Smart Electrical Energy Monitoring System

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***Abstract*—Voltage constant are probably the most important part in power distribution's industry especially for domestic user such as hospitals, factories, airport other places that related with emergency cases including University. As known, University consists of many essential building that need constant voltage such as clinic , server room, building of dentistry and many more. In power system, there are many problems that we cannot obtain voltage that is in their range. In addition, unstable voltage are probably the most important power quality problem affecting industrial customers. In industry, customers are that are using sensitive equipment will definitely facing huge loss because of unstable voltage. Recently, power quality data are collected manually by chargeman using power quality meter. Chargeman need to install the power quality meter at distribution switchgear and get the data a week after. To mitigate this problem, an open source Energy Monitoring System was implemented. The main goal of this system is to provide a very simple, user friendly and reliable monitoring system that is capable of reading recent voltage, current and real power from any building electrical panel with database ability. The system is based on Arduino Uno boards for reading and processing the data (current and voltage) from the sensor and Arduino Ethernet Shield for sending the data to the database.**

Keywords: monitoring, database, Arduino, power quality

I. INTRODUCTION

In worldwide industry, customers that are using sensitive equipment will definitely facing huge loss because of unstable voltage. The equipment can be damaged if unstable voltage always occurred. Generally, unstable voltage are caused by fault in distribution and transmission system. The performance of unstable can be estimated by determining the area that easy to get this voltage sag happened. The area that easy to having this voltage sag are similar to the region of the network that includes buses and lines where the occurrence of faults will lead to voltages lower than the sensitivity threshold of a load.

It is essential to control and organized the behavior of power quality intended to reduce unstable voltage occurrences and getting a better environment. Getting the objective come true is not an easy way, chargeman need to have detail record of power behavior frequently. Chargeman should enable to monitor their energy consumption by implementing an Energy Monitoring System with database ability.

Existing power quality meter such as Fluke meter can be used to measure, record all the data or voltage all over the day and also displaying waveform. The deficiency of these meter are it have to be install at the switchgear for a week or month to get the data. The chargeman have to wait within that duration to get the recorded data after uninstalling the meter. The problem is, it take to much time to take an action on the power quality behavior which can lead to disturbance on unstable voltage or other power quality issues.

The data should instantaneously been monitor to make the power quality engineer analyze and take an instant action to mitigate the issues. By doing that, it can reduce the disturbance and keep sensitive equipment damage because of power quality issues.

The main objective of this project is to develop a hardware system that can measure power, voltage, power factor and current with database ability using Arduino and webserver. This project also offer a cheaper and reliable technology that can measure and record the data instantaneously.

II. BASIC THEORY

A. Power Quality

IEEE 100 Authoritative Dictionary of IEEE Standard Terms have defined that power quality is a concept of grounding and powering an electronics equipment in a condition such that appropriate to the process of equipment and suit with the building wiring system and extra connected equipment. Power utilities always describe power quality as reliability [1]. Power quality determines the fitness of electric power to consumer devices. It is defined as "the availability of pure voltage sinusoidal waveform at delivery point". A good distribution system should be able to convey fit quality supply power to the end users.

Recently, a survey from Power Quality specialist signify that 50 percent of every Power Quality crisis are associated with neutral, grounding, ground voltages, ground current and any other grounding related issues. Equipment that operated or associated electrically are affected by Power Quality [2][3][4][5][6][7]. The commonly Power Quality problem occurs are Voltage sags, Voltage swell, low power factor and others.

Nowadays, new equipment especially related to power electronic device, such as variable speed drives and switched mode power supplies are more sensitive to power quality variations. Electricity that distributed to costumer should be in stable form to avoid these equipment malfunction. Power quality researcher need a reliable meter to instantaneously detect and mitigate the problems.

B. Power Quality Meter

Power quality meter is a device that can be used to measure, record all the data or voltage all over the day and also displaying waveform. Its help power quality engineer to analyze and get use the data obtained by the meter.

There are various type of power quality meter that used to determine the behavior of electricity. The meter are selected by determine what type of data that want to analyze. Power quality meter are selected to measure parameters such as the voltage, current, peak demand, energy usage, harmonics and others related parameter. One of the meter that commonly use for power quality issues is 'Fluke 437'. The meter have the ability to measure, logging capture, view and examine several categories of power quality issues.

