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Dual Server Implementation for Improving Reliability of Online Energy Monitoring System

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ABSTRACT

Smart Systems require not only features for improving productivity, but also the system reliability. The energy monitoring system commonly uses one of two server types, where the local servers tend to better reliability, and the internet-connected servers have to allow accessible anywhere. This study merges both server types by applying the proposed dual server system. In the proposed method, the Arduino connected PZEM-004T energy sensor sends its data to the Raspberry Pi 4 based local server for obtaining reliability. Then, the local server forwards the received sensor data to the internet-connected server to enabling internet accessibility. The results show that both servers can store the sensor data simultaneously, and the designed energy monitoring system can access across an internet connection. These results indicate that applying dual servers in the energy monitoring system can combine two advantages, namely reliability and internet connectivity. Accordingly, implementing the dual server system produces an online energy monitoring system with improved reliability.

Key words: Dual Server, Energy Monitoring System, PZEM-004T, Raspberry Pi.

1. INTRODUCTION

Internet of Things (IoT) is an exciting topic in the era of the industrial revolution 4.0 cause of its concept which has the potential effect not only to our lifestyle but also the way we work [1]. The idea of IoT refers to the relationship between communication and information technology with electronic devices. So, it more accessible for various objects to exchange information and communicate with the others because of the IoT system is connected through the internet network which connected continuously thus it can run automatically or can be controlled remotely by the user [2][3]. IoT technology reaches many aspects of human life, one of which is the home automation system [4].

The home automation system is a technology that allows electronic devices connected to the internet so that it can be monitored or controlled remotely [5] [6]. Several studies have been reporting designed and implementation the system monitoring and control of electronic devices remotely using GSM [7], smartphone [8] and Raspberry Pi 3 [9] and with Arduino microcontroller based on nRF24L0+ wireless transceiver [10]. The web-based management information system presents in [11]. The research on security systems for smart home based on GSM technology report in [12][13] and based on ESP32 present in [14]. Based on the research, monitoring and controlling electronic devices can be carried out over the internet by utilizing servers as data and processing centers.

The energy monitoring system is part of the home automation system which enabling report energy usage anywhere through internet connection. However, the performance of an internet-connected (online) energy monitoring system is highly dependent on the quality of the internet. Alternatively, a local server-based monitoring system is used for a reliable data logger system which can work well without the internet, although it must be compensated with only accessible on the local network. This study is to combine these two systems by applying two servers in the monitoring system. So, this proposed dual server design to takes advantageous both the reliability of local server-based energy monitoring system and accessibility of online energy monitoring system.

2. COMPARISON OF LOCAL SERVER AND INTERNET-CONNECTED SERVER ON ENERGY MONITORING SYSTEM

This section discusses the energy monitoring systems capabilities with two different types of server configurations, namely local servers and internet-connected server. Figure 1 shows a block diagram of both server types. In the local server, the energy sensor module consisting of Arduino Mega 2560 with Ethernet Shield and PZEM-004T connects to the

