Multi-Area Smart Monitoring of Electrical Quantities Based on Mini Single Board Computer BCM 2835

Dikpride Despa[#1], Mardiana[#2], Gigih Forda Nama[#3] , M. Komarudin[#4], Michael Zontche Bernard[*5]

[1]*Department of Electrical Engineering,* [2,3,4] *Department of Informatics Engineering*
[#] *University of Lampung, Lampung-Indonesia*
despa@eng.unila.ac.id, mardiana@eng.unila.ac.id, gigih@eng.unila.ac.id, komar@eng.unila.ac.id
[5]*Department of Electrical and Computer Engineering*
[*]*University of Alberta - Edmonton, Alberta, Canada*
mzbernard@ualberta.ca

***Abstract*— Multi-Area Smart Monitoring Systems are applications and devices that can monitor the amount of electricity at various locations in the distribution panel. This paper presents a scheme for multi-area smart monitoring of electrical quantities trends in real-time, to overcome the limitations of techniques that are applicable only to one panel of a three-phase distribution system. The implementation of the proposed scheme increases the possibility of taking preventive action for protection in case of abnormal conditions. A Single Board Computer BCM2835 SoC, ARM11767JZF-S 700 MHz processor is utilized to serve as an interface for obtaining data of the electrical quantities. It collects the data and saves them to a database system. All data utilized in this study are obtained from the LAB-JTE and the ICT-unila. Both locations are on the campus of the UNILA. These data have been recorded and sent to a computer server through the Local Area Network connection and monitored in real time. The monitoring of data which was conducted from the 29th May to the 31st May 2016 produced significant results, showing that the voltage, current and load connected to the monitored phase, relatively has asymmetric trends. The results also demonstrated that at noon, the electrical energy consumption trends at the Unila is in accordance with the working hours there. Finally, by comparing the results obtained from the monitoring of the electrical quantities trends at the LAB-JTE and the ICT-Unila, it is shown that the conditions of the electrical quantities at the ICT-Unila has better measurement results.**

Keywords*— Multi-area panel distribution, real-time monitoring, Electrical Quantities, BCM2835, Unila

I. INTRODUCTION

University of Lampung (Unila) has always been implementing some of its developmental plans by working tirelessly to increase its quality and services in various ways. Some of its key efforts include the development of information technology, improvement of infrastructure as well as laboratory equipment, which have an influenced in increasing the number of electrical energy consumption. Generally, electrical equipment should be able to work normally within their pre-specified limits or standard values. But in reality, abnormal conditions may occur within the electrical system for a long period of time. If these conditions are not properly monitored, they can result in electrical outages and even damage to the equipment.

To alleviate the above-mentioned problems, Unila built a system that can provide real-time information in cases of both normal and abnormal events. With such a system, it is expected that if an abnormal condition is monitored, the operator can take proper action early, so that problematic conditions such as sudden blackout and the risk of equipment damage can be avoided.

In fact, Unila has many buildings that need to be monitored in order to take preventive action for protection, in the case of abnormal conditions. Hence, this research is developed for multi-area systems, in an effort to enable the possibilities of monitoring the electrical quantities at multiple locations panels in a three-phase power distribution network that are located in different buildings at the same time. Multi-Area smart monitoring of electrical quantities is advantageous in that, it overcomes the limitations associated with techniques that are applicable only to one panel of a three-phase distribution system.

In this study of multi-area smart monitoring, the Mini Single Board Computer BCM 2835, ARM11767JZF-S 700 MHz processor (Raspberry Pi model B) are the main components utilized. Raspberry Pi serves as an interface for the acquisition of the electrical quantities data and saves them to the database system. The electrical quantities data which are measured by sensors via two distribution panels is sent through the Internet and stored on a computer server that can be accessed by the manager. The trend information of electrical quantities at multiple locations can then be monitored simultaneously in real-time. Furthermore, the expected results of monitoring may be used as a reference for stakeholders, in helping them to make decisions with regards to maintenance and planning for future models.

