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Web-based Real Time Monitoring of Electrical Quantities Measurement

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Abstract— This study aims to build an applications, that can monitor the value of electrical quantities in a real-time using web technology at H Building of Engineering Faculty, University of Lampung (Unila). The whole system consist of several hardware and software components. Some hardware components such as current sensors, voltage sensors, signal conditioning circuit, embedded computer Arduino Uno, and Ethernet Shield. The programming language used for data acquisition was C language. The web-based applications produced the electrical quantities data measurement, appears in the form of text and graphical format that can be access anytime and anywhere. Some of web development tools used in this web development those are HTML, CSS, JS, JSON, and PHP programming languages. The results of monitoring data shown, the amount of electricity at distribution panels at this building was not balanced. This happen due the electrical load was unbalanced on each phase, other fact found that the trend of electricity usage still follows the trend of working hours.

Keywords— web-based application; real-time monitoring; electrical quantities, distribution panels, engineering faculty unila

I. INTRODUCTION

Changes of electricity value will indirectly affect electronic equipment used; therefore, the value of the electrical quantity must be measurable in a real-time, to ensure that its value is still within tolerance standard. Example for voltage; the standards permitted by IEEE should be range from 80% to 90% of nominal value of voltage.

Faculty of Engineering, University of Lampung (Unila) always strives to improve the quality of its services, including in terms supply of electricity quality to whole building. From the results of measurements that have been done on work [1] shown that the value of some electricity magnitude in existing buildings in the Faculty of Engineering Unila tend to conditions not in accordance with standards. This condition is commonly referred to as abnormal conditions, if it occurs in a long time can cause harm to electronic equipment, even the worst condition if no termination at this situation, total blackout could also happen [2]. For this reason, a system of measurements of electricity quantities that can be monitored in real-time should be develop and applied to overcome negative impact of these abnormal conditions, and it is very important immediately identified the electricity quality for any preventive action to avoid the worse consequences of changes in the value of the electrical quantity.

Web technology nowadays popularly used to display a variety of information interactively and supported by many platforms, allowing users to access information anytime anywhere. In this study, the measurement results of electrical quantities successfully displayed in a web-based application, the data shown in the form of text and graphical information that can be accessed in real-time via the Internet network both n local area network and global internet.

Furthermore, an important point in this research is the system has been tested and calibrated with various variations of load and standard equipment in the laboratory, before implementing the whole system on distribution panel in H building of Engineering Faculty.

Monitoring system already deployed to power system distribution panel and the measurement results can also be accessed through web application. Finally, real-time web monitoring has provided an overview of real conditions electrical quality in H Building Engineering Faculty of Unila.

By devising a system to monitor real-time electrical quantities which can be access from the web seamlessly, preventive action can be taken more quickly before any bad consequence happen.

II. LITERATURE REVIEW

A. Related Works

Online monitoring power system using sample data that recorded by PMU for many locations with same frequency research has been done for specific purpose of power flow stability [3][4], [5]. This research has been done at electrical power system 50 Hz in Japan, Singapore and Malaysia. Despa did previous research related with monitoring electrical quantities for 3-phase system at Unila [1] and [6]. The research of monitoring electrical quantities, create a prototype of electrical quantities monitoring system, and the prototype have been implemented at some distribution panels in Engineering Faculty Unila. Unfortunately, [1] and [6] only do data collecting and not able to publish through the web application, and also the data frequency of power system not counted.

In addition to the above research studies related to the measurement of electrical quantities, other studies supporting current research is real-time monitoring based on web

technology are found on work [7] and [8]. In the study Gigih has built a monitoring system that can be accessed through web application, although only basic information is monitored, electrical connectivity system and temperature on the server room of UPT TIK Unila building. Other related works on [9], built a web-based monitoring system to monitor power systems in cell towers. Although already web-based, but the data measurement results are not displayed on the web-page. Measurement data was only sent to the server for storage and processed manually. Another research was entitled "Development of Power Monitoring and Analysis System based on Web Server" [10], this research builds a web server based monitoring system for power system monitoring using Raspberry Pi. Results data measurement can be displayed in real-time in the form of tables on the web page. Nevertheless, this research still needs to be refined because the display in table form on web was less effective in terms of providing information related to the changing trend of measured electrical quantities. Another previous research related to the implementation of web technology can be found on works [11] [12].