Figure 1 : Fluke 437 power quality meter

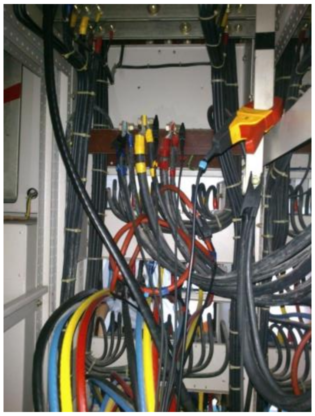


Figure 2 : Installation of Fluke 437

III. METHODOLOGY

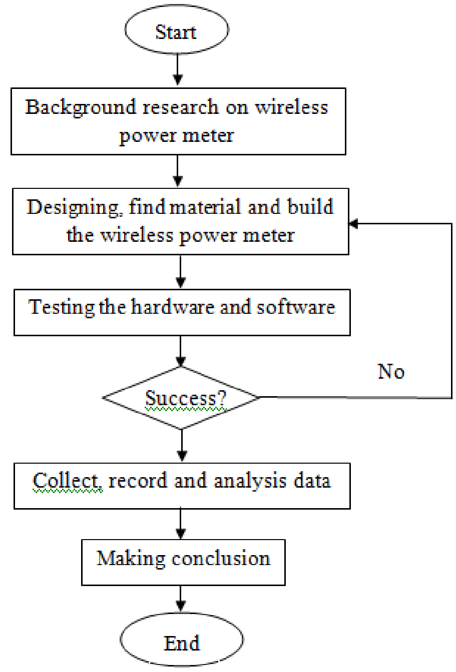


Figure 3 : Flow Chart of Energy Monitoring System

A. Hardware Design

There are three parts of hardware used in this system. The parts are the processor, sensors and wireless board. For the processor, "Arduino Uno" Revision 3 which is a standalone Arduino Duemilanove development board are used.

Figure 4 : Arduino Uno

The sensor capture hardware consists of Non-invasive current sensor connected to the analog to digital converter (ADC) of the input of Arduino. For measuring voltage, AC to AC power adaptor are used for safety measurement of voltage due to the transformer in the adapter provides isolation between the high and low AC voltage.

Figure 5 : Non-invasive current sensor

To interface current and voltage sensor, the supply voltage and current must be not exceed the analog Arduino capability. For non invasive current sensor, the device have its build in burden resistor. To calibrate the sensor with Ardunio, calculation below have to be consider.

Typical table of technical parameters:

input current	output voltage	non-linearity	build-in sampling resistance (R_L)
0-30A	0-1V	±1%	62Ω
turn ratio	resistance grade	work temperature	dielectric strength(between shell and output)
1800:1	Grade B	-25℃~+70℃	1500V AC/1min 5mA

Figure 6 : Non-invasive current sensor datasheet

Current Const= Ratio/BurdenResistor1800/62 = 29

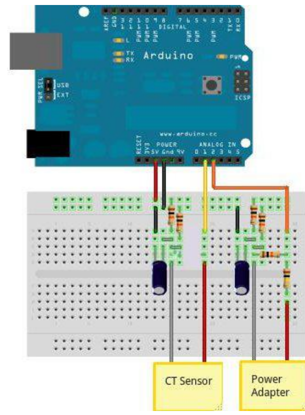


Figure 7 : Interfacing voltage and current sensor

For measuring supply voltage, voltage divider need to implement to reduce incoming voltage that going into Arduino analog pin. In this project, a 9V (RMS) AC voltage adapter are used with 12.7V peak to peak voltage. If the Arduino is running at 5V the resultant waveform of the circuit has a positive peak of 2.5V + 1.15V = 3.65V and negative peak of 1.35V satisfying the Arduino analog input voltage requirements and leaving plenty of room so that there is no risk of over or under voltage.

Peak-voltage-output = R1 / (R1 + R2) x peak-voltage-input

= 10k / (10k + 100k) x 12.7V = 1.15V

Ethernet shield are used to make connection between Arduino Uno board and the database. To create a database, phpMyAdmin which is a free and open source tool written in PHP intended to handle the administration of MySQL with the use of a web browser are used.

