Application of the Internet of Things (IoT) in Reviewing Electrical Energy Consumption on Solar-Powered Cadet Training Ships

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Abstract. Solar energy is energy obtained by converting solar energy into electrical energy which does not produce pollutants and has no negative impact on the environment. Solar energy can be implemented with various vehicles, one of which is an electric motorboat. However, the ship's propulsion engine depends on the capacity and condition of the battery to efficiently distribute electrical energy to the ship's propulsion engine. So a real-time monitoring system for battery capacity and condition is needed. Internet of Things (IoT) is a design that can be connected to everything by considering various objects that are widely spread through connections between wireless devices. IoT is suitable for monitoring the condition and capacity of solar panel electric ship batteries in real-time. However, in its application IoT is very dependent on internet connectivity in the data transfer process, so this research discusses the performance of IoT devices in monitoring solar panel ships based on Quality of Service (QoS), accuracy/precision of data monitoring, and Root Mean Sequare Error (RMSE) from data errors. The results of the research show that QoS parameters, including the number of packet losses, average delay and jitter, will affect the precision accuracy of data monitors and the RMSE of data errors.

Keywords: Solar Energy, Monitoring, IoT, QoS, Internet Nework.

1 Introduction

1.1 Background

Industrial growth causes increased energy use globally [1]. The growth in energy consumption results in conventional energy being depleted and its excessive use producing dangerous emissions [2]. Renewable energy is needed to overcome these problems [2].

Solar energy is energy obtained by converting solar energy into electrical energy [3] which does not produce pollutants and has no negative impact on the environment [4]. Plus, Indonesia is a tropical country with a large potential for solar energy where the

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average daily radiation is 4.5 kWh/m2 per day [5]. Based on these reasons, solar energy can be used as an alternative to replace conventional energy [6].

Solar energy can be implemented with various vehicles, one of which is an electric motorboat [7]. Research [7], [8] and [9] utilize solar panels as a source of electrical energy to drive ship engines. However, the ship's propulsion engine depends on the capacity and condition of the battery to efficiently distribute electrical energy to the ship's propulsion engine [9]. So a real-time monitoring system for battery capacity and condition is needed.

Internet of Things (IoT) is a design that can be connected to everything by considering various objects that are widely spread through connections between wireless devices [10]. IoT has been widely used in monitoring electricity usage, including research [11] and [12]. Research [11] measures the load, voltage, current and power required to operate electronic devices in real-time through an application-based interface. So based on this foundation, this research focuses on the application of IoT devices in reviewing energy consumption on solar-powered cadet training ships.

2 Research Methodology

2.1 System Diagram

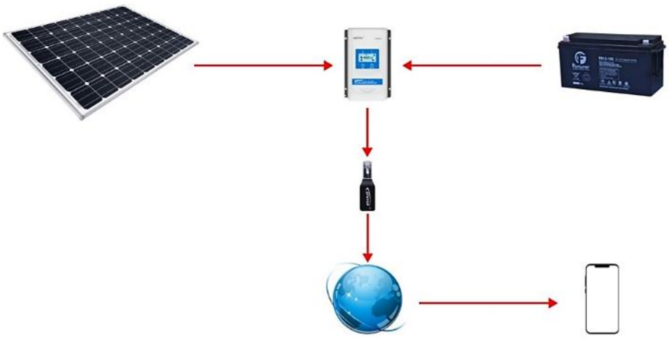

Fig. 1. IOT Plan.

The IoT design has three main components including input, processing and output which are shown in Figure 1. The solar panel and battery device act as input, where the solar panel will provide heat conditions and potential electrical energy that can be produced while the battery provides input data on the amount of energy used in moving the ship's engine and the remaining electrical energy stored. While Maximum Power Point Tracking (MPPT) acts as a processor, both electrical energy processors as charge controllers and inverters also convert solar panel and battery input into digital data. Next, the MPPT connected to the WiFi module transmits data using the internet network to produce output in the form of digital data in the form of Javascript Object Notation (JSON) so that it can be received and displayed by mobile devices. Where the

WiFi Module on the MPPT and the mobile device must be connected to the internet network.

