International Journal of Reconfigurable and Embedded Systems (IJRES)
Vol. 14, No. 1, March 2025, pp. 136~144
ISSN: 2089-4864, DOI: 10.11591/ijres.v14.i1.pp136-144

Waste incinerator monitoring system based on remote communication with android interface

Moechammad Sarosa, Septriandi Wirayoga, Ratna Ika Putri, Supriatna Adhisuwignjo
Department of Electrical Engineering, State Polytechnic of Malang, Malang, Indonesia

Article Info

Article history:

Received Jan 18, 2024
Revised Jun 24, 2024
Accepted Aug 12, 2024

Keywords:

Android
CO_2
Combustion
Internet
Thermocouple

ABSTRACT

Raya Ngijo Housing, one of the areas in Karangploso in Malang District has a temporary waste management team that organises the collection of waste from residents and sends it to the landfill. The process of collecting waste from residents is usually at the temporary disposal site (TPS) in the form of moving waste from residential cleaning vehicles and accommodated at the TPS until collection by the Malang District environmental service container for disposal to the transferred to landfills (TPA). Problems often occur when the container collection process is delayed for various reasons, so that the amount of rubbish in the TPS is excessive. One of the solutions made by the cleaning team is to burn excess waste and can be burned using a furnace. However, the combustion carried out cannot be ensured perfect combustion which is feared by the environmental service. Therefore, a remote communication-based furnace monitoring system and android application were made to ensure the perfection of the combustion process so that it could be monitored by the cleaning team. Parts per million (PPM) carbon dioxide (CO_2) levels of combustion smoke and combustion temperature are also monitored and controlled in accordance with the safe standards set by the environmental agency.

Corresponding Author:

Septriandi Wirayoga
Department of Electrical Engineering, State Polytechnic of Malang
Malang, East Java, Indonesia
Email: yoga.septriandi@polinema.ac.id

1. INTRODUCTION

The waste is collected at the neighborhood temporary disposal site (TPS) before being transferred to landfills (TPA). However, waste containers used for waste transfer from the TPS to the landfill are often delayed due to several factors that led to the construction of waste incinerators by the cleaning team. It is hoped that this combustion furnace will be able to reduce the problem of unpleasant odors in the environment caused by the accumulation of garbage in the TPS [1], [2]. Waste incineration is a necessary solution as one of the alternatives to overcome the problem of waste volume that always increases every year in each region's landfills along with population growth, changes in consumption patterns, and people's lifestyles. The issue of waste accumulation in landfills in residential areas is not only related to environmental cleanliness and aesthetics, but can cause other problems such as disease. This condition has a negative impact on the environment and shortens the life of TPS and TPA, which in general in cities in Indonesia have the same waste management, namely the "collect-transport" method where it is collected first at the TPS and then sent to the landfill [3], [4].

Incineration is done to treat waste so that its volume and hazards can be reduced, and to capture or destroy hazardous substances that may be released during combustion. The incineration process can also be used to obtain energy, minerals, or chemical content from waste. There are various types and sizes of kilns, as well as combinations of pre- and post-combustion treatments [5], [6]. In addition, there is a relationship between the design of selectable municipal solid waste, hazardous waste, and incineration sludge waste. Kilns are usually built for full oxidative combustion with temperatures of 850 °C to 1,400 °C [7], which is probably the temperature at which calcination and melting processes occur [8]. This was the problem encountered by the cleaning team from the Malang City environmental agency as there was no evidence that the combustion temperature had reached the required standard and the escaping gas was polluting the vicinity of the TPS. So the environmental agency requested remote monitoring of the temperature and combustion gas particles so that it could ensure the conditions were safe [9].

In reference to article [10], research has addressed the challenge of solid waste management through incineration, specifically by evaluating the efficiency of temperatures. However, it is noteworthy that the measurements are confined to the combustion site. Drawing inspiration from advancements in remote telemonitoring, exemplified in article [11] where the monitoring of remote lockers is seamlessly executed through web or smartphone interfaces, there is potential for extending such technology to enhance temperature measurement systems. This prospect is particularly evident in article [12], where a system designed for high-temperature measurement could be evolved into a robust platform for remote monitoring applications.

