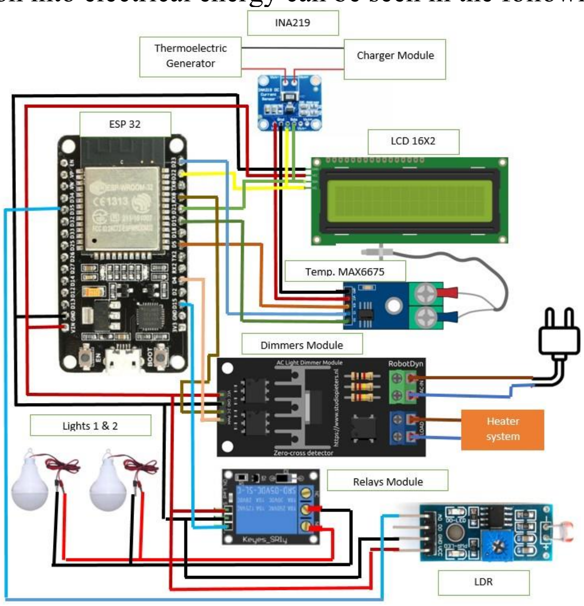

Figure 2. Tool Schematic Diagram

2.2.2 Tools Schematic

When designing what we have to pay attention to is the working principle of the circuit, the specifications of the components to be installed in the circuit so that during the design there will be no damage when we install the components. The flowchart of the tools made can be described as follows:

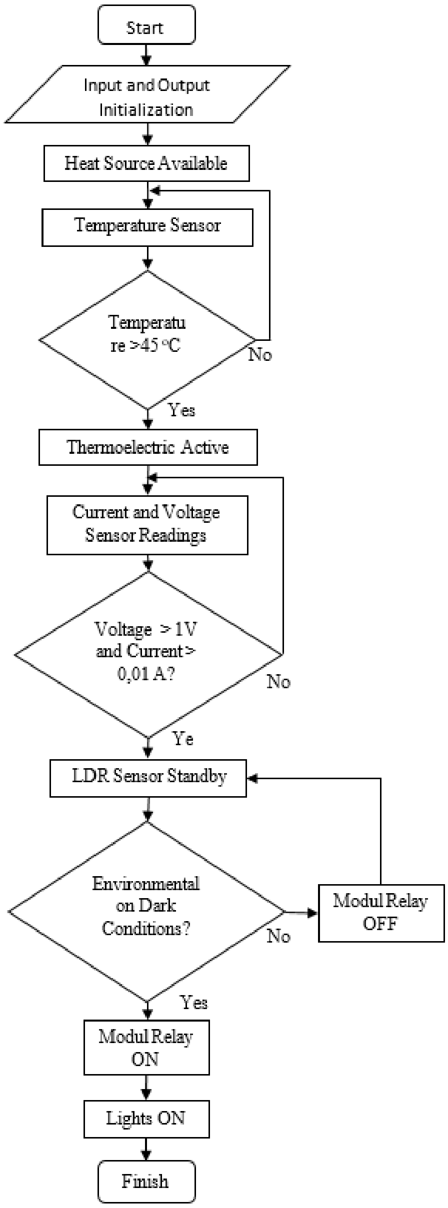

Figure 3. Flowchart system

2.3 How the Tool Works

The working system of the tool that is made is thermoelectric to convert pipe heat into electrical energy. In this tool, the pipe heat energy is replaced by using a heater or heater. The output heat of the heater can be adjusted using the dimmer module [14]. The value of the temperature generated by the heater can be determined using the MAX6675 thermocouple temperature sensor, besides that the current and voltage will also be read by the INA219 sensor. The sensor used requires a 5V power supply so that it can be used to read the actual value generated by the tool. These sensors will be integrated with the ESP32 microcontroller which has a wifi module. This microcontroller will send the readings of the sensors to the internet of things, in this case using Thingspeak View. In Thingspeak View, we can read the resulting temperature, current, and voltage values so that they can be monitored remotely using electronic equipment such as laptops or cell phones. In addition to Thingspeak, the value sent by the sensor will also be read on the 16x2 LCD. Then according to its purpose, the electrical energy that has been produced by the thermoelectric will be used to turn on the lamp for lighting.

2.4 Tool Assembly

Figure 4. Assembly of All Components

In Figure 4, all the components that have been assembled are installed. All components are connected and placed on the table that has been created. Installation of power supply components such as transformers, diodes, capacitors, and IC regulators which are useful as a source of electricity

3 Results and Discussion

3.1 Tool Testing

Tool testing is done by collecting data directly on the components that have been installed. Testing is done by measuring components such as power supplies, microcontrollers, and sensors. The image of the measurement points carried out for testing the tool can be seen in Figure 5 as follows.