2.2 Research Flowchart

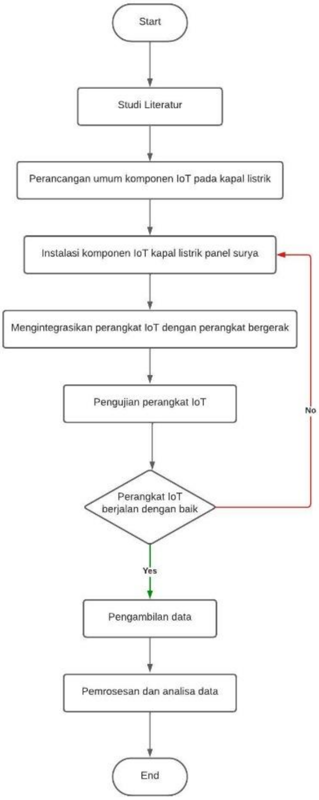

Fig. 2. Research Flowchart.

The research stages for implementing IoT devices on solar-powered electric ships are shown in Figure 2 with the following explanation:

1. Literature study, collecting information and literature related to the implementation of IoT lifters on solar-powered electric ships.
2. Designing the composition and calculating the needs for IoT devices that will be implemented on solar-powered electric ships.
3. Installation and configuration of IoT devices on solar-powered electric boats.
4. Integrate IoT devices installed on solar-powered electric ships with mobile devices.
5. Testing the installation of IoT devices on solar-powered electric boats. If the IoT device is working properly then you can proceed to the data retrieval stage, but if it is not suitable then return to the IoT component installation stage.

6. Retrieve measured data from MPPT and mobile devices.
7. Compare and analyze the data that has been obtained and present it in graphical form so that the pairing process is easy.

2.3 Parameter Data

There are several data parameters that will be sent from MPPT to mobile devices via the internet network which are listed in Table 1.

Energy Information	
Total daily generation	Total energi yang diperoleh oleh baterai perhari.
Total monthly generation	Total energi yang diperoleh oleh baterai perbulan.
Total annualy generation	Total energi yang diperoleh oleh baterai pertahun.
Total generation	Keseluruhan energi yang diperolah oleh baterai.
Total daily usage	Total energi yang digunakan oleh baterai perbulan.
Total monthly usage	Total energi yang digunakan oleh baterai pertahun.
Total annually usage	Total energi yang digunakan oleh baterai pertahun.
Total usage	Keseluruhan energi yang digunakan oleh baterai.
PV Information	
PV voltage	Potensi energi yang dihasilkan oleh PV.
PV current	Potensi arus yang mengalir keluar dari PV.
PV power	Potensi untuk mengubah dari dari PV.
Battery Information	
Battery voltage	Total potensi listrik yang dimiliki baterai.
Battery current	Total potensi kecepatan arus pengisian baterai.
Battery Power	Total energi listrik yang tersimpan di dalam baterai.

2.4 Data Processing and Analysis

Before testing to measure the level of accuracy and error level in comparing data on MPPT with mobile devices, throughput, packet loss and delay are first measured at each Internet Service Provider (ISP) [15]. This is to measure the quality of network services at the research location by measuring the data transfer capacity in a certain time unit on the internet network which can be searched using Formula 1.

$$Troughput = \frac{Jumlah\ data\ yang\ dikirim}{Waktu\ pengiriman}$$

Meanwhile, packet loss in describing the condition that the total packet cannot reach its destination can be found using Formula 2.

$$Packet\ Loss = \frac{(Paket\ data\ dikirim - paket\ data\ diterima)}{Paket\ data\ dikirim}$$

Meanwhile, delay in network communication can be found using Formula 3.

$$Delay = \frac{Total\ delay}{Total\ paket\ diterima} + 1000$$

Next, data processing is carried out by standardizing the units for each data parameter so that when compared, the data has the same units. Meanwhile, data analysis is carried out by encoding the data and calculating comparison accuracy and Root Mean Square Error (RMSE). Calculating the accuracy of comparing data on MPPT and mobile devices is intended to review how accurately the data is similar on each device [16]. Where Formula 4 can be used to find the level of accuracy [17].