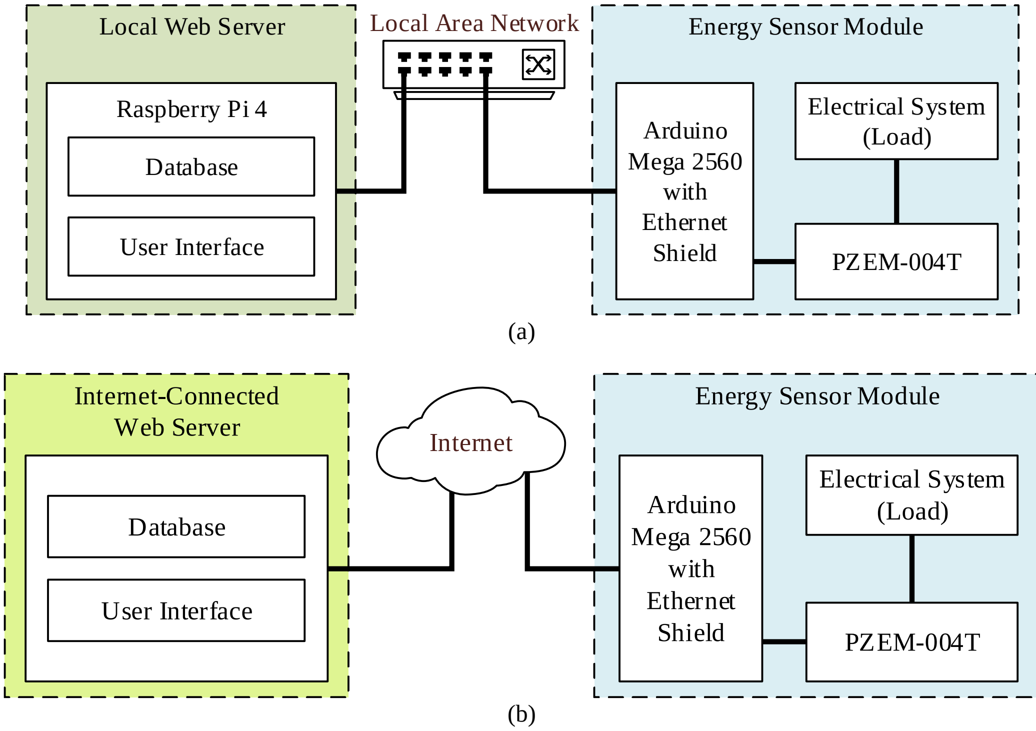


Figure 1: Block Diagram of Energy Monitoring System with (a) Local Web Server and (b) Internet-Connected Web Server

Raspberry Pi 4 based local server via a local area network to allow data transmission through the local network. Meanwhile, in the second test, the energy sensor module is connected to an internet connection. Through the internet network, energy sensor data sent to an internet-connected server. This internet-connected system is advantageous in accessibility because it allows access to the energy monitoring system on the internet network compared to systems with local systems which can only accessed on the local area network. Both server types tested using a constant load, namely a 100-watt bulb in 3 attempts with a duration of 60 minutes for each trial. On the first and second attempts, the energy sensor sends data every second to each server. As a result, there are 3600 transmitted data in one trial. Meanwhile, the time interval for sending data was reduced to once in 5 seconds on the attempt 3 to determine the effect of lower server loading to system performance. The transmitted data consist of voltage, current, power, power factor, and energy. Its data send to the database on the server using the post method, where Arduino sent post request to PHP file on the server and its PHP file store the data to the database. On testing, the amount of data lost in transmission is calculated. The amount of data lost converts into a percentage using

$$\%\ \text{Data Lost} = \frac{\text{Number of Data Loss}}{\text{Total Transmitted Data}} \times 100\% \qquad (1)$$

Table 1: The percentage of data lost on energy sensor data transmission to the local servers and the internet-connected servers

Server Types	**Data Lost (%)**			
	Attempt			**Average**
	1	**2**	**3**	
Local Server	0.14	2.14	0.28	0.85
Internet-connected Server	35.14	26.69	34.44	32,09

Table 1 shows the data losses on energy sensor data transmission to the local servers and the internet-connected servers. In average, the energy monitoring systems with the local server has much smaller data losses percentage than the energy monitoring systems with an internet-connected server. On the other hand, there is small difference in the percentage of lost data between attempt 1 and 2 against 3, which represent that the effect of server loading is negligible so that it ignores the impact of server specifications. As a result, it indicates the type of transmission line has a more significant effect on data losses. It is due to the complexity of data transmission over the internet, which has to pass through many routers compared to local server systems where data transmission processes using one router. Based on this experiment, both server types server is an option between reliability and accessibility. The local server prefers to the reliability of the energy monitoring system. In contrast, the internet-connected server is chosen for the energy monitoring system with internet accessibility.