B. WEB-Monitoring System

A monitoring system has many different point of view. Dickson [13] on their paper, furthermore explain decomposes monitoring systems into several functional components shown on Figure 1, measurement flows through a pipeline of steps. Each step will receive the configurations from base-set configuration and uses the system storage to read or write any metrics and results.

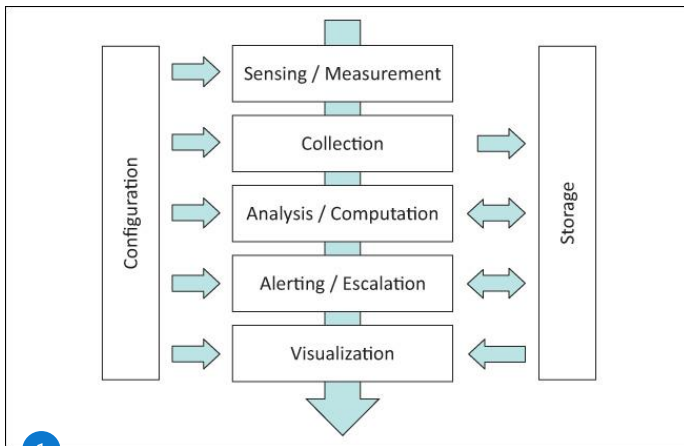


Fig. 1. The components of a monitoring system [13]

The measurement and sensing system gather the measurements data. The collection system then transports data to system storage. From there, the data will be analyzed to extract required information. The alerting and escalation process will communicate these conditions to others interested parties, while visualization systems display the data for human interpretation and analysis. Each of those components contain information about how to do its job base on configuration-set. How measurements or sensing system work can be categorized as whitebox or blackbox model, depend on how much the system is explored. Measurements can be used directly or synthesized, and it depend on whether each part is separately counted, or

totals are retrieved and averaged periodically. User can monitor the rate at specific operation happening or the capability of system for allowing that operation to happen. Systems may also consist of instrumented to provide gauges, such as percentage CPU utilization, or counters, such as the number of times that something has occurred.

C. Electrical Quantities

The current can be defined as the transfer of charge through a conductor. The total amount of charge passing through a random cross-section of a material per second is defined as ampere [14] and can be written as follows:

$$I = \frac{Q}{t} \text{ atau } Q = I.t \quad (2.1)$$

Where Q is the symbol of charge measured in the coulomb (C), I is the current in amperes (A) and t is the time in seconds (s). An electric current can also be defined as the charge through a point in an electrical circuit, written as:

$$i = \frac{dQ}{dt} \quad (2.2)$$

A constant electric current is known as a direct current or DC denoted by symbol I, while an electric current that changes with time is known as an alternating current or AC is represented by the symbol i or i (t). Voltage is defined as the energy required to move the electrical charge between two points [15] expressed as:

$$V = \frac{dw}{dq} \quad (2.3)$$

Where V is the symbol of the voltage measured in volts (V), and dw is the energy in joule (J). Further, the relationship between current and voltage by George Simon Ohm known by Ohm's law [16], can be expressed as:

$$I = \frac{V}{R} \text{ or } V = I.R \quad (2.4)$$

Where R is the symbol of the resistance in ohm (Ω).

The unit of power is expressed in watts, i.e. the amount of energy absorbed or sent within 1 second. can written as [14]:

$$P = \frac{dw}{dt} \quad (2.5)$$

Where p is the symbol of power measured in watts (W). Mathematically the relationship between power, current, and voltage is expressed as follows:

$$P = V.I \quad (2.6)$$

In alternating current power system, known three kinds of power, namely: apparent power or complex power is the result of multiplication of voltage phasor (V) and conjugate of electric current (I *). The unit of apparent power is expressed in Volt Ampere (VA). The active power or the real power of the Watt (W) unit, is the power fully absorbed by the resistive loads, while the reactive power of the Reactive Volt Ampere (VAR) unit is the power absorbed by the reactive (inductive and

capacitive) loads stored in the form Electric field and electric charge [17].

III. RESEARCH METHODOLOGY

The methodology in this research adopted from Design Science Research (DSR) framework, that introduced by Ken Peffers, on their paper A Design Science Research Methodology for Information Systems Research [18].