The rest of this paper is organized as follows: Section 2 deals with related work, including limitations of the works previously carried out in this area of research. This section also provides the contribution of the current work. In section 3, the research methodology is presented along with the block diagram system. The two hardware prototypes utilized in this research are also presented in the section. Section 4 focuses on results and discussions where the prototypes testing have been implemented and graphically illustrated to validate the effectiveness of the proposed monitoring scheme. The paper is concluded in section 5 where significant directions for future work are also provided.

II. Related Work

A. Previous Research

The application of real-time monitoring of electrical quantities and stability of power systems have been considered by several studies [1]-[4]. In addition, previous studies regarded as significant references in this research considered the use of Microcontroller, Raspberry Pi, Arduino and web application for the measurement and monitoring system [1],[4]-[11]. [1] and [4] are also considered key references of this work. These references are mainly associated with the design and prototype of monitoring electrical quantities such as voltage, current, power, the power factor (cos ϕ), and energy consumption application using BCM2835, and they focused on one of the panels a three phase distribution system that exist at Unila.

In [4],[5] the measured data are stored in real-time on a database server such as Linux and MySQL server. Data obtained are further processed by the web server so that it appears in the form of a historical statistical chart that can be accessed online via the Internet. However, [4] and [5] are only applicable to one panel of a three phase distribution system in Unila. The favorable properties of applying the monitoring techniques of the above-mentions references which include their applicability to only one panel of a three phase distribution system are diminished by the need for the monitoring of multi-area system in real time, which is an objective achieved in this research.

B. Hardware Design

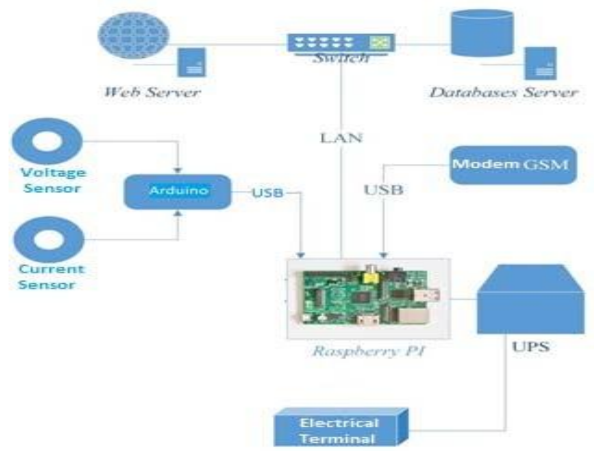

Fig. 1 Hardware Topology Design for Smart Monitoring System

Fig. 1 illustrates a design of the hardware topology for smart monitoring devices connected to Arduino and BCM 2835 (Raspberry Pi) through a general-purpose input/output (GPIO) pin. Data such as current, voltage, power, energy consumption and power factor are recorded in real-time via database servers: Linux and MySQL servers. These data are further processed by a web server and appear in the form of a historical statistical chart that can be accessed online through the Internet.

III. Research Methodology

A. Blok Diagram System

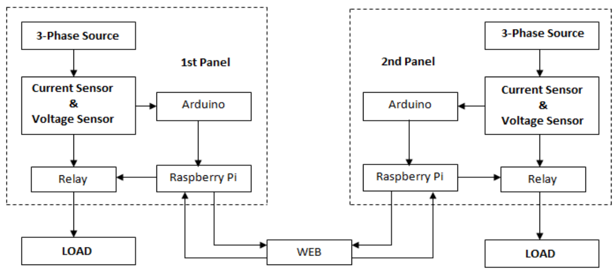

Fig. 2 Block Diagram System

The block diagram shown in Fig. 2 is described to facilitate and a better understanding of the system.

B. Hardware Design

In this study, two hardware prototypes with the same design are made and positioned in two of the three-phase distribution panels at different locations. The design of the hardware is structured by electronic components as illustrated in Fig. 3 below.