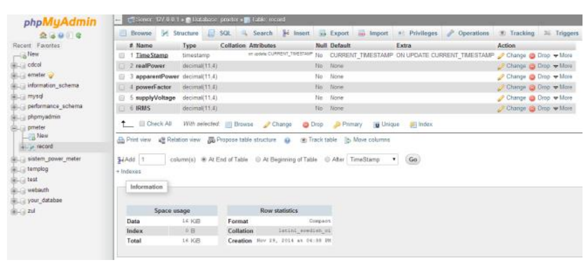


Figure 8: phpMyAdmin

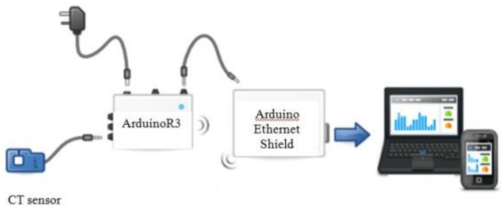
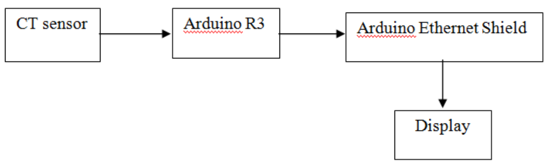


Figure 9: System Overview

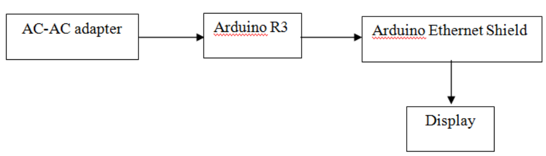
Block diagram

a) Measure current



Non invasive current sensor (CT sensor) will sense the current flow in the circuit. Arduino R3 will convert analog input from CT sensor to digital and process the data. The data will be send to the Arduino Ethernet shield and connected to the database server. The data then can be display to the computer for analysis.

b. Measure voltage



AC-AC adapter will convert incoming voltage 230V to 9V input of Arduino. Arduino R3 will convert analog input from CT sensor to digital and process the data. The data will be send to the Arduino

V. RESULTS AND DISCUSSION

The results of this project are it can displays, current, voltage real power, apparent power and power factor (for sinusoidal waveform). Then the data will be send to the database from the ' Energy Ethernet shield and connected to the database server. The data then can be display to the computer for analysis.

Monitoring System' using transmitter and receiver. The data can be access using smart phone (android application) and personal computer via the internet.

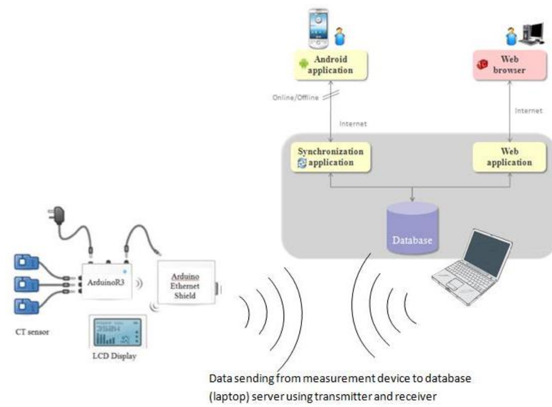


Figure 10 : Energy Monitoring System

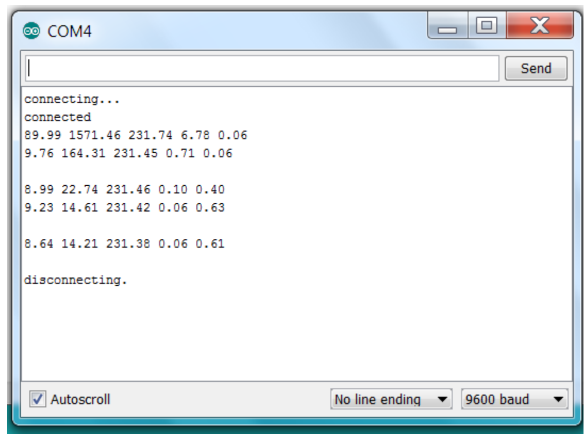


Figure 11 : Arduino Serial Print

Arduino Serial Print display the data from voltage and current sensor. Based from the sensors that attached to the Arduino analog port, Serial Prints record data to the serial port as human-readable ASCII text. Current through the load is measured using split core current transformers. This data is then transmitted through the home's wireless router using Arduino Ethernet shield. The router send the data to the phpMyAdmin database and is represented visually to the user by using web browser.