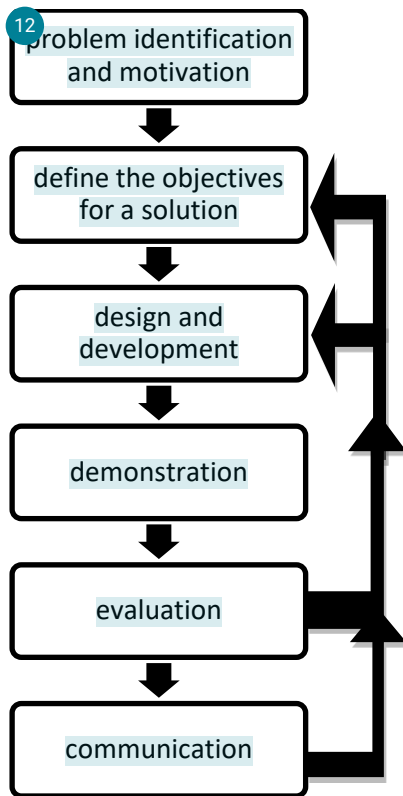


Fig 2. DSR Model [5]

DSR method model shown of Fig. 2, consist of 6 important activities that are; problem identification and motivation, define the objectives for a solution, design and development, demonstration, evaluation, and, last, communication.

There are iterations after defining problem and motivation. Iterations being done to achieve better solution based previous result.

IV. RESULT AND DISCUSSION

A. Activity 1: Problem identification and motivation.

Problem identification and motivation could be driven by various reasons such as new developments in industry, or in a reference discipline, or some important case that need to be discussed and explored by organization. Specific in this research, some interesting phenomenon identified in electricity usage consumption of H Building of Engineering Faculty Unila.

A detailed information of electricity usage could be used in decision-making for future organizational development.

B. Activity 2: Define the objectives for a solution.

Any possibility of objectives for solution to overcome the problem definition is presented. The objectives can be quantitative or qualitative. The objectives solution should strive to inferred rationally from the problem specification. Understanding problem, there's a need to develop an application accessible online to gather and gauge any information of power consumption on H building.

C. Activity 3: Design and development.

In this phase, some artifact is proposed, such as constructs, models, methods. The system based on solution offered, consists of 2 main part which are hardware and software;

1. Hardware Design

The hardware used in this online monitoring system is grouped by several subsystems those are; hardware for receiving input using sensor and data acquisition, hardware for data processing, and hardware for data communication needs.

- Hardware for Sensor and Data Acquisition

The sensor system hardware installed at 3-phase power distribution panel that consists of 3 unit voltage sensors, 3 unit current sensors, and a signal conditioning circuit. The voltage sensor used was a combination between a resistive voltage divider circuit and a voltage transformer, producing a voltage wave-form output that a same shape as the input. Current sensor used was a combination of YHDC SCT 013 which is a type of current transformer with a ratio of 100: 0.05 and a burden resistor with a value of 33Ω. YHDC SCT 013 produces the output of an electric current with the same wave-form as its input and can only measure alternating current (AC), therefore a burden resistor was used for the conversion of current to voltage values. The signal conditioner circuit used to add offset of the current sensor output signal and the voltage sensor was 0.5 times of the working voltage controller board. The signal conditioner used was a resistive voltage divisor circuit with a 2:1 ratio by a voltage source from the controller board, composed of two resistors with values of 470 kΩ each and a capacitor. In a signal conditioner circuit there are six resistive voltage divisors in charge of adding offsets to the six sensor outputs. The circuit of the sensor system hardware can be seen in Fig. 3.

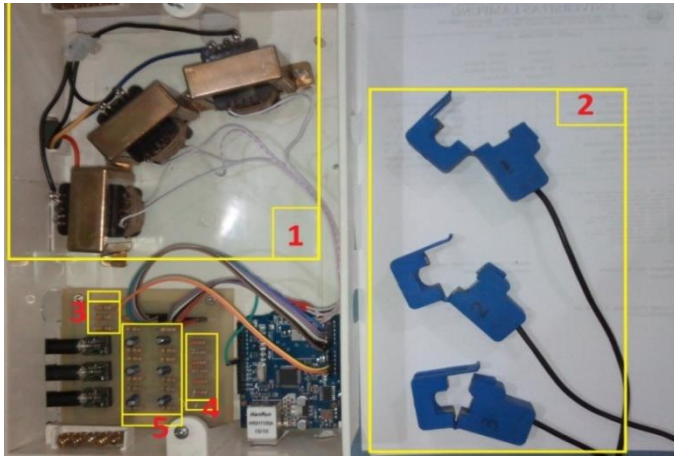


Fig. 3 Hardware component

1. Voltage transformer 220V:12V, 500 mA
2. Current sensors YHDC SCT 013
3. Resistor burden 33Ω
4. Voltage divider
5. Signal conditioner circuit

• *Hardware for Data Processing*

The data processing hardware consists of an Arduino Uno controller board on each power distribution panel, and a server computer at the data center. The data processing hardware reads the current sensor output data and the voltage sensor through the analog input pins as well as the arduino digital controller, process the data, identify by its property and value. And, last, readied the data to send via data communication.