Therefore, monitoring system for outdoor waste burning based on internet of things (IoT) was created which aims to optimize monitoring of waste combustion in the furnace for the cleaning team and the environmental service of the City of Malang. In this research, a remote monitoring system has been made using hardware in the form of sensors and microcontrollers integrated with the internet network [13], [14]. Every data obtained by each sensor will be sent to the cloud using a microcontroller so that it can be accessed by the android application that has been made for the monitoring system [15]. The communication used in this research is internet-based from a monitoring device connected to an access point via wireless communication, so that to do remote monitoring there must be internet around the monitoring system and android application [16], [17].

2. RESEARCH METHOD

To get the results of the research that has been completed there are several stages that must be done [18]. The first stage is an understanding of waste storage and combustion. The second stage is about the use of sensors for gas particle measurement. The third stage is about the use of high temperature combustion detection sensors, namely K-type thermocouples. Then the fourth stage of understanding about remote communication via the internet. The fifth stage is the creation of a system block diagram and its implementation. The last stage analyzes the system that has been made. In the analysis process there are 3 things that will be measured, namely the gas particle sensor accuracy test, the high temperature sensor accuracy test, and the overall system test [19].

2.1. Waste on district area

Waste is an item left over from human activities, daily activities, or natural processes. Waste management is very important as the next step after waste is formed, with the aim of reducing the accumulation of waste that can cause various problems [20]. Waste management includes systematic, comprehensive, and sustainable activities that include waste reduction and handling. This process needs to be carried out in a comprehensive and integrated manner from the source of waste to the end of the process, in order to provide economic benefits, health for the community, environmental safety, and change people's behavior. Thus, improper waste handling and processing can cause environmental diseases and disrupt daily life [21].

One of the other options for dealing with plastic waste in landfills is to burn it. However, there are growing concerns regarding the potential release of harmful chemicals into the atmosphere during the process. For example, smoke from burning plastic can release halogenated additives and polyvinyl chloride, as well as furans, dioxins, and polychlorinated biphenyls can also be emitted. This can lead to air pollution, as these substances can vaporize and be released directly into the air, posing risks to both human health and the environment [22]. Additionally, the combustion of plastics can damage the combustion heaters of flue systems, further contributing to environmental harm.

The purpose of incinerating garbage is to reduce its amount and dangers while also destroying or capturing any hazardous materials that might be released during burning. Energy, minerals, or chemical compounds from garbage can also be obtained through the incineration process. Kilns come in a variety of sizes and shapes, and can be customized with a combination of pre- and post-firing treatments to choose from. Furthermore, there is a connection among hazardous waste, incinerator sludge waste, and chosen municipal solid waste design [23]. 850 °C to 1,400 °C is the typical temperature range for kiln construction, which is most likely the temperature at which calcination and melting processes take place. The result from incinerating garbage shown on Table 1.

Table 1. Common operational situations for waste-to-energy conversion technologies through thermochemical and biological processes

Technology	Temperature (Celcius)	Heating rate (Celcius/s)	Residence time	Typical product distribution
Incineration	800-1,200	Variable	Variable	BottomAsh>FlyAsh>Slag>Gases
Fast pyrolysis	400-500	10-200	30-1,500 ms	BioOil>Gases>BioChar
Slow pyrolysis	300-700	0.1-1	10-100 min	BioChar>BioOil>Gases
Intermediate pyrolysis	500-600	2-10	10-20 $	BioOil>BioChar>Gases
Flash pyrolysis	800-1,000	1,000	0.5 s	BioOil>Gases>BioChar
Liquefaction	250-450	0.05-5	1-40 min	BioOil>Tar
Gasification	700-1,000	Variable	30-90 min	Syngas>BioChar
Anaerobic digestion	35-37	None	Days	Methane>Othergases>BioSludge
Composting	25-55	-	1-2 months	Humus>Nutrients>Minerals

2.2. Sensor gas MQ

The MQ sensor is a gas sensor used in devices to detect carbon monoxide (CO) gas in various situations, both in everyday life, in industry, and in motor vehicles [24]. The MQ gas sensor has high sensitivity to CO is stable, and has a long lifespan. This sensor uses a heater with a 5 V AC/DC power supply and a 5 VDC circuit power supply. The effective measurement range of CO gas is 20 to 2,000 ppm. This research will use the MQ-7 sensor which has the ability to detect residual combustion. Figure 1 shows the sensitivity value of the MQ-7 to other gases. The sensitivity of the MQ-7 sensor affects the precision level of the gas reading. Sensor sensitivity refers to how responsive the sensor is to a particular gas. The higher the sensitivity, the smaller the gas concentration that can be detected [25]. However, too high sensitivity can also result in the sensor becoming more susceptible to interference from other gases in the surrounding environment.

