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# Energy Monitoring System Based on Internet of Things Toward Smart Campus in Institut Teknologi Sumatera

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**Abstract.** The critical subject to provide energy consumption graphs from a building is an energy monitoring system. With the rapid Internet of Things (IoT) development, it is possible to develop a better energy monitoring system based on IoT. This system presents the real-time energy consumption data. Hence, this paper proposes the development of an energy monitoring system prototype based on IoT for buildings in Institut Teknologi Sumatera campus area. The current and voltage are measured in real-time for each wiring phase on the building electrical panel. The data is collected in the cloud server and displayed in a web-based system using custom web panel. Finally, the prototype is implemented in the building during 24/7 for one week achieving about 97% of the accuracy.

## 1. Introduction

Institut Teknologi Sumatera (ITERA) is a new state university in Lampung, Indonesia, that is currently carrying out a large-scale development compared to other campuses. ITERA has a slogan of Smart, Friendly and Forest Campus. It should be noted that building a smart campus involves many aspects having to be taken into account. Particularly, the smart campus must have an energy management system that guarantees the use of electrical energy with effectively and efficiently.

The first step to be taken in establishing the ITERA smart campus is to monitor the use of electricity used in every infrastructure that has been built. Hence, in this research, we provide a solution to design and create an Internet of Things (IoT)-based electric energy monitoring system toward smart campus at ITERA. The IoT is chosen as the foundation of data communication with consideration of the resulting scalability. The smart energy monitoring is having good accessibility, easy to combine to other system and accurate [1]. Therefore, the system can enlarge according to the needs without creating significant changes to the established system. Also, the smart meter has additional feature to switch power supply when minimum tariff available [2]. For instance, we prefer to use energy from solar panel rather than State Electricity Company (PLN).

The main component of this system is a microcontroller. Then, the element continuously measures several electrical variables such as voltage, current, power and time. After that, the data are sent to the storing database in cloud server based on the IoT. In the next level, data in cloud server can be analysed to create energy consumption pattern [3]. Hence, the data can be accessed and processed in cloud computing. The Atmega328 has been success to be implemented in smart energy meter to detect theft electricity [4].



The output of this research is a prototype energy monitoring system for the establishment of a smart campus where electric power can be utilized effectively and efficiently. To the best of our knowledge, this system can be submitted to obtain ITERA becoming the first campus in Indonesia having a smart campus system being implemented. Hence, this research result is very important to be realized. This is because the beginning of realization of smart campus system is aspired by ITERA with the slogan of Smart, Friendly and Forest Campus.

## 2. Model System

The research location was conducted in two places. They are located at (a) the ITERA Laboratory as a place for system design and testing and (b) several buildings in ITERA as a place for prototype testing. Furthermore, there are three stages in this research. For more detailed, they are consisted of the design system in stage 1, build a prototype system in stage 2, and test system in stage 3, as shown in Figure 1.

In the first stage, all the problems are identified, and several alternative solutions are established, where the output is the system design for the next stage. The second stage is to build the prototype system, where the results in the previous stage are realized in the form of hardware and software. Hence, all areas of expertise from the research team are utilized to realize the system design that has been made. The third stage is the system testing, where the system created in the previous stage is tested with several techniques starting from the basic feature until the accuracy and durability of the system against the time of use.

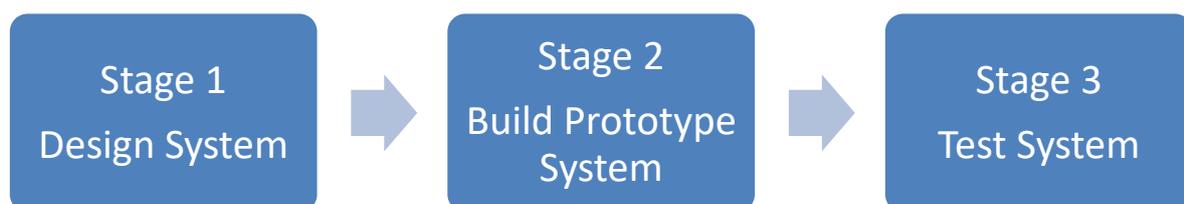
It is shown in Figure 2 that each sensor node sends the energy measurement data independently through the internet to the cloud server. The data are then stored and processed in the cloud server. Hence, they can be accessed and processed by other systems and users. The advantages of this system are that the increase in the number of measurement points do not require a system change. Therefore, the performance system has good scalability and unlimited size to expand. Besides, the system can develop according to the needs without limits.

## 3. Design and Implementation

Figure 3 shows the initial design scheme for each node in this field. The flow sensors and voltage sensors provide the input to the Atmega328 microprocessor by converting the analog signal from the sensor to digital signal. In Atmega328, the energy consumption is calculated by performing mathematical operations on the value of current and voltage. Then the data are pushed to the ESP8266 module which sends the data to the web server wirelessly with WI-FI communication. The ESP8266 module has advantages, i.e., low cost and easy to modify the firmware. In the previous work, ESP8266 has been success in sending data from the node sensor to server lossless [5].