• *Hardware for Data Communication Needs*

For data communication, HTTP protocol is preferred because it's port (80) is rarely being blocked across computer network and it also directly interface to the web server acting as the data server. Arduino Ethernet Shield used to access data communication via wired connection of Unila Intranet Local Area Network (LAN).

2. *Software Design*

There are several tools used to develop web application as a meaningful interface to see electricity usage consumption. The user experience (UX) must adhere to three aspects: functionality, accessibility, and reusability.

System designed as a client –server. Arduino act as the client which it's job is sending data to the web server via HTTP protocol and inserted it into database.

The server is web server which receive data using its database and provide web application to give meaningful information to the user. It is decided, because of the real time nature of energy consumption, a real time line graphic chart is used to communicate the data to the user.

To maintain every part of the system without causing much interference with other part it may interact with, an agnostic approach is advised. For received data from Arduino, a code is created which only interact with database and nothing else, written in PHP. And, web application is created using only

html, css, and javascript along with its necessary library to access a web service in JSON format. And web service interacting with database is created to provide JSON data to web application.

D. *Activity 4: Demonstration.*

In this demonstration activity, the use of the artifact to solve one or more instances of the problem. We made an experiment for data calibration and data retrieval.

1. *Hardware Testing on Laboratory*

Hardware testing experiment in this research including the linearity testing of voltage transformer (VT), and testing the linearity of current or current transformer (CT). Both types of transformers is very important because it deals directly with the quantity to be measured. The result of current measurement on the primary coil and the secondary coil of current transformer can be seen in table 1.

TABLE I. TRAF0 VOLTAGE MAEASUREMENT RESULT

No	Trafo R		Trafo S		Trafo T	
	Vp (volt)	Vs (volt)	Vp (volt)	Vs (volt)	Vp (volt)	Vs (volt)
1	60,2	3,367	60,3	3,367	60,6	3,378
2	80,8	4,46	80	4,4	80,4	4,41
3	100,2	5,56	100,2	5,53	100	5,51
4	120,1	6,66	120,4	6,66	120,5	6,65
5	140,6	7,8	140,4	7,77	140,4	7,77
6	160,1	8,9	160,5	8,89	160,5	8,89
7	180,3	10,03	180,5	10	180,4	10
8	200,7	11,16	200,8	11,14	200,2	11,09
9	220	12,24	220,4	12,21	220,5	12,23
10	240,4	13,36	239,9	13,28	240,4	13,32

From the measurement results in Table 1, it shown that the transformer has excellent linearity and it can be concluded that the voltage transformers are suitable for use as voltage sensors.

TABLE II. CURRENT MAEASUREMENT PRIMARY AND SECONDARY COIL OF TRAF

No	CT-R		CT-S		CT-T	
	Ip (A)	Is (A)	Ip (A)	Is (A)	Ip (A)	Is (A)
1	0,502	0,000181	0,502	0,000181	0,502	0,000182
2	1,001	0,000392	1,001	0,000392	1,001	0,000394
3	2,022	0,000904	2,022	0,000904	2,022	0,000909
4	3,007	0,001386	3,007	0,001386	3,007	0,001394
5	4,07	0,001928	4,07	0,001928	4,07	0,001939
6	5,03	0,00238	5,03	0,002349	5,03	0,002364
7	6,1	0,002892	6,1	0,002892	6,1	0,002909
8	7,06	0,003373	7,06	0,003373	7,06	0,003394
9	8,09	0,003886	8,09	0,003886	8,09	0,003909
10	9,17	0,004428	9,17	0,004428	9,17	0,004455

From the measurement results in Table 2, it is known that the transformer has excellent linearity and it can be concluded that the voltage transformers are suitable for use as current sensors.