Figure 2 shows the circuit of the MQ-7 used. This circuit works by heating the sensor element, which in turn responds to the presence of CO gas with a change in resistance. This change is then measured and processed by the microcontroller to obtain the level of CO gas concentration in the environment. To find out the relationship between components and detection, it is described in (1):

$$x = \sqrt[-1.53]{\frac{y}{100}} \tag{1}$$

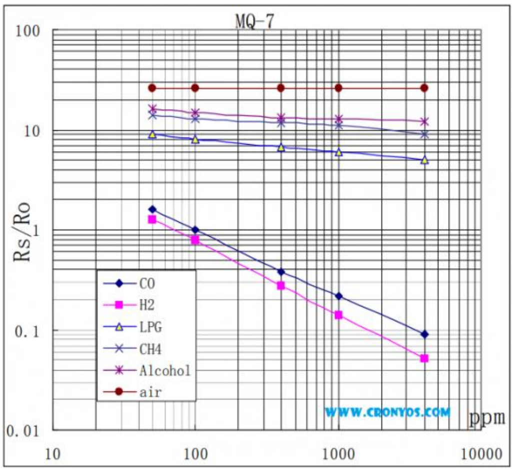

Figure 1. MQ-7 sensivity graphic

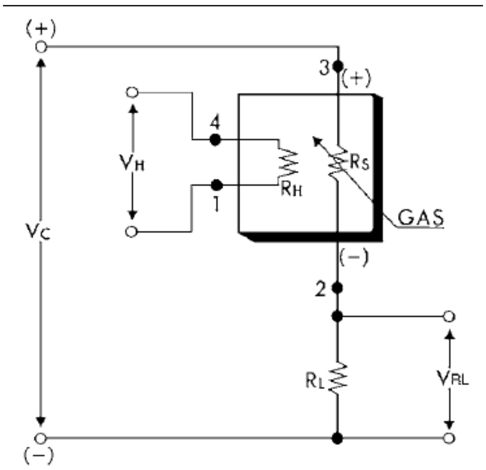

Figure 2. MQ-7 sensor circuit

After obtaining the x value, proceed to (2) where y is the desired air quality standard (in ppm):

$$Rs = (Vc * RL / VRL) - RL \tag{2}$$

in this context, Rs is the sensor resistance, Vc is the sensor input voltage, RL is the load resistance of the circuit, and VRL is the circuit output voltage. After calculating with the previous two equations, the next step is to calculate the value of Ro, which is the comparison resistance for normal clean air conditions used as a reference in (3).

$$Ro = x/Rs \tag{3}$$

2.3. Max 6675 thermocouple

The K-type thermocouple data is digitalized and used to provide cold-junction compensation, which forms the basis of the MAX 6675 [26]. The output data is compatible with common microcontroller serial peripheral interface (SPI) communication and has a resolution of 12 bits. By transforming the outcomes of reading 12-bit data, data may be read. The cold end of the MAX6675 can only monitor temperatures between -20 and +85. The MAX6675 can detect temperature variations in other areas of the device with accuracy even if there are variations at the cold end. With cold-junction correction, the MAX6675 can adjust for variations in the surrounding temperature. Using a temperature diode sensor, the apparatus transforms the actual ambient temperature into voltage. The MAX6675 monitors the voltage from the sensing diode and the thermocouple output in order to do actual measurements [27]. When the temperature of the cold-junction thermocouple and the MAX6675 are same, the MAX6675 operates at its best. This is to prevent putting other heat-producing parts in close proximity to MAX6675. To measure temperature with a K-type thermocouple, the voltage change is about 41 µV per °C, using a characteristic approximation, which can use (4):

$$VOUT = (41\mu V\ /\ °C)\ 5\ (TR - TAMB) \tag{4}$$

where $TAMB$ is the ambient temperature (°C), TR is the remote junction temperature (°C), and $VOUT$ is the thermocouple voutput (µV). There are several temperature ranges and material kinds for thermocouples. Type K thermocouples are one example of an operating temperature range that may be produced by combining several types of metal conductors. Nickel and chromium make up the positive side (thermocouple grade) of type K thermocouples, whereas nickel and aluminum make up the negative side (extension grade). Due to its tendency to be less expensive, this kind of thermocouple is frequently employed for common applications. available between 0 °C and +1,100 °C in temperature.