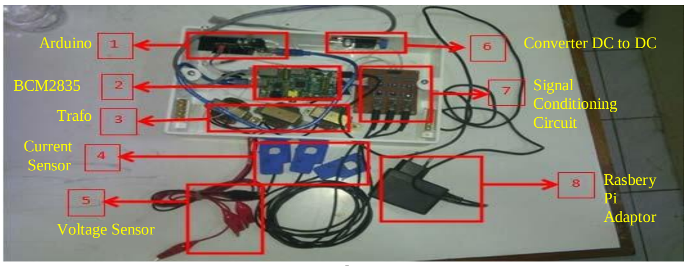

Fig. 3 Hardware Design

C. Programme Design

Python programming [12] is used to create several function and routine that run on Raspberry Pi. These include sensors' data program reader, a calculation program for obtaining the electrical quantities and recording the electrical quantities data, a web interface display, and a database system receiver program.

Current and voltage values are measured directly, while other electrical quantities are determined by the use of the equations below [13]:

$$E = (P.t) / 1000 \text{ (kWh)} \quad \ldots\ldots(1)$$

$$P = E / t \quad \ldots\ldots\ldots\ldots(2)$$

$$P = VI \cos \phi \quad \ldots\ldots\ldots\ldots(3)$$

$$Pf = \cos \phi = P / (VI) \quad \ldots\ldots\ldots\ldots(4)$$

where P is the Power in Watts, E is the Energy consumption in KWh, t is the time in hours, V is the voltage in Volts, I is the current in Ampere and Pf is the power factor.

IV. Result And Discussion

A. *Prototype Testing*

The designed prototype has been tested with variations of load.

TABLE I : TEST RESULTS

No	Various of Load	Test Results					
		Volt (v)		Current (I)		Pf (cos ¢)	
		Proto type	Volt meter	Proto type	Ampere meter	Proto type	Cos ¢ meter
1	Load 1	221,10	220	2,2	2,2	0,99	0,99
2	Load 2	221,95	222	5,28	5,27	0,99	0,99
3	Load 3	220,75	221	0,44	0,59	0,99	0,99

Table.1 shows the data of the measurement test results using the hardware prototype and compared the results to those of a standard measuring device, namely the multi-meter. It can be seen from the table that the prototype and multi-meter have a very small difference in results. This indicates that the tool is significantly reliable.

B. *Results of System Testing*

The testing of the system was done at two different locations: the 3-Phase distribution panels of LAB-JTE building and ICT-Unila building.

The results of the monitoring system in both buildings are stored in a database system: MySQL server. The final step is displaying the data from the existing database into a web interface. In this test, the database was split into five tables. They are voltage, current, power, cos ϕ and energy consumption. The trends of measurement results are displayed in the statistical chart of the web interface. The monitoring charts results for each measurement described are shown in Fig. 4 (a, b, c, d, and e).

