Development of generator set operation monitoring system for performance analysis and periodic maintenance based on IoT technology

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Abstract. Generator sets or Genset, widely used as primary or backup source electric power generators. When the generator set is used as the main power to support field operations, it must be ensured that the generator set is in good condition. If the generator set in trouble when it is already in the field, it certainly will hamper the work significantly. This research developed an online monitoring system of generators operation based on the ThingSpeak, an IoT technology platform. The system can record the historical data of generators operation parameters, starting from the measurement of fuel level, engine temperature, until total energy (kWh) generated. The measurement data are used to offline analysis the performance condition of the generator or to determine the length of time to the next periodic maintenance. The development results showed the system has worked well following the design. The measurement data has been sent to the ThingSpeak IoT platform as a data logger. The data stored in ThingSpeak are the time stamp when the data received. It can be used to determine the duration of operation, fuel consumption, average operating temperature, and total energy (kWh) produced. The test results show the difference in the quality of the radiator water gives a difference in temperature gradient up to 0.8°C/kW. While fuel consumption in no-load conditions, the difference in fuel consumption is up to 0.2ml/sec.

1. Introduction
The use of generator sets or Genset, both diesel and gasoline fuel, has been widely used both as main or backup power generation. The working principle of the generator to producing electricity is based on the work of the combustion engine, which generates electric power as the generator rotates. In locations that unreached by PLN electricity or field area without electricity, generators used as the primary source of electricity generation. In urban areas, especially in commercial buildings, generators are used as backup power, when no electricity from PLN. In general, generators equipped with electrical indicators, like the output voltage, current and frequency, and fuel level. However, there are no indicators that give some information about the current performance of the generator or time into the next periodic maintenance. If the generator used as the main power to support field operations, the generator must be in good condition, so it can be assured that there will be no problems. If the generator set in trouble when it is already in the field, it undoubtedly will hinder the work significantly. To solved these problems, a monitoring system of generator operation is needed. The system can record the historical data of the generator parameters. Starting from the measurement of fuel level, engine temperature until
total energy (kWh) generated. The measurement data are used for offline analysis of the performance condition of the generator or to determine the length of time to the next periodic maintenance. Furthermore, if there are more recording data of parameters of the generator set, it can be used for failure analysis.

Several studies related to the development of a fuel monitoring system have been carried out, among others, conducted by M Wildan Firdaus et al. [1]. In this research, the ESP-8266 control module, which has wifi communication facilities and eases in making internet connections, is used. The system built is intended to monitor the condition of the fuel level and operation status of the generator, whether it is in on or off condition. The test results show the instability of the system in the monitoring of the operating conditions of the generator set. Wherein the Firebase application, the accuracy reaches 100% but by using the Xampp application the accuracy is only 10%. Edem and Ezeofor researched the development of a generator fuel monitoring system and battery level using GSM communication infrastructure [2]. In this study, the Atmega328 microcontroller used as a controller and the HC-SR04 sensor used as a level gauge, which uses the ultrasonic method. The monitoring system will send information related to fuel level and battery level conditions on the generator using the SMS feature via the AT command. The same research was also carried out by G.D. Obikoya developed a fuel level monitoring system. But in this study, the measurement of the fuel level used a resistance method from the fuel float sensor [3]. Several other studies have shown that the development of a generator operation monitoring system, it’s used to conduct maintenance planning based on running time [4]. To detect damage of the generator by analyzing the quality of the generated power [5]. Detect the generator failure based on measurements of working temperature and generator oil level [6]. Based on some of the studies, the development of a complete monitoring system of the generator operation has not yet been carried out. So, in addition to analyzing the performance, information of the generator operating time can be used to determine the time of periodic maintenance.

This research will develop an operation monitoring system of the generator set by measuring several generator operating parameters such as fuel level and output power. Based on the measurement of fuel consumption compared to electric energy generated, the performance of the generator can be analyzed. It is still following the operating standards or has there been a decline in performance. Through recording the operation time, it can determine when the next periodic maintenance must be carried out. This research will develop an innovative product of the generator operating monitoring system that can add to each generator set. This product is not only able to display/store electricity parameters and fuel level conditions, but also performance and total operation time. This product such as indicators of fuel consumption and the odometer on a car or black box on an aircraft.

2. Method

2.1. Generator Set (Genset)
Generator Set (Genset) is an engine that able to produce electric power. This generator set is a set or combination of a Generator or Alternator and an Engine that can use as a power plant. In 1831 Michael Faraday, a very famous physicist, discovered electromagnetic induction, which later developed into a Modern Generator. While Rudolph Diesel was the inventor of the Diesel Generator, where he began issuing patents on his engine in 1892 [7]. Generator Set consists of Engine as motor drive and generator/alternator. The generator itself is a coil of wire made of copper consisting of a static coil or stator and also equipped with a spinning coil or rotor. In the process of its work, according to physics, the engine rotates the rotor in a generator, which in turn creates a magnetic field in the generator coil.

Furthermore, this Magnetic Field will then interact with the Rotors, which will then spin and will produce an electric current, which is by Lorentz's law [8]. In technical language, a generator is a modern machine that converts mechanical energy to electrical energy by utilizing the induction of an electric magnetic field. Genset engines, as mentioned above, use a variety of engines, including gasoline engines, diesel engines, gas engines, turbine engines [9]. In a diesel generator, a diesel engine is used as
the prime mover system of the generator. Prime mover is part of a generator that has the function of producing the mechanical energy needed to rotate the generator rotor [10].