TABLE III. RESULT OF VOLTAGE SYSTEM MEASUREMENT

No	V _{reff}	Measurement Result			deviation (%)		
		VR	VS	VT	VR	VS	VT
1	60,10	59,51	59,48	59,53	0,98169	1,03161	0,9484
2	80,20	79,75	79,81	79,69	0,56109	0,48628	0,63591
3	100,10	99,69	99,81	99,58	0,40959	0,28971	0,51948
4	120,10	119,81	119,63	119,54	0,24146	0,39134	0,46627
5	140,30	140,02	140,17	139,96	0,19957	0,09265	0,2423
6	160,20	159,96	160,04	159,88	0,14981	0,09987	0,1997
7	180,30	180,18	180,35	180,10	0,06655	0,0277	0,1109
8	200,10	199,95	200,09	199,92	0,07496	0,00499	0,0899
9	220,3	219,94	220,04	219,93	0,16341	0,11802	0,1679
10	240,4	239,72	239,70	239,67	0,28286	0,29118	0,3036

E. Activity 5: Evaluation.

Observation is being done on hardware, web application, and data. Every observation is evaluated to validate the expected result vs the aim of the research.

Hardware Testing on Distribution Panel

Information from table 2, shown the results of measurement accuracy of voltage has a maximum error percentage of 1.031614 %, which indicate the measuring device has a low percentage of error. So it can be concluded that the measurement device has a good accuracy.

TABLE IV. RESULT OF CURRENT SYSTEM MAEASUREMENT

No	I _{reff}	Measurement Result			Deviation (%)		
		IR	IS	IT	IR	IS	IT
1	2,16	2,22	2,11	2,11	2,777777	2,314814	2,314814
2	3,58	3,59	3,55	3,59	0,279329	0,837988	0,279329
3	5,27	5,24	5,19	5,29	0,569259	1,518026	0,379506
4	9,19	9,28	9,33	9,08	0,979325	1,523394	1,19695
5	27,06	26,93	26,62	26,61	0,480413	1,62601	1,662971
6	31,00	30,73	31,57	30,56	0,870967	1,838709	1,419354

From table 4 it can be seen that the current measurement results by our device, has a maximum error percentage of 2.777777778 %, which means the measuring device has a low percentage error current error. So it can be concluded that the measurement device has a good accuracy.

TABLE V. RESULT OF ACTIVE POWER MAEASUREMENT

No	P _{reff}	Measurement Result			Deviation (%)		
		PR	PS	PT	PR	PS	PT
1	1142	1082	1093	1203	5,253940	4,290718	5,34150
2	1826	1910	1824	1823	4,600219	0,109529	0,16429
3	2047	2059	2080	2016	0,586223	1,612115	1,51441
4	4260	4108	4144	4346	3,568075	2,723004	2,01877
5	5474	5373	5348	5534	1,84508	2,301790	1,09609
6	6088	5921	5981	6283	2,743101	1,757555	3,20302

In Table 5 shown the results of the accuracy test of active power measurement, it is seen that the measured active power value has a maximum error percentage of 5.34150613 %, which means the measuring device has a percentage of medium-level active power error measurement.

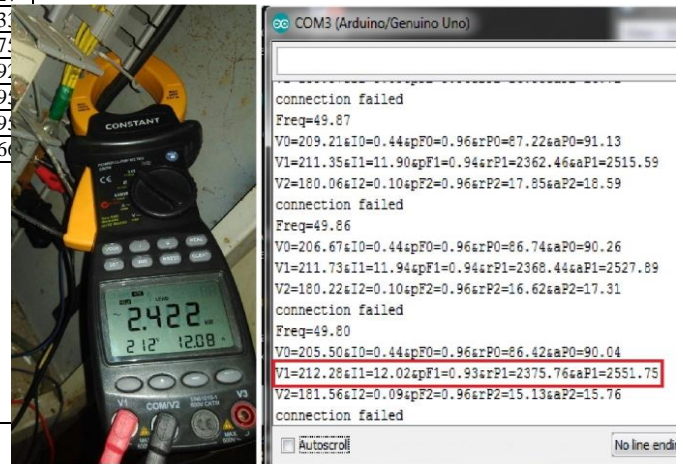


Fig 4. Hardware Testing on Distribution Panel

Fig. 4 shown, the testing activity for the accuracy of voltage measurement, current, active power, power factor. In the picture denote that there were a difference value between the measurement result conducted by device and clam meter. From the sample of voltage measurement result, found the average error value was 2.22% at phase R, 1.58 % at phase S, and 0.82% at phase T. For test results on current measurements got average error 2.31% at phase R, 1.20% at phase S, and 2.56% at phase T. For the accuracy of the measurement of active power the average error measurement was 2.58% at phase R, 1.63% at phase S, and 4.48% at phase T. Measurement of average power factor average error was 1, 79% at phase R, 0.52% at phase S, and 2.06% at phase T.