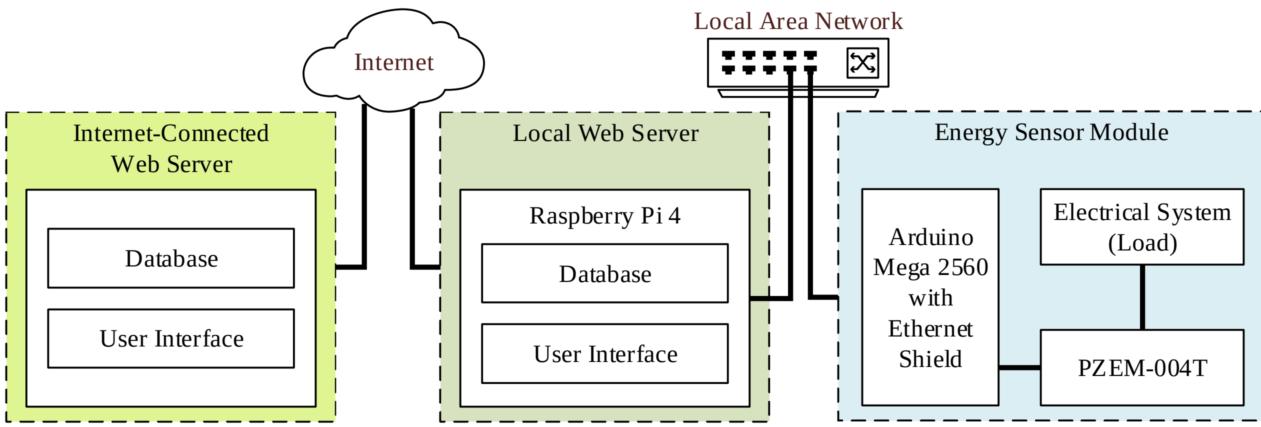


Figure 2: Architecture of Proposed Dual Server Energy Monitoring System.

3. THE PROPOSED DUAL SERVER ENERGY MONITORING SYSTE

The main idea of this study is improving the reliability of internet-based energy monitoring system. As stated in section 2, the internet-connected energy monitoring system has much lower reliability than the energy monitoring system with a local server. Therefore, the online energy monitoring system redesign with additional local servers to obtaining the reliability of the monitoring system with local servers, as shown in Figure 2. In this proposed method, the sensor module, which consists of Arduino Mega with Ethernet Shield as a data sender and PZEM-004T for energy data acquisition connected to Raspberry Pi 4 based local server. The sensor module design to send the energy data to the local server due to attain lower data loss rate compared to connected it directly to the internet-connected server. Then, Raspberry Pi 4 forwards the received sensor data to the internet-connected server using a synchronization mechanism. The Synchronization mechanism is allowing data accessibility across an internet connection because it provides the energy data store to the database on the internet-connected server. The synchronization mechanism also involves checking and retransmitting lost data, so that the energy data on a server connected to the internet is the same as on a local server. Thus, the internet-connected server has the same reliability as a local server. As a result of this method, the energy monitoring system has features to accessibility trough internet connection as a standard online energy monitoring system with better reliability as well as the energy monitoring system with a local server.

4. RESULTS AND DISCUSSION

4.1 Accuracy of the PZEM-004T based energy sensor module

The experiment initiates with measuring the accuracy of the energy sensor PZEM-004T in reading electrical energy parameter measurement consists of current, voltage, and power. It is necessary to examine the accuracy of the PZEM-004T energy sensor so that the proposed energy monitoring system displays valid data. The accuracy of the data observes in eight load variations using eight incandescent lamps with 100 watts of power specification arranged in parallel. It allows for accuracy testing for load variations from 100 watts to 800 watts to represent the data accuracy toward its application for the energy monitoring system of household in Indonesia. This study takes Fluke 303, a standard voltage and current measuring instrument as a comparison to energy sensor PZEM-004T. Based on the measurement of the voltage and current of both measuring instruments, the PZEM-004T power measurement accuracy calculates, which represents the accuracy of energy measurements of PZEM-004T. The power measurement deviation between the PZEM-004T and the standard instrument express in percentage using the following equation