$$Presisi = \frac{TP_i}{TP_i + FP_i}$$

TP_i is a True Positive, namely an appropriate comparison between the data displayed by the MPPT and the mobile device. Meanwhile, FP_i is a False Positive, namely an inappropriate comparison between the data displayed by MPPT and the mobile device. Meanwhile, RMSE is used to measure the average error rate. A comparison model can be searched using Formula 5.

$$RMSE = (\frac{\sum(y_i - \hat{y}_i)}{n})^{\frac{1}{2}}$$

Where y_i is the value that appears on the MPPT and ŷi is the value that appears on the mobile device. Meanwhile, $_i$ is the order in which data is collected and n is the total amount of data taken. The smaller the RMSE value, the closer the observed comparison value [17].

3 Result and Discussion

3.1 Implementation of IoT Devices on Solar Panel Ships

The implementation of IoT in this research begins with a literature search regarding IoT and designing IoT configuration components and implementing an IoT component installation that is integrated with mobile devices. Test the IoT device as in Figure 3 to prove the device is working properly or not, and if there is a discrepancy then reinstallation will be carried out. If the device is running well, data can be taken from the MPPT and analyzed and processing battery consumption on the solar-powered cadet training ship.

Fig. 3. Solar Panel Boat Trial.

IoT devices connected to the MPPT will display rooftop PV and battery data, with the installation of IoT components to the MPPT as in Figure 4.

Fig. 4. Installation of IoT devices on MPPT.

3.2 Quality of Service (QoS) Measurement and MPPT Data Pairing with Mobile Devices

MPPT which is connected to a cellphone produces an application display with the help of JSON consisting of Rooftop PV and ship battery data, then this display will be connected to the mobile device. Monitoring the condition of the photovoltaic battery will appear in real-time in the application as in Figure 5 below. QoS confirmation on training ships in reviewing battery consumption can be seen in the MPPT data connected to the application.

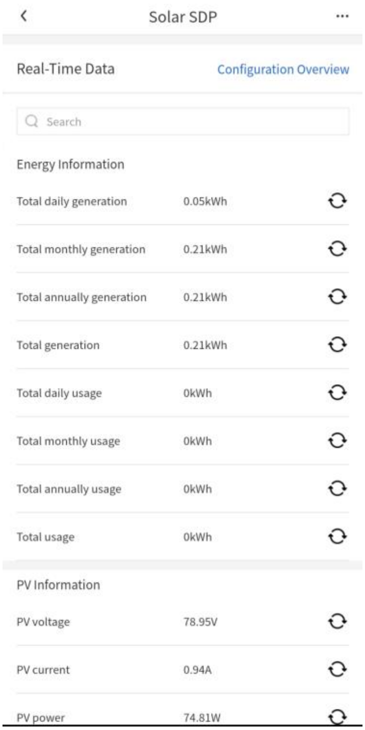

Fig. 5. Monitoring the condition of batteries and solar panels via mobile devices.

3.3 Average Ping of Internet Network Providers

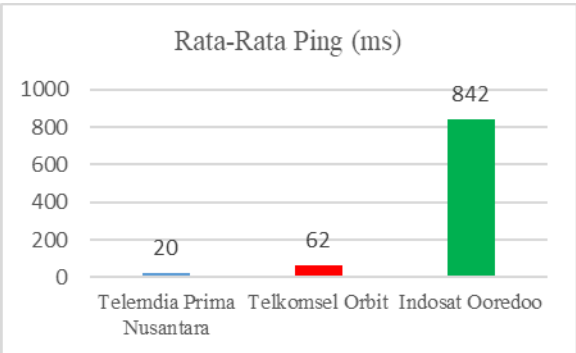

Fig. 6. Average Ping of Internet Network Providers.

The implementation of IoT in this research begins with a literature search regarding IoT and designing IoT configuration components and implementing an IoT component installation that is integrated with mobile devices. Test the IoT device as in Figure 3 to prove the device is working properly or not, and if there is a discrepancy then reinstallation will be carried out. If the device is running well, data can be taken from the MPPT and analyzed and processing battery consumption on the solar-powered cadet training ship.