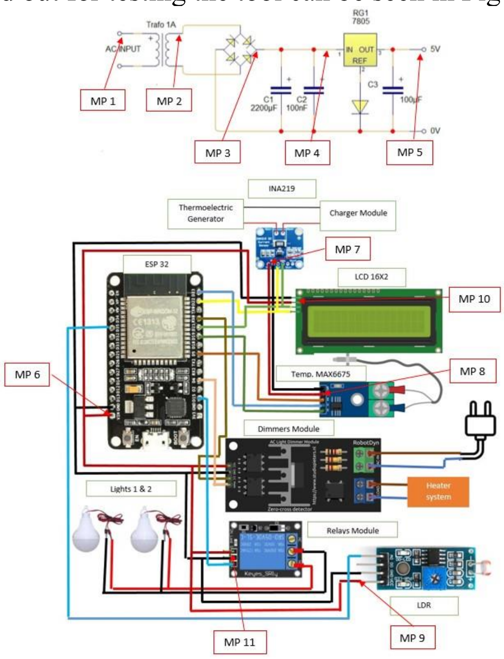

Figure 5. Tool Measurement Point

To get a good measurement value, measurements were carried out 5 times for each component. So the measurement results require an average value to get the measurement value. The formula for calculating the average of the measurement values is.

$$\overline{X} = \frac{X_1+X_2+X_3+X_4+X_5}{n} = \frac{\sum X_i}{n}$$

Ex :

$\overline{X}$ = average measurement value

$\sum X_i$ = total number of samples

n = number of measurements

The tool testing process includes measuring height with a tool that has been designed and will be compared with manual height measurement and testing of sound output. Tool testing data from measurements and calculations can be seen in Table 1.

Table 1. Testing Tool Voltage

Measurement Point	Measurement Voltage (V)					
	V_1	V_2	V_3	V_4	V_5	$V_{average}$
Power Supply (MP1) - Vac	219,0	219,2	220,2	218,9	220,7	219,6
Trafo (MP2) - Vac	12,07	12,09	12,08	12,07	12,10	12,08
Diode (MP3) - Vdc	12,63	12,63	12,66	12,64	12,65	12,64
Capacitor (MP4) - Vdc	12,71	12,69	12,68	12,70	12,68	12,69
IC 7805 (MP5) - Vdc	4,98	4.97	4,98	4,96	4,98	4,97
ESP 32 (MP6) - Vdc	4,96	4,94	4,96	4,95	4,97	4,95
INA219 Sensor (MP7) - Vdc	4,97	4,96	4,96	4,95	4,94	4,95
Thermoucouple Sensor (MP8) - Vdc	4,93	4,95	4,95	4,94	4,93	4,94
LDR Sensor (MP9) - Vdc	4,95	4,94	4,94	4,93	4,92	4,93
LCD 16x2 (MP10) - Vdc	4,94	4,97	4,95	4,94	4,96	4,95
Relay (MP11) - Vdc	3,04	3,03	3,04	3,05	3,04	3,04

The form of application of diodes as a rectifier for alternating current to direct current, usually this rectifier circuit uses four diodes arranged in a rectangular shape with a diode on each side. To find out the bridge diode voltage before it is filtered by the capacitor, it can be calculated using the formula below. To find out the bridge diode voltage before it is filtered by the capacitor, it can be calculated by the formula below.

$V_m = V_{rms}.\sqrt{2}$

Ex:

$V_m = V_{max}$

V_{rms} = Secondary transformer voltage

The percentage error is the difference between the estimated value and the exact value and the percentage of the exact value. To find out the percentage of errors from the tool, it is necessary to compare the test data with the specifications of the tool. The formula for calculating the percentage of errors is.

$$\% \text{ Error} = \frac{|\text{Measurement Value} - \text{Specification Value}|}{\text{Specification Value}} \text{ x } 100$$

A measuring tool is used to determine the quality and value of the component to be measured. Data comparison of measurement values and tool specification values can be seen in Table 2.

Table 2. Error Percentage

Measurement Point	$V_{Average}$	$V_{Spefication}$	$V_{Calculation}$	% Error
Power Supply (MP1) - Vac	219,6	220	-	0,001
Trafo (MP2) - Vac	12,08	12	11,98	0,006
Diode (MP3) - Vdc	12,64	-	9,97	0,267
Capacitor (MP4) - Vdc	12,69	-	16,78	0,243
IC 7805 (MP5) - Vdc	4,97	5	-	0,006
ESP 32 (MP6) - Vdc	4,95	3,3 - 5	-	In Range
INA219 Sensor (MP7) - Vdc	4,95	5	-	0,012
Thermoucouple Sensor (MP8) - Vdc	4,94	5	-	0,012
LDR Sensor (MP9) - Vdc	4,93	5	-	0,014

LCD 16x2 (MP10) - Vdc	4,95	5	-	0,010
Relay (MP11) - Vdc	3,04	3 - 5	-	In Range

3.2 Tool Experiment Results

The experiment was carried out by taking data measured by the sensors that have been installed on the device. The measurement results are in the form of sensor readings displayed on the LCD and the Thingspeak website. The units for the voltage and current values read by the INA219 sensor are Volts (V) and Amperes (A). Meanwhile, the unit for the temperature value read by the MAX6675 Type K sensor is degrees Celsius (ºC). Measurements are carried out indoors with the aim of knowing the characteristics of the Light-dependent resistor (LDR) by turning the room lights off or on. If the room light is on, it means you are in the daytime, while the room light is off, it means you are at night. Measurement data is displayed on the LCD as shown in Figure 6 and displayed on the Thingspeak website as shown in Figure 7.