From the average error rate obtained on the measurement test, shown this monitoring device has percentage of measurement error was belonging of class of 1.5, 2.5 and 5 (IEC Standard No. 13B-2) [19]. This measuring instrument is feasible to be used for the measurement of the distribution panel with an average value of error less 5%.

2. Web-base Application Result



Fig 5. Web base application

Fig. 5 shown the appearance web page application of the electrical measurement when the measuring device is working, it provide graphical information in a real-time condition.

There are three line presented in every graphic chart which represented each phase from the three-phase. Every chart is live and shows information about voltage, current, power, kWh, and frequency.

7. Trend Results The Profile of Real Time Monitoring Electrical Quantities

Real time monitoring electrical quantities has been done in power distribution panel located at Building H Faculty of Engineering Unila. Data monitoring result saved in server. Data is processed using chart tool on Voltage, Current and Real Power to described the trend of electrical quantities as shown Fig 6.

From Fig 6, it can be seen the value of electrical quantities at distribution panels at this building was not balanced. This happen due the electrical load was unbalanced on each phase, other fact found that the trend of the value of electrical quantities has follows the trend of working hours. It can be seen that a considerable drop voltage was happened in the time span at 08.00 AM until 04.00 PM, Meanwhile at the same time, the value of current and power is increasing. This illustrates that the use of electrical energy is tends to during working hours.

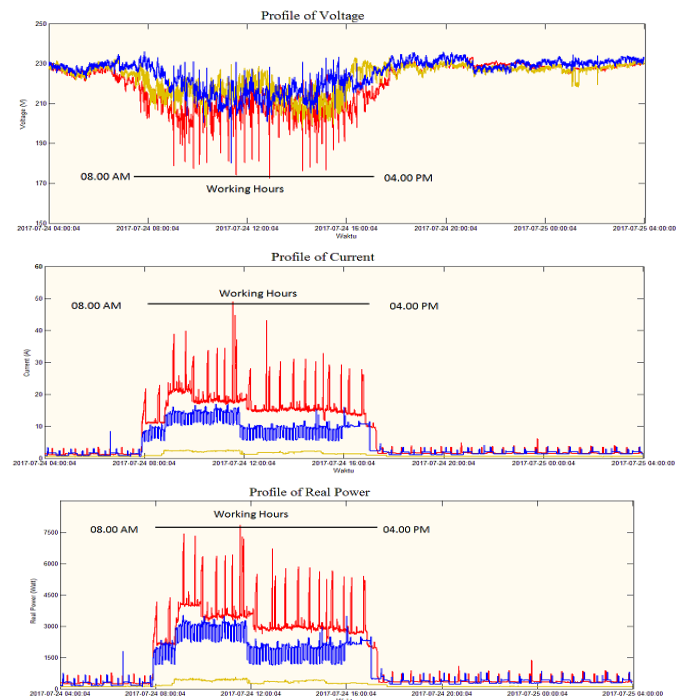


Fig 6. Profile of Real Time Monitoring Electrical Quantities

Overall evaluation for proposed design and implementation, yield a good result for a real-time electrical quantities information especially on H building of Engineering Faculty.

F. Activity 6. Communication

Last activity aim was to communicate the problem and its importance, disseminate to other researchers and other relevant audiences, such as practicing professionals, when appropriate. And we still continue this research and open the chance of any collaboration.

14. CONCLUSION

The result of this research is a real-time web application for monitoring the electrical quantities in graphical chart format meaningful to the user and can be accessed anytime and anywhere provided user have access device and connection. Software development tools used in this research are C, HTML, CSS, JS, JSON, and PHP. Based on data of electrical consumption usage, the amount of electricity at distribution panels in H Building Engineering Faculty of Unila is not balanced. This is due to the electrical load was uneven on each

phase. And, also, there's fact found that electricity usage trend still follows the working hours trend.

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