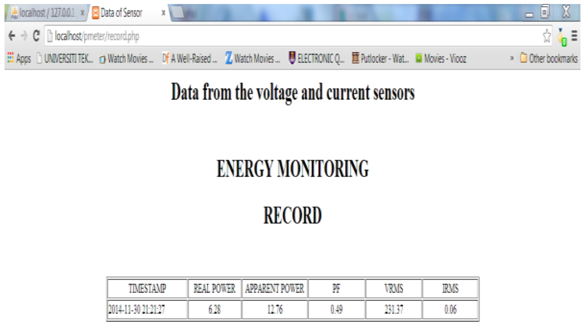


Figure 12 : Energy Monitoring Record web browser

In order to make the data give a detail information, the data have to be frequent. In this sample, the duration of data are taken by delay it at 5 second for construct power quality analysis to be more reliable and accurate.

Table 1 : Data of 50 sample analysis

Date	Time	Real Power	Apparent Power	Voltage	Current	Power Factor
12/3/2014	3:44:45	10.83	15.16	230.55	0.07	0.71
12/3/2014	3:44:51	11.49	15.39	231.6	0.07	0.75
12/3/2014	3:44:56	10.76	15.22	230.51	0.07	0.71
12/3/2014	3:45:01	10.89	15.19	230.51	0.07	0.72
12/3/2014	3:45:07	11.7	15.35	230.52	0.07	0.76
12/3/2014	3:45:12	10.95	15.17	230.57	0.07	0.72
12/3/2014	3:45:17	11.13	15.26	230.55	0.07	0.73
12/3/2014	3:45:22	11.15	15.19	230.54	0.07	0.73
12/3/2014	3:45:28	11.18	15.3	230.5	0.07	0.73
12/3/2014	3:45:33	11.15	15.29	230.68	0.07	0.73
12/3/2014	3:45:38	10.81	15.24	230.54	0.07	0.71
12/3/2014	3:45:44	11.08	15.31	230.54	0.07	0.72
12/3/2014	3:45:49	10.59	15.08	230.51	0.07	0.7
12/3/2014	3:45:54	10.29	15.08	230.55	0.07	0.68
12/3/2014	3:46:00	10.72	15.08	230.42	0.07	0.71
12/3/2014	3:46:05	10.77	15.04	230.51	0.07	0.72
12/3/2014	3:46:10	10.75	15.09	230.4	0.07	0.71
12/3/2014	3:46:16	11.34	15.26	230.53	0.07	0.74
12/3/2014	3:46:21	11.07	15.25	230.51	0.07	0.73
12/3/2014	3:46:26	11.34	15.24	230.47	0.07	0.74
12/3/2014	3:46:32	10.29	14.89	230.51	0.06	0.69
12/3/2014	3:46:37	9.91	15.05	230.57	0.07	0.66
12/3/2014	3:46:42	11.15	15.21	230.54	0.07	0.73
12/3/2014	3:46:48	10.54	15.06	230.55	0.07	0.7
12/3/2014	3:46:53	11.34	15.33	230.51	0.07	0.74
12/3/2014	3:46:58	11.05	15.21	230.65	0.07	0.73
12/3/2014	3:47:04	10.12	14.96	230.46	0.06	0.68
12/3/2014	3:47:09	10.69	15.09	230.47	0.07	0.71
12/3/2014	3:47:14	10.9	15.12	230.53	0.07	0.72
12/3/2014	3:47:19	10.54	15.01	230.57	0.07	0.7
12/3/2014	3:47:25	10.28	15.03	230.47	0.07	0.68
12/3/2014	3:47:30	11.26	15.14	230.6	0.07	0.74
12/3/2014	3:47:35	10.21	14.95	230.42	0.06	0.68
12/3/2014	3:47:41	10.49	15.06	230.46	0.07	0.7
12/3/2014	3:47:46	11.66	15.28	230.56	0.07	0.76
12/3/2014	3:47:51	10.33	15.05	230.34	0.07	0.69
12/3/2014	3:47:57	10.83	15.11	230.45	0.07	0.72
12/3/2014	3:48:02	10.2	14.91	230.45	0.06	0.68
12/3/2014	3:48:07	9.19	14.45	230.55	0.06	0.64
12/3/2014	3:48:13	9.83	14.85	230.47	0.06	0.66
12/3/2014	3:48:18	7.38	13.25	230.45	0.06	0.56
12/3/2014	3:48:23	10.77	15.06	230.54	0.07	0.72
12/3/2014	3:48:29	10.81	14.91	230.41	0.06	0.73
12/3/2014	3:48:34	6.9	13.06	230.4	0.06	0.53
12/3/2014	3:48:39	6.07	12.32	230.55	0.05	0.49
12/3/2014	3:48:44	10.01	14.81	230.62	0.06	0.68
12/3/2014	3:48:50	9.42	14.61	230.54	0.06	0.64
12/3/2014	3:48:55	10.19	14.84	230.55	0.06	0.69
12/3/2014	3:49:00	9.33	14.43	230.29	0.06	0.65
12/3/2014	3:49:06	9.8	14.65	230.49	0.06	0.67