2.4. Internet of things

The IoT system seen in Figure 3 consists of various functional blocks that facilitate various functions in the system, such as sensing, identifying, actuation, communications, and management [28]. IoT systems are based on devices that perform sensing, actuation, control, and monitoring activities. IoT devices can communicate with other connected devices and applications, collect data from other devices, and process data either locally or by sending data to a centralized server or cloud-based application for processing. IoT devices can also perform some tasks locally and others within the IoT infrastructure according to constraints such as space, time, memory, processing capability, communication latency, speed, and deadlines. IoT devices can have various interfaces to communicate with other devices, both wired and wireless. These include I/O interfaces for sensors, internet connectivity interfaces, memory and storage interfaces, and audio/video interfaces. IoT devices come in many types, such as wearable sensors, smartwatches, light emitting diode (LED) lights, cars, and industrial machinery. Almost all IoT devices generate data in various forms that, when processed by data analysis systems, provide useful clues and information to guide further actions, both locally and remotely.

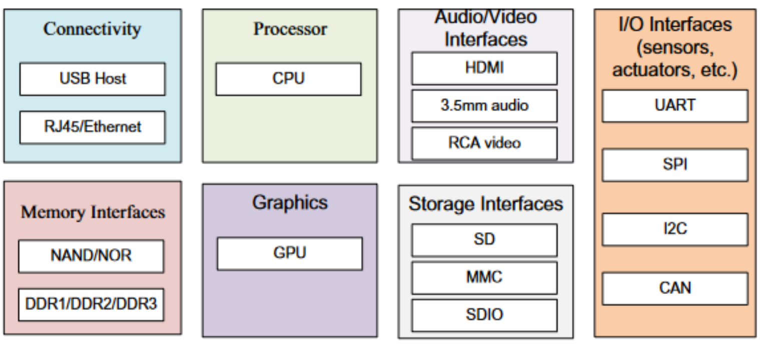

Figure 3. IoT

For example, sensor data generated by soil moisture monitoring devices in a garden, when processed, can help determine the optimal watering schedule. The communication block in IoT is responsible for communication between devices and remote servers. IoT communication protocols generally operate at the data link layer, network layer, transport layer, application layer, and audio/video link. Data obtained from soil moisture monitoring devices in the garden can be used to establish an optimal watering schedule. Communication between devices and remote servers is done through communication blocks, with IoT communication protocols generally operating at the data link, network, transport, and application layers [29].

2.5. System block diagram

In the research that has been done, the system block diagram shown in Figure 4 is a description of the system that has been used to achieve the desired data in this article. In Figure 4, it can be seen that there are 3 nodes used to monitor the waste incinerator which measures 150×150×200 cm. The description of node 1 represents the description of nodes 2 and 3. From each node, there are 2 types of measurement sensors used in the system are used, each is an MQ-7 sensor and MAX 6675 sensor (K-type thermocouple) connected to the ESP32 microcontroller. The MQ-7 sensor functions to detecting compressed air on carbon that arises from residual combustion. The MAX 6675 (thermocouple K-type) sensors are used to measure the heat or combustion temperature in units of degrees centigrade in the furnace utilizing long iron steel. When the air content is very bad as a result of burning waste, namely 50 ppm, buzzer will activate to alert the on-site personnel. The 16×2 liquid crystal display (LCD) is used to display the values generated by the sensors during the process. After the sensors detect the values, the information will be forwarded to the microcontroller and then sent to the cloud database via the internet network. This process can be done when the microcontroller is connected to a wireless network to an access point that has a service provider. After the data is successfully entered into the cloud database, the android application on the smartphone can retrieve data from the cloud database to be displayed on the smartphone device. This data retrieval is done to monitor whether the combustion has been carried out with the right temperature both from the environmental agency and from the garbage burning workers. From this data it is hoped that both parties will be able to maintain the quality of the environment around the garbage burning site.