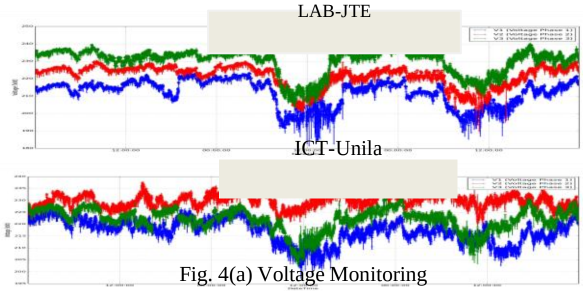

Fig. 4(a) Voltage Monitoring

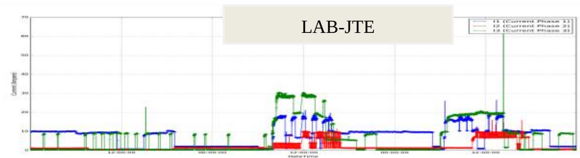

Fig. 4(b) Current Monitoring

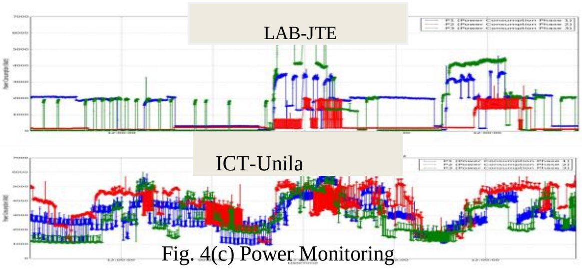

Fig. 4(c) Power Monitoring

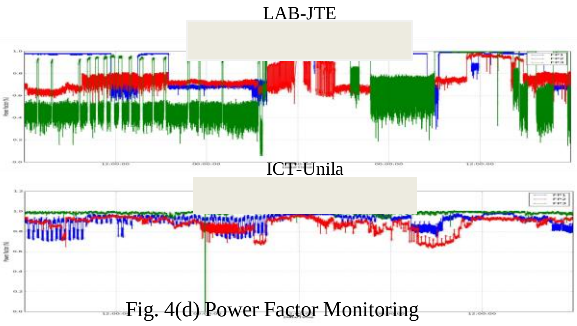

Fig. 4(d) Power Factor Monitoring

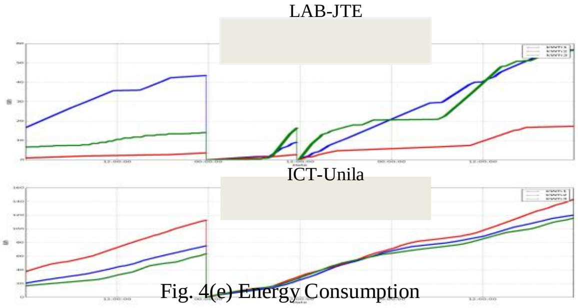

Fig. 4(e) Energy Consumption

Fig. 4 Results obtained from Monitoring from 29th May to the 31st May 2016

As seen in Fig.4, the graphs represent the results obtained for multi-area monitoring, from the 29th May to the 31st May 2016. The monitoring results and the trends of the electrical quantities shown in Fig. 4 (a) –(e) for LAB-JTE and ICT-Unila are discussed as follows:

a. Voltage Monitoring Results

The voltage rating is about 200 V to 240 V. It can be seen from the graph of Fig.4 (a) that, for each phase shown, the voltage value at the two locations are not balance. The voltage drop occurs during the day (working hours) with the lowest value for the three-phase system observed in both LAB -JTE and ICT Unila. This illustrates the imbalance load mounted on each phase and electric energy consumption patterns are not evenly distributed, especially during a certain time of the day.

b. Current Monitoring

The data shows that the monitored current in each phase at two locations is not in balance condition. From the graph of Fig. 4 (b), it is observed that the current increases during working hours (8:00 to 16:00) with 35A being the highest value at ICT-Unila building. This is because there are more activities at Unila during working hours. At night, the activities at Unila are reduced significantly. During this time, the university is basically used for lighting and air conditioning only.

c. Power Monitoring

According to Fig. 4 (c), the power consumption tends to be higher during the working hours. If we note the power at each phase, then the electrical energy consumption in ICT-Unila building is greater than that of LAB-JTE. This is understandable because of the many activities carried on during the day at the ICT-Unila building.

d. *Power factor (cos ¢) Monitoring*

The power factor monitoring charts shows where the value of the power factor was obtained from the calculation using voltage and current measurement data. This is illustrated in Fig. 4 (d), where the power factor at the ICT building ranged from 0.7 to 0.99, while in the LAB-JTE building it is around 0.3 to 1. This means that the ICT-Unila building has a better power factor as compared to LAB-JTE. One of the factors that can influence the value of the power factor is a reactive load. Hence, if the value of the power factor is unstable, a possible cause is due to the changes in the reactive power of the load.

e. *Energy Consumption Monitoring*

In general, since the load connected to each phase is not balanced, the energy consumption of each phase will behave in the same manner. The total energy consumption at ICT- Unila building is greater than the total energy consumption at LAB-JTE. This scenario is illustrated in Fig. 4 (e) which explains that there are more activities involving the use of electrical appliances within the ICT-Unila building as compared to that of Lab-JTE.