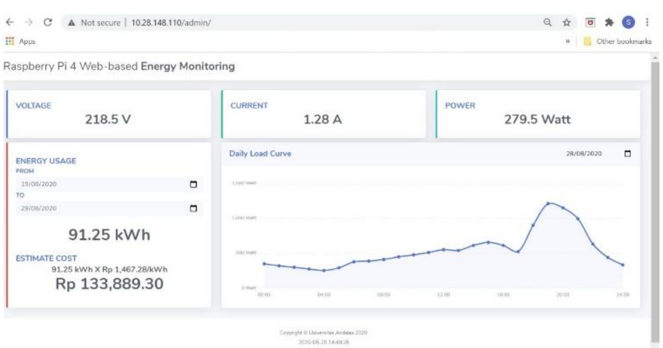
$$\%\text{Error} = \frac{|P_{\text{PZEM-004T}} - P_{\text{Fluke}}|}{P_{\text{Fluke}}} \times 100\% \quad (2)$$

where P_{Fluke} is calculated based on voltage and current of the standard measurement instrument and $P_{\text{PZEM-004T}}$ obtain based on measurement using PZEM-004T.

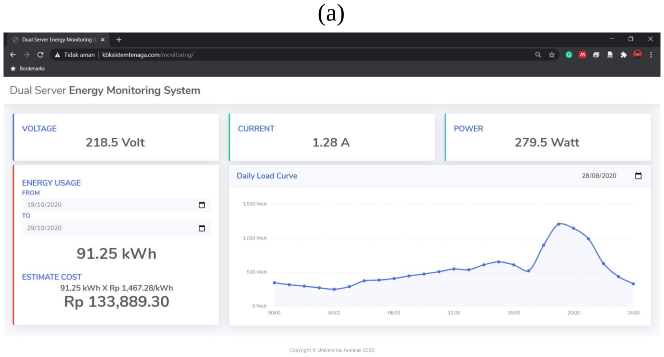
Table 1: The comparison of PZEM 004T and Fluke on power measurement

Load (Watt)	Fluke			PZEM-004T			Error (%)
	V (V)	I (A)	P (Watt)	V (V)	I (A)	P (Watt)	
100	219.30	0.40	87.72	219.40	0.40	87.76	0.05
200	218.60	0.80	174.88	218.50	0.82	179.17	2.45
300	217.60	1.30	282.88	217.60	1.24	269.82	4.62
400	216.90	1.70	368.73	217.00	1.65	358.05	2.90
500	216.80	2.10	455.07	216.80	2.07	448.78	1.38
600	216.10	2.50	540.25	216.10	2.52	544.57	0.80
700	215.20	2.90	624.08	215.30	2.91	626.52	0.39
800	215.00	3.30	709.50	214.90	3.27	702.72	0.96

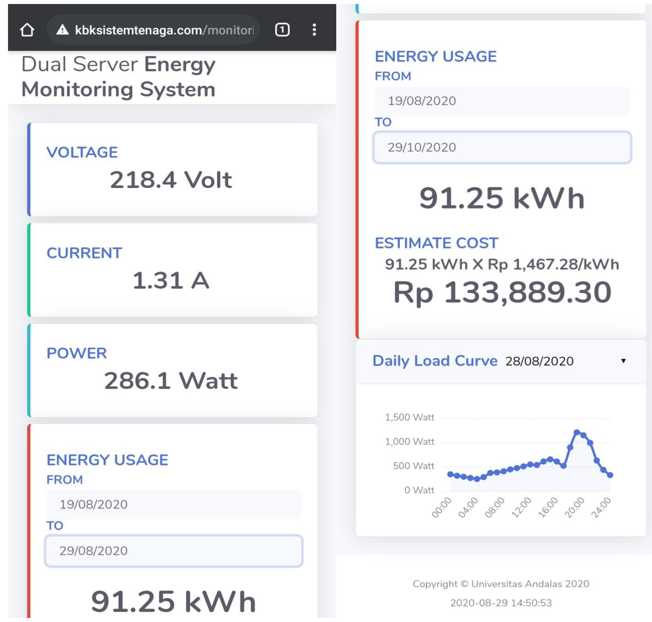
Table 1 shows the testing results of PZEM-004T and standard measuring instrument (Fluke) in voltage and current measurement with its calculated power. Based tests on eight load variation, the voltage obtained from the standard measuring instrument for 100W, 200W, 300W, 400W, 500W, 600W, 700W, and 800W successively is 219.30V, 218.60V, 217.60V, 216.90V, 216.80V, 216.10V, 215.2V and 215.00V. Meanwhile, voltage measurement based on PZEM-004T with identical load respectively 219.40V, 218.50V, 217.60V, 217.00V, 216.80 V, 216.10V, 215.30V, and 214.90V. This result shows, there are no significant differences between both measuring devices, which indicates the PZEM-004T has high accuracy on voltage measurement. The current measurement test shows similar performance, where the current measurement at the load is 100W, 200W, 300W, 400W, 500W, 600W, 700W, and 800W on standard measuring instruments, respectively 0.40A, 0.80A, 1.30A, 1.70A, 2.10 A, 2.50A, 2.90A and 3.30A, while the measurement by the PZEM-004T shows measuring current successively 0.40A, 0.82A, 1.24A, 1.65A, 2.07A, 2.52A, 2.91A, and 3.27A. As a result of the high accuracy of PZEM-0004T on both voltage and current measuring, error on PZEM-004T power measurement relatively small. The result shows the deviation value of error (%) for each load is 0.05%, 2.45%, 4.62%, 2.90%, 1.38%, 0.80%, 0.39%, 0.96%. The error values obtained from eight data variation has the smallest error value at 0.05% and the largest error value at 4.62% with an average error at 1.7%. Based on the percentage error value, it can be concluded that the results of the test data can be received well because average error data less than 2 %. The average power deviation result is within acceptable limits of IEC-61724 standard [15]. Based on this standard, the PZEM-004 based energy sensor module qualifies as a measurement instrument for the proposed energy monitoring system.