Figure 6. Display on LCD

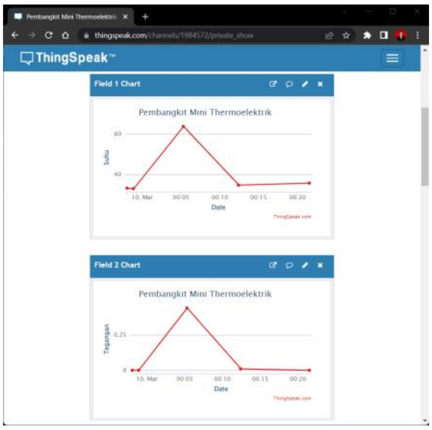

Figure 7. Display on the thingspeak website

Measurement or observation data expressed in the form of numbers requires a basis for managing measurement results data so that it is easier to process data. The results of measurement data can be seen in Table 3.

Table 3. The measurement results of the sensors

Measurenment Time	Temperature (ºC)	Voltage (V)	Current (A)	Power V x I (W)	Energy P x t (Joule)	Information
0th minute	30,25	0,00	0,00	0,00	0,00	Lamps Off
1st minute	36,00	0,42	0,00	0,00	0,00	Lamps Off
2nd minute	39,75	0,61	0,00	0,00	0,00	Lamps Off
3rd minute	47,23	1,01	0,01	0,0101	1,818	Lamps On
4th minute	51,12	1,13	0,01	0,0113	2,712	Lamps On
5th minute	55,74	1,27	0,01	0,0127	3,810	Lamps On
6th minute	58,53	1,62	0,02	0,0324	11,664	Lamps On

7th minute	61,77	1,87	0,02	0,0374	15,708	Lamps On
8th minute	66,34	2,06	0,03	0,0618	29,664	Lamps On
9th minute	71,00	2,30	0,03	0,0609	32,886	Lamps On
10th minute	75,01	2,32	0,03	0,0696	41,76	Lamps On

From the data shown in Table 3 it can be seen that the first time the device was turned on the voltage and current had not been read because the thermoelectric was not active. When the heater turns on and distributes heat to the thermoelectric, there will be voltage and current values. It can be seen in the third measurement that the lighting lights are on.

3.3 Overall Tool Work Process Testing

One of the signs of damage to watch out for is when the motor indicator light is on or flashing continuously. When it is first turned on, the power supply indicator light will light up with the LCD flashing as shown in the picture in Figure 8.

Figure 8. The Power Supply and LCD Displays Light Up

This indicates that the DC voltage source for the microcontroller and sensor is properly available. In Figure 8 measurements are taken to test whether the tool is working at a good working voltage or not. It can be seen that the percentage error between the measurement value and component specifications is relatively small so that the tool works in optimal conditions. During the day the LDR will give a signal that the lights must be turned off as shown in Figure 9 below.

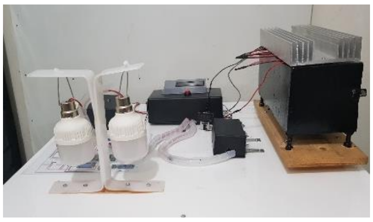

Figure 9. Lights Off When Bright Conditions

The lights turn on according to the conditions in the field supported by LDR. The LDR here is used as a light sensor to detect the light from the lamp. At night the LDR will give a signal that the lights must be on as shown in Figure 10 below.

Figure 10. Lights On When Dark Conditions

In 3 it can be seen that the higher the temperature value, the higher the resulting voltage will be, but the thermoelectric has a work limit on temperature with a working limit of -55 ºC to 83 ºC so that the heat output from the heater must be maintained so that it does not exceed the specified limit. but by setting using the dimmer module. The dimmer module receives commands from the ESP32 microcontroller according to the values written in the program.

4 Conclusion

Based on the results of the study it can be concluded that the Internet of Things System is capable of monitoring Temperature, Voltage and Current values which can be displayed via the LCD and the Thingspeak website. The lamp can turn on when the thermoelectric heat is fulfilled so that it can be used as street lighting. The light will turn on when the environment is dark and the light will turn off when the environment is bright. The highest thermoelectric power output is at a temperature of 75.1 ^{o}C. Where at this temperature a voltage of 2.32 V is generated and a current of 0.03 A is generated.

Acknowledgements

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