3.4 Average Throughput of Internet Network Providers

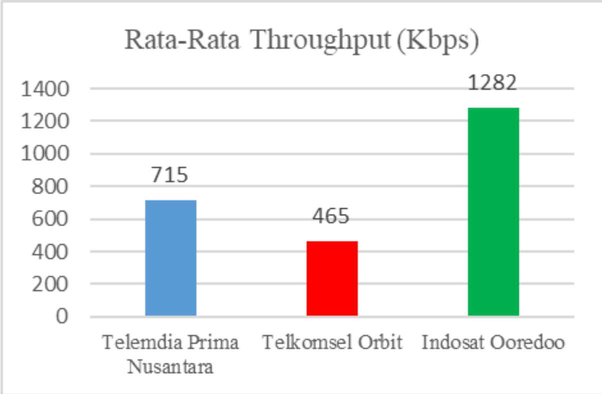

Fig. 7. Average Throughput of Internet Network Providers.

Measuring throughput for each internet network provider which shows how much the network is capable of transferring files within a certain period of time [15] shows that Indosat Ooredoo is better than Telemedia Prima Nusantara and Telkomsel Orbit as shown in Figure 7, this is shown by the average value -average throughput reaches 1282 Kilobits per second (Kbps). Meanwhile, Telkomsel Orbit has the lowest average throughput, namely 465 Kbps.

3.5 Average Packet Loss for Internet Network Providers

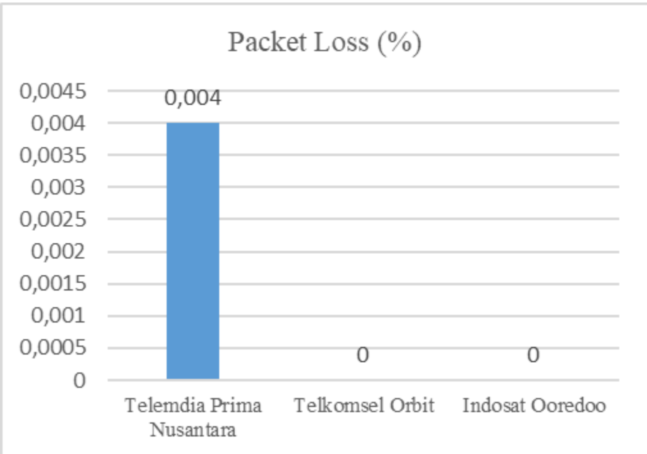

Fig. 8. Average Packet Loss for Internet Network Providers.

The results of observing packet loss at each internet network provider show that data transfers using Telemedia Prima Nusantara still contain data packets that do not reach their destination, amounting to 0.004% of the total data packets sent. Meanwhile, sending data packages using Telkomsel Orbit and Indosat Ooredoo, there were no data packages that did not arrive.

3.6 Average Internet Network Provider Delay

Each internet network provider has a low delay, namely under 11 ms. This indicates that there is no network delay problem with each internet network provider.

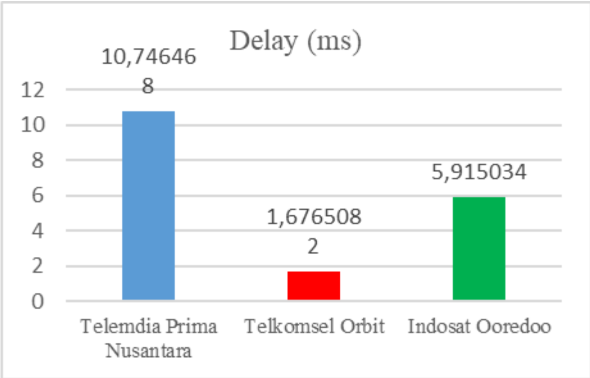

Fig. 9. Average Internet Network Provider Delay.

3.7 Average Internet Network Provider Jitter

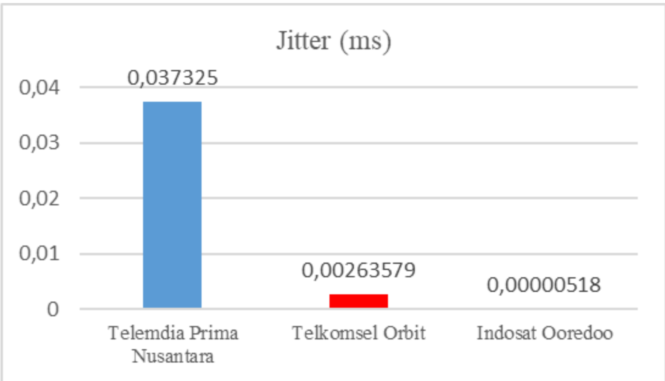

Fig. 10. Average Internet Network Provider Jitter.