(a)



(b)



(c)

Figure 3: The user interface of the energy monitoring system on (a) local server accessed using desktop and internet-connected server accessed using (b) desktop and (c) mobile phone.

4.2 Implementation of The Proposed Dual Server Energy Monitoring System

The implementation of the proposed method requires two servers, consist of a local server and an internet-connected server, as in Figure 2. This study takes Raspberry Pi 4 with pre-installed LAMPP server as a local server which has 4 GB RAM and 16 GB SD Card for operating system and data storage. The Raspberry Pi 4 set using static IP Address at 10.28.148.110 to avoid IP replacement due to changing of DNS server table on the router. Meanwhile, the internet-connected server using server of paid web hosting services provider at domain www.kbksistemtenaga.com.

Figure 3 shows the user interface of the energy monitoring system on both servers, where both servers display similar information consist of real-time voltage, current, and power measurement, daily load curve, and estimate cost of energy usage which calculated from electricity fare in Indonesia. The dual server system allows the energy monitoring system user interface accessed through two servers, where the local server accessed by write down the server's IP address and the internet-connected server accessed through the website domain. This user interfaces design based on Bootstrap framework that is responsive on various platform, which can be accessed not only on desktop platform but also on the mobile phone as shown in Figure 3c. This responsive design on both the desktop and the mobile phone provides more flexibility for users. As a result, Figure 3 shows that all features and tools of user interface work normally on both servers.

Figure 3 also use as a parameter to determine the data synchronization process between databases on both servers. Figures 1a and 1b take using different devices at the same time on August 29, 2020, at 14:29:28, where both devices display the same voltage, current, and power readings. In contrast to Figure 1c, which take a few seconds later, where the user interface shows a different measurement. It indicates that the data on the local server shown in Figure 1a has been synchronized with a server connected to the internet, as shown in Figure 1b. Thus, the data synchronization mechanism of the two databases which aims to increase reliability is working correctly.

5. CONCLUSION

The result shows the performance of each component on the proposed dual server energy monitoring system. The PZEM 004T-based energy sensor module ables to measure electrical energy in high accuracy and to qualify the standard IEC-61724. The user interface functionality test also indicates that the energy sensor module has successfully transmitted its data to a local server and synchronized with an internet-connected server. This Data transmission model allows high-reliability data transmission because of shorter data transmission to the database on the local network, as shown in section 2. Then, the synchronization mechanism between databases on both servers enabling data on the local server similar to data on the internet-connected server, so that it allows to access high-reliability energy data via the internet network. These two experiments prove the dual server energy monitoring system can work correctly. So, it creates an energy monitoring system with internet accessibility with higher reliability.

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