### A. Survey and Data Collection

The field surveys has been conducted in this research by visiting the places used for data collection. The places are the main electricity terminals in each building at the ITERA campus. For the illustration, Figure 4 shows a picture of the main terminal electric panel on the ITERA campus building. On the panel, there are four main conductive cables where the current sensors and voltage sensors are installed.



**Figure 1.** Block diagram showing the three stages of research.

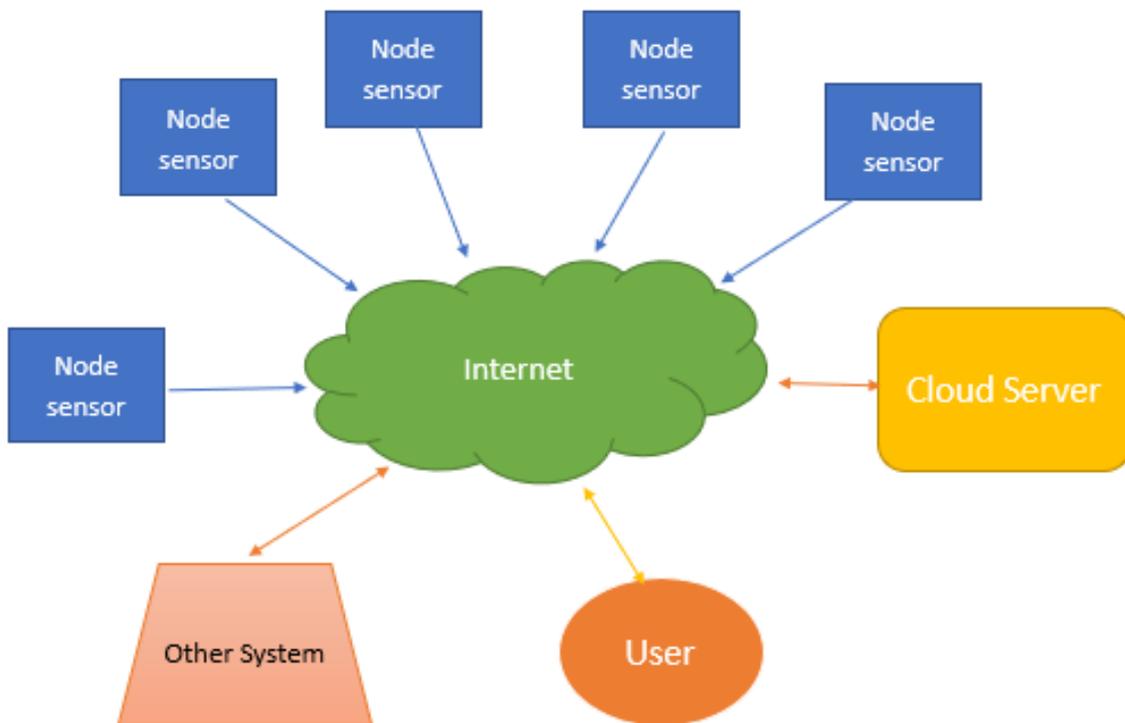


Figure 2. Block Diagram system.

The four cables consist of three phase cables and one neutral cable. Hence, for each sensor node, three pairs of current and voltage sensors are required. The installation of this sensor is designed not to interfere or damage the existing installation. Especially, the current sensor uses a clamp, hence, it does not require to tear or damage the insulator on the conductive cable.

**B. Cloud Server**

This paper selects and uses the Google cloud server. This is configured as CPU Single core, 1 GB RAM, and Ubuntu Operating System. Furthermore, Webserver (NGINX) and database (MYSQL) application are installed in this server.

**4. Experiment and Result Analysis**

This research has obtained several research results. The result of sending data wirelessly from the sensor node to the web server obtained by the WebSocket protocol are very satisfying. With the fact that there is no lost during performing the data sending. Moreover, the data sent from the sensors can be monitored in real-time through other devices.