V. CONCLUSIONS AND FUTURE WORK

A. *Conclusions*

This paper carried out monitoring of the electrical quantities trend at LAB-JTE and compares the result to that of ICT-Unila. The results of the monitoring may be utilized as a reference for stakeholders, in helping them make decisions with respect to maintenance and planning for future models. The results obtained from the monitoring of electrical quantities at two different locations show that there are unbalance conditions during working hours. It is also observed that the results in the trends of electrical quantities that were monitored in ICT-Unila are better as compared to those of LAB-JTE.

On the other hand, the electrical quantities for each phase that have been monitored in Unila are not in a balance condition. This indicates that the load distribution for each phase is unbalanced and needs to be fixed. The electrical energy consumption in Unila is higher during the day, especially during working hours, as compared to the evening or night time. Furthermore, it has been shown that the conditions of the electrical quantities within the ICT-Unila is better as compared to conditions of the electrical quantities within the LAB-JTE building.

B. *Future Works*

In order to make the utilized system become better, this application should be integrated with a notification system. The development of a mobile application for this project is also highly recommended. Furthermore, the project should be extended to several locations, for experimentations with more than two areas. Finally, the data results from this research should be used as a reference for planning, estimation as well as the improvement of the electrical system of Unila in the future.

REFERENCES

[1] D. Despa, A. Kurniawan, M. Komarudin, Mardiana, G. F. Nama, "Smart monitoring of electrical quantities based on single board computer BCM2835", 2nd International Conference on Information Technology, Computer, and Electrical Engineering, pp 315-320, Indonesia, 2015.

[2] Qing Liu, Despa. D, Y. Mitani " Application of Phasor and Node Voltage Measurements to Monitoring Power Flow Stability " International Journal Electrical Engineering and Informatics, Printed ISSN 2085-6830/online, Volume 4. Number 3 Pp 276-288, July 2012.

[3] D. Despa, Y. Mitani, M. Watanabe, "PMU Based Monitoring and Estimation of Inter-area Power Oscillation for Singapore-Malaysia Interconnection Power System", Journal of Energy and Power Engineering, USA, 2012.

[4] Dikpride Despa, Mardiana, Gigih F N, "Smart Monitoring Data Centre base on Mini Single Board Computer BCM 2835", The 1st International Conference on Science, Technology, and Interdisciplinary Research (IC-STAR), Indonesia,2015

[5] G. F. Nama, M Komarudin, Hanang. P, Mardiana, H. D. Septama, "Electricity, Temperature, and Network Utilization Monitoring at Lampung University Data Centre Using Low Cost Low Power Single Board Mini Computer", Regional Conference On Computer Information Engineering, Indonesia, pp. 184-189, 2014.

[6] E. Baker, "Open source data logger for low-cost environmental monitoring", Biodiversity Data Journal, 2014.

[7] G. Aceto, A. Botta, D. Donato, P. Marchetta, A. Pescape, G. Ventre, " Open Source Platforms for Internet Monitoring and Measurement", Eighth International Conference on Signal Image Technology and Internet Based Systems (SITIS), G. 2012.

[8] T. Michael Silver, "Monitoring Network and Service Availability with Open-Source Software", Information Technology & Libraries. Mar 2010, Vol. 29 Issue 1, 2010.

[9] Riyanto, R.O Wiyagi, "Sistem Monitoring Suhu Ruang Server Berbasis Web", Junal Ilmiah Elite Elektro, 2(1), pp. 50 – 54, 2011.

[10] G. F. Nama, M. Komarudin, H. D. Septama, "Performance Analysis of ArubaTM Wireless Local Area Network Lampung University", 2015 International Conference on Science in Information Technology (ICSITech), pp 41-46, Yogyakarta, Indonesia, 2015.

[11] BCM2835 ARM Peripheral, http://www.raspberrypi.org/wp-content/uploads/2012/02/BCM2835-ARM-Peripherals.pdf. Accessed: 24 July 2016.

[12] B. Rhodes, J. Goerzen, 2010. Foundation of Python Network Programming. 2nd Ed. New York: Apress.

[13] Fowler, Richard J, "Electricity Principles & Applications, McGraw-Hill", 2008.