![Diagram of genset](image)

**Figure 1.** Diagram genset.

The Genset diagram as shown in Figure 1. The prime mover rotating a synchronous generator that will produce the electrical energy. The generator voltage regulator known as Automatic Voltage Regulator (AVR) would be added to keep the output electricity stable against load changes [11].

### 2.2. Fuel level sensor

There are several methods of measuring fuel level sensors, including measurements with resistance, capacitance, and ultrasonic methods. Analysis by the resistance method is carried out by a buoy mechanism where an increase in the liquid level will move the buoy, which will rotate the rheostat sensor so that it will give a different resistance value at each fuel level.

![Fuel level measurement methods](image)

**Figure 2.** Fuel level measurement method with a. Resistive (Float), b. Capacitive, and c. Ultrasonic.

### 2.3. Genset performance measurement

The Genset performance measure does by measuring the consumption of material used to produce energy (Wh) within a specific time interval. For this reason, it is necessary to measure the fuel level at the beginning of the operation and the fuel level at the end of the action. It can be known the fuel consumption during operation in that time interval. If the measurement carried out at the output power within a specific time interval, then the performance of the generator engine can be obtained, where the generator performance is expressed as a ratio of the amount of energy produced to fuel consumption.

### 2.4. Research design

In this research, an operation and monitoring system of the generator will develop. This will monitor the performance of the generator in a recorded report. As shown in Figure 3. In this study, the developed system will provide information on the generator's performance and total operational hours. So that a
regular maintenance schedule can be determined. For this reason, the fuel level sensor will install with a fuel level sensor and the measurement of output power using a power meter.

The control module will read the generator condition, whether it is in on or off operation. This used as a trigger to start or stop the operation reading of the fuel level sensor and power meter. Information related to the state of the fuel level, output power, and the operating time, will send to the IoT application of ThingSpeak to display parameter of the generator and as a data logger. The recorded data will be carried out for performance analysis and maintenance time determination.

![Research design](image)

**Figure 3.** Research design.

3. Results and discussion
In this research, a generator operating monitoring system would develop that will monitor the performance of the generator in a recorded record. Research activities so far have resulted in several achievements, including the development of power meter applications developed using the Nodemcu ESP 8266-12E. The test results show the measurement module can already read data on voltage, current, power, and energy consumption. The test results by comparing the measurement results of power measuring devices made with CM3286-20 measuring instruments show the measurement results obtained are entirely accurate as shown in the following figure 4.

![Comparison of power meter PZEM with clamp meter CM3286-20 measurement](image)

**Figure 4.** Comparison of power meter PZEM with clamp meter CM3286-20 measurement.

For temperature and level measurement, modules have been developing and testing the measurement accuracy because it needs to make a stand for the measure at engine temperature and fuel level. The temperature and fuel level measurement modules were develop using an Arduino controller.
Temperature and fuel level data are sent using the ‘Nodemcu’ module. The developed power meter, temperature, and fuel level measurement modules as shown in figure 5. In this research, the generator monitoring system has also been developed based on the Android application. This application will display the output power of the generator. The monitoring application was developed using the App inventor to design the display on Android and Firebase as a data buffer before displaying it in the Android application, figure 6.

![Figure 5. Power meter, temperature, and fuel level measurement modules.](image1)

![Figure 6. IoT display of ThingSpeak, firebase and android application.](image2)

According to the initial design, the measurement data will be used to analyze the generator performance. By comparing with the historical data of the generator operation, it can be seen whether the generator performance is still good or needs to be maintained. To see the effect of changes in performance due to changes in the characteristics of the engine temperature parameters. The test are made to see the effect of changes in the quality of the radiator cooling water on the radiator working temperature and the generator performance when genset running with 20 ml fuel. Testing is done by mixing the coolant radiator with plain water. A mixture of coolant with plain water is expected to represent the quality of
the radiator water. The difference in the quality of the radiator water is done by adjusting the concentration of the radiator water by mixing ordinary water with radiator coolant water in several percentages of the mixture. The test results show the difference in the quality of the radiator water gives a difference in temperature gradient up to 0.8°C/kW. While fuel consumption in no-load conditions the difference in fuel consumption is up to 0.2ml/sec, but in line with the increase in load, fuel consumption is relatively the same, as shown in figure 7. This shows that the changes in operating temperature can be use as identification of changes in the radiator water quality, either due to dirt or reduced in volume.

![Graphs showing temperature vs. % coolant, fuel consumption vs. % coolant, and kWh vs. % coolant](image)

**Figure 7.** The characterization of the effect of radiator water quality.

### 4. Conclusion

Based on the results of tests conducted on measurements of temperature and level output power, the measurements obtained are entirely accurate when compared to other measuring devices. Overall the system has worked well by sending measurement data to the IoT Thingspeak application and display it in Android application using App inventor and Firebase. Measurement data will be used to determine the periodic maintenance and to analyze the generator performance, by comparing with the historical data of the generator operation. The test results show the difference in the quality of the radiator water gives a difference in temperature gradient up to 0.8°C/kW. While fuel consumption in no-load conditions the difference in fuel consumption is up to 0.2ml/sec.

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