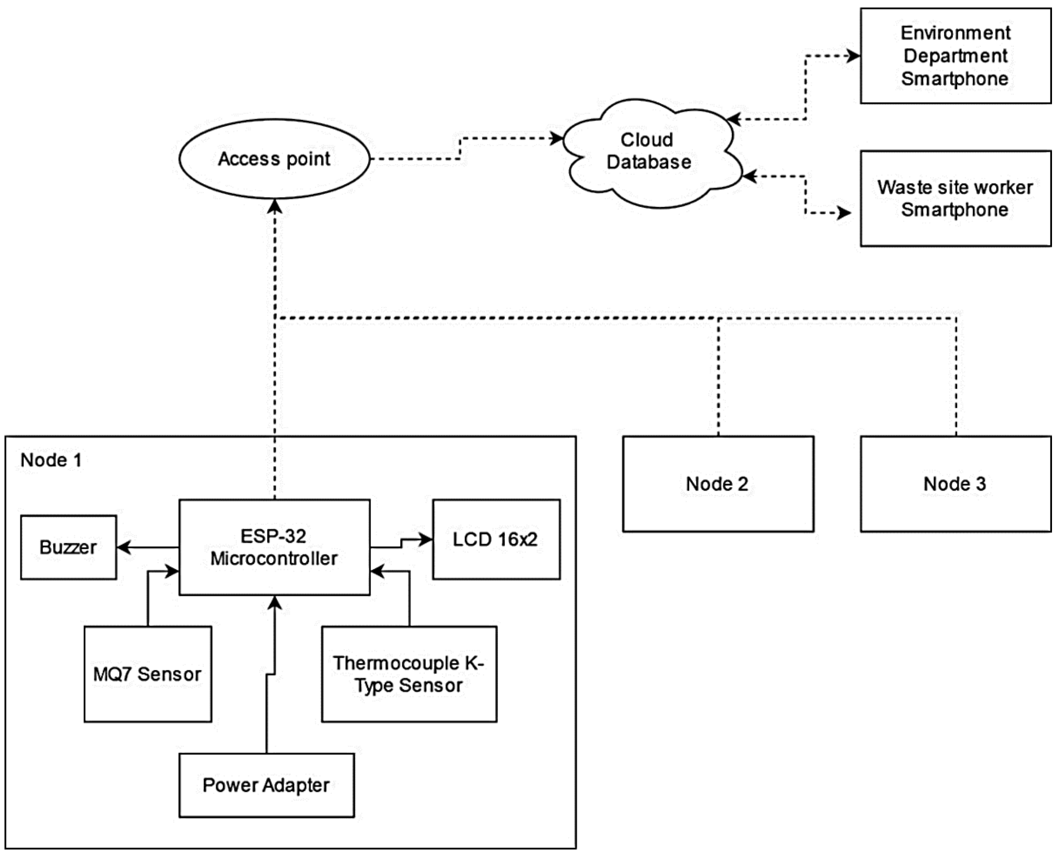

Figure 4. System block diagram for monitoring

3. RESULTS AND DISCUSSION

The following is the implementation of the hardware schematic per detection node that has been assembled into a module as shown in Figure 5. The components consist of the ESP8266 microcontroller, MQ-7, MAX6675 sensor, and 16×2 LCD connected together with jumper cables according to the designed pins. In the initial phase of this study, we conducted a sensitivity analysis of the MQ-7 sensor to CO gas. This involved comparing the gas measurements obtained from the sensor with those from a CO detector. The results are detailed in Table 2, displays the excellent capabilities of the MQ-7 sensor seamlessly integrated into the microcontroller program. Notably, the sensor demonstrated accuracy ranging from a minimum of 97.81% to a maximum of 100%. These accuracy values were determined using the gas type with the lowest concentration among the five tested variants, and each gas type underwent three repetitions for robust assessment [30].

Figure 5. Implementation system

Table 2. MQ-7 sensor accuracy

No.	Sensor detection (ppm)		CO detector detection (ppm)		Accuration (%)
	Results in three iterations	Average	Results in three iterations	Average	
1	69	60.67	68	59.67	98.32
	67		66		
	46		45		
2	66	61.00	67	61.00	100.00
	57		56		
	60		60		
3	31	57.00	29	57.00	100.00
	45		46		
	95		96		
4	76	46.00	75	46.00	100.00
	25		27		
	37		36		
5	96	62.33	95	61.00	97.81
	58		57		
	33		31		
Average accuration					99.23

The second measurement pertains to assessing the temperature measurement accuracy of the MAX6675 sensor. This evaluation involved a comparative analysis, where we tested the sensor's ability to read temperature against the readings obtained from a factory-calibrated K-type thermocouple thermometer. The results of these accuracy tests are detailed in Table 3. A glance at the table reveals the MAX6675 sensor's remarkable temperature measurement accuracy, consistently yielding high values. Across ten measurements, the sensor exhibited an accuracy spectrum, with the lowest value recorded at 96.60% and the highest at 99.02%.