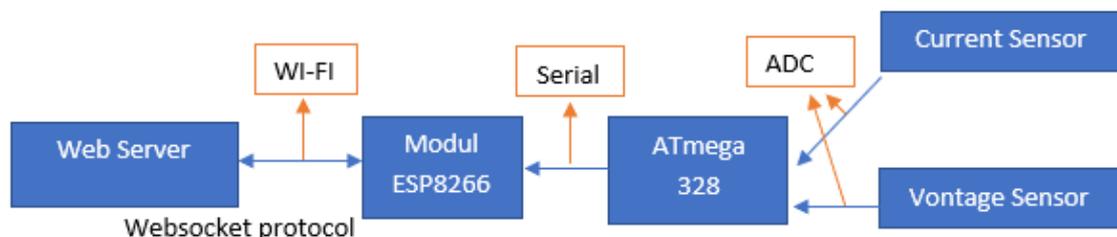


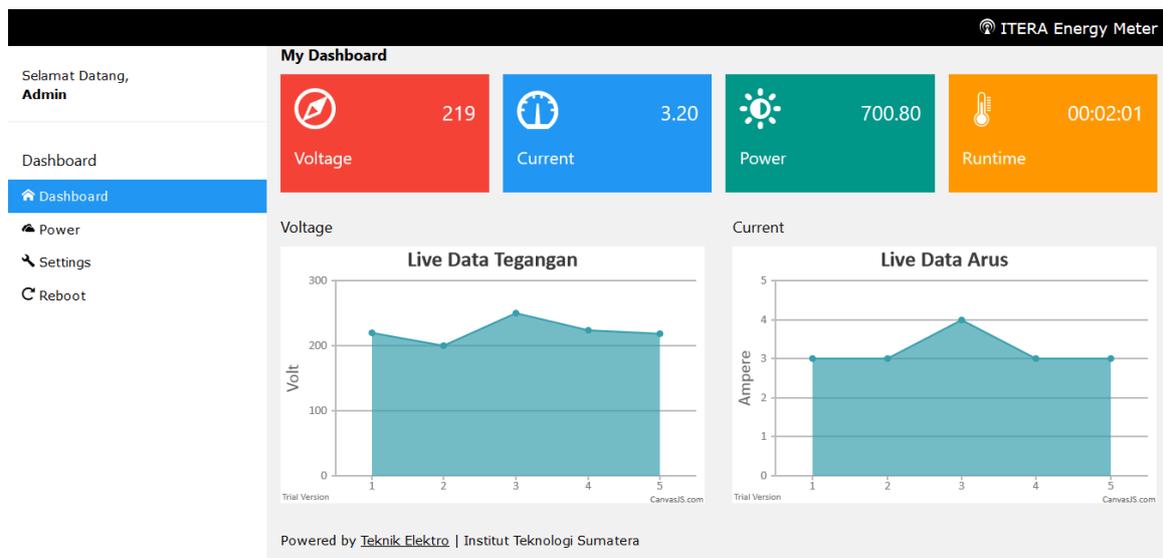
Figure 3. Initial Design for each node sensor.



**Figure 4.** Main terminal electric panel.

Figure 5 shows one of the devices display connected to the node sensor. It can be seen that the observer can monitor the data sent from the sensor nodes with real-time on the web server as mentioned above. Additionally, there are displayed several main data that can be observed, namely, the data voltage, current and energy, with the corresponding unit of volt (V), ampere (A) and kilo watt hour (kWh), respectively.

After conducting several trials, a circuit on a printed circuit board (PCB) is fabricated. Hence, more complex monitoring system is assembled as shown in Figure 6. Also, there is a microSD module inside the box utilized to store the sensor measurement with the aim of being back-up to anticipate the communication problem with the server. The next component is real time clock (RTC) module which the function is to provide the date and time data of the voltage and current during transmission process.



**Figure 5.** Web panel energy monitoring system.



**Figure 6:** Main PCB of Energy monitoring node

The main board is stored in a box made of plastic which is fire-resistant. Given that, the dimension of the plastic box is adjusted to the width and length of the PCB. Here on the side of the box, a hole is given for the sensor connectors and cables having the access to the PCB. It should be noted that the calibration process of this research prototype has been carried out several times. For that reason, the process is performed by comparing the measurement results with the other tools considered having valid values.

The current sensor in the proposed prototype being the primary sensor to measure energy consumption has been tested in this research. The tests are carried out with the load of four fluorescent lamps where each has a load of 100 W which is switched sequentially. Hence, Table 1 shows the results of current sensor testing in the prototype. From these results, the rate of curation from the prototype is about 97%.

**Table 1.** Prototype Measurement Result.

No	Load	Trusted Digital Ampere meter	Prototype Current Sensor	Accuracy
1	1 Lamp	0.479 A	0.463 A	96.60%
2	2 Lamp	0.961 A	0.927 A	96.45%
3	3 Lamp	1.500 A	1.458 A	97.18%
4	4 Lamp	1.964 A	1.913 A	97.42%
			Average	96.91%

## 5. Conclusion

The new proposed architecture based on IoT to create energy consumption monitoring system has been presented. The research results show that the data transmission using the WebSocket protocol can produce satisfactory results without any failed sending data. Moreover, all applications used in the web server can be obtained from the open source. Hence, the purchase of any licenses is unnecessary. Additionally, the Atmega328 microprocessor and ESP8266 module are quite reliable in processing and sending data for each sensor node. Finally, the measurement results achieve 97 % of the accuracy.

Hence, the proposed design is promising for future innovation of energy monitoring system toward smart campus in ITERA

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