Observing jitter on the network is intended to determine ping variability from time to time, so that it can be seen that network interference is evenly distributed in the data transmission process [15]. Telemedia Prima Nusantara has the potential for greater variations in data delivery delays than Telkomsel Orbit and Indosat Ooredoo, but the jitter value for each internet network provider is still in good condition, namely below 0.038 ms.

3.8 MPPT Data Precision Level with Mobile Devices

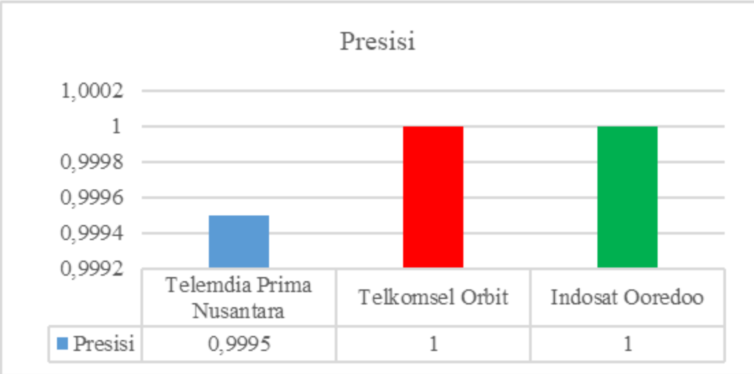

Fig. 11. MPPT Data Precision Level with Mobile Devices.

Based on the observation results, it was found that the accuracy/precision level of data between MPPT and mobile devices on the Telkomsel Orbit and Indosat Ooredoo network providers reached number one, which means there were no errors in the data displayed on either MPPT or mobile devices. Meanwhile, the Telemdia Prima Nusantara network provider has a precision value of 0.9995, which means that almost all of the data that appears between MPPT and mobile devices is not wrong, but there are still 0.0005 or a small number of errors, namely the values that appear between MPPT and mobile devices do not match.

3.9 RMSE Score

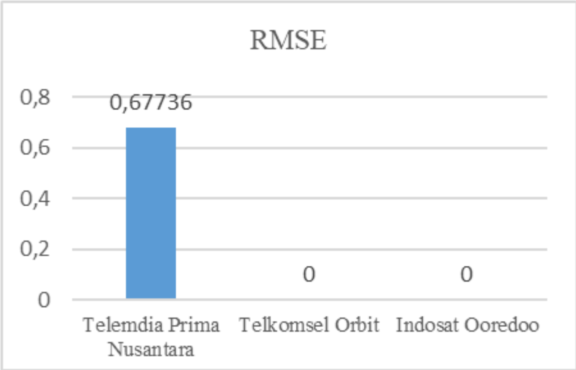

Fig. 11. RMSE Score.

Based on the calculations carried out, it was found that the RMSE value for Telkomsel Orbit and Indosat Ooredoo was at zero because there were no errors. Meanwhile, referring to precision level observations, Telemedia Prima Nusantara still has data display errors between MPPT and mobile devices, namely 0.0005 where the error rate of the displayed data values reaches 0.67736, which means the error frequency is low but the error rate of the values is quite different.

4 Conclusion

4.1 Conclusion

Based on the discussion and analysis of the data that has been presented, the following conclusions can be drawn on the research:

1. The level of accuracy/precision of data displayed on MPPT and solar panel ship IoT mobile devices is influenced by the network conditions used. Both the network conditions used on MPPT and mobile device networks.
2. The network QoS parameters that most influence data accuracy/precision on solar panel ship IoT infrastructure include the number of packet losses, average delay and network jitter, while throughput and ping have little influence.
3. IoT instruments can be used to monitor the condition and battery capacity of solar panel-powered cadet training ships using the internet network.

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