Table 3. Thermocouple meter accuration result

No.	Sensor value (°C)	Thermocouple meter (°C)	Accuration (%)
1	155	157	98.73
2	200	197	98.48
3	167	163	97.55
4	165	163	98.77
5	152	147	96.60
6	133	131	98.47
7	101	102	99.02
8	194	190	97.89
9	115	117	98.29
10	203	200	98.50
Average value			98.23

The last test is about sending data from the system to the cloud database [31], which will be presented in Table 4. From Table 4, it can be seen that out of 10 measurements, all data in the application was successfully updated, with a success rate of 100%. In the 10 measurement, it was found that the system also worked well by providing an alert update when the gas particles exceeded the predetermined threshold of 50 ppm.

Table 4. System test result

No	Send stats	CO value (ppm)	Temperature combustion chamber (°C)	Status condition
1	Success update	7	28	Safety
2	Success update	10	29	Safety
3	Success update	14	29	Safety
4	Success update	15	29	Safety
5	Success update	20	29	Safety
6	Success update	21	29	Safety
7	Success update	25	29	Safety
8	Success update	30	29	Safety
9	Success update	35	29	Safety
10	Success update	52	31	Danger

4. CONCLUSION

The system's conclusion highlights its effective functionality. Initially, the seamless delivery of output data from the sensor to the cloud database, subsequently presented via the application, ensures reliable real-time monitoring via a smartphone. Calibration testing of the CO gas detection sensor was conducted by collecting data from 5 measurement points every 5 minutes. The calibration results showed an impressive average, with a success rate exceeding 90%. Similarly, the temperature sensor test, with 10 data points gathered every 6 minutes, yielded an average calibration result surpassing 95%.

These robust calibration outcomes underscore the system's accuracy and reliability. Beyond technical achievements, the research holds significance as a valuable resource for monitoring waste incineration, providing a potential solution to mitigate waste accumulation in temporary and final landfills worldwide, with a particular focus on Indonesia. The versatility of this research positions it as a credible reference for waste management strategies, especially in Indonesian regions employing waste burning practices. The potential implementation of these findings in waste management practices across Indonesia further solidifies the research's practical relevance and positive impact on environmental sustainability.

ACKNOWLEDGEMENTS

This work was supported by the Malang State Polytechnic campus through DIPA 2022 funds, the Trust [grant numbers SP DIPA – 023.18.2.677606/2022].

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BIOGRAPHIES OF AUTHORS

Moechammad Sarosa received the bachelor's degree from Universite De Nancy I, France, in 1990, and the master's and Ph.D. degrees from the Department of Electrical Engineering, Bandung Institute of Technology, in 2002 and 2007, respectively. He is currently a Lecturer and a Professor in computer science and in electrical engineering with the State Polytechnic of Malang. His research interests include information communication technology, artificial intelligence, mobile computing, embedded systems, and the internet of things. He can be contacted at email: msarosa@polinema.ac.id.

Septriandi Wirayoga received bachelor in bachelor of electrical engineering, Department of Engineering, Faculty at Universitas Brawijaya on 2014. He is working as junior lecturer in Department of Electrical Engineering at Politeknik Negeri Malang. He focuses on the field of antenna microstrip, signaling communication, and microcontroller. He can be contacted at email: yoga.septriandi@polinema.ac.id.

Ratna Ika Putri received the B.E. and M.E. degree in electrical engineering from Brawijaya University, East Java Indonesia in 1994 and 2006. She has got teaching experience nearly 12 years. Currently a Lecturer of Department Electronics at Malang State Politechnic, East Java, Indonesia. Her current research interest in control, power electronics, and AI technique. She is a member of IAENG. She can be contacted at email: ratna.ika@polinema.ac.id.

Supriatna Adhisuwignjo received the S.T. and M.T. degrees in electrical engineering from the University of Brawijaya Malang, in 1998 and 2007. He has been a Lecturer of electrical engineering with the State Polytechnic of Malang, since 2000. He is currently the director, of the State Polytechnic of Malang, Indonesia. He has authored or coauthored more than 10 research, 7 publication journal, and one book. His research interests include the applications of artificial intelligence, fuzzy logic, interface system, image processing, artificial neural networks, and control. He can be contacted at email: supriatna@polinema.ac.id.