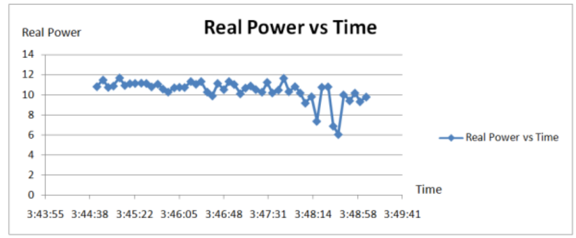


Figure 13 : Real power vs time graph

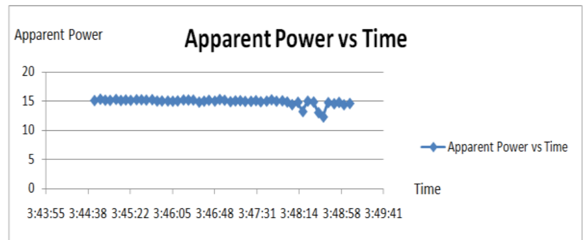


Figure 14 : Apparent power vs time graph

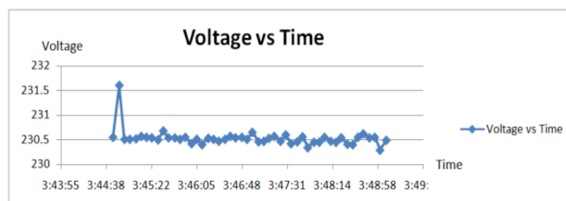


Figure 15 : Voltage vs time graph

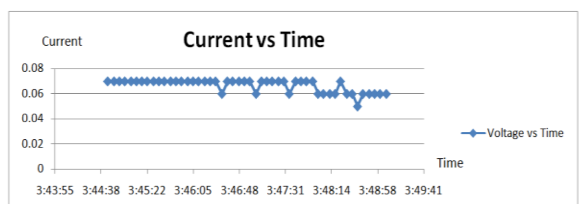


Figure 16 : Current vs time graph

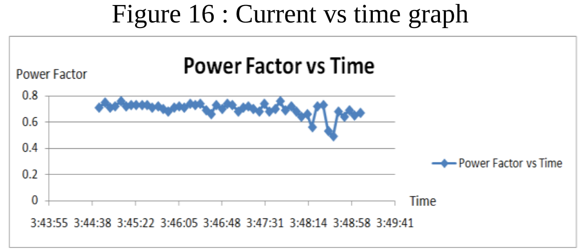


Figure 1 : Power Factor vs time graph

VI. CONCLUSION

Based on the system that have been implemented, its show that the system have achieve the objective which is to develop a hardware system that can measure power, voltage and current with database ability using Arduino. It can be concluded that the need of this Energy Monitoring System is to give awareness and help the electric consumer to reduce electricity consumption. This method provides the domestic power consumption accurately, safely, and with a relatively fast update rate, thus helping the user optimize and reduce their power usage.

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