Development of a System for Monitoring the Parameters Determining the Quality of Electric Power and Power Consumption within Consumer Premises

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Abstract - Many researchers have studied power quality measurements and monitoring. Power quality has always been important as it is equated to reliability - undisturbed operation or functionality of electrical systems in customer facilities. This study reports on the development of a system for measuring and monitoring the parameters characterizing the quality of electrical power used in facilities within consumer premises. The determining of quality parameters such normal voltage operating range, current, power factor, apparent power, reactive power and the real power. Also the study includes the computation of total power and power consumption at specific date and time. The raw data of these parameters are process and log in real time. It can be access remotely via the internet or mobile application through SMS. The system employed the developed software for remote accessing and data base using Visual Basic programming and MySQL. Testing revealed the developed system to be reliable and appropriate for operation related to monitoring electrical power in the customer premises. Monitoring of the power used in customer facility can be a possible ground in initiating correcting measures in order to minimize power consumption. The study can be further improved by including parameters such as waveform distortion, frequency and voltage flickers to comply with all the specifications demanded for such systems by national norms and regulations.

Keywords- Power Quality; Power Factor; Apparent Power; True Power; Reactive Power; Power Consumption

I. INTRODUCTION

Power is define as the flow of energy and the current demanded by a load. While power quality is a description of a power supply that is free of disturbance, it also determines the suitability of electrical power to consumer devices. The term is also used to describe electric power that drives an electrical load and the load's ability to function properly. Without the suitable power, an electrical load may malfunction, fail prematurely or not operate at all [1]. While power quality is a convenient term, it is the quality of the voltage rather than power or electric current that is actually defined by the term.

As mentioned, a power supply that is free of disturbance is of good quality. Electrical disturbances occur at everything from planned to unplanned events on the power and transmission network. Examples of causes of power quality problems are; connections in the power and transmission network, connection and disconnection of electrical loads, lightning strikes, disturbing electrical apparatus, weak power and transmission networks, etc. When these electrical disturbances occur, the electrical system may fail to meet its purpose – that is to support proper operation of the loads.

Industry, commerce, health care services, academic institutions, banks and other service providers are extremely dependent upon electrical and electronic systems. These systems influence power quality themselves in many ways, but they react sensitively to any disturbance as well. Many power quality problems are easily identified once a good description of the problems is obtained. Unfortunately, the tensions caused by power problems often result in vague or overly dramatic descriptions of the problem. When power problems happen, the exact time of the occurrence should be noted, its effect on electrical and electronic equipment, and any recently installed equipment that could have introduced problems to the system. Also, the causes of poor power quality should be pinpointed and the elimination of faults should be implemented through the use of suitable measuring equipment.

The quality of power delivered to the load can be determine by monitoring the following parameters; voltage variations, voltage sage, voltage swells, transients, flicker, unbalance, harmonics, frequency, efficiency, etc [2]. There are a lot of instruments that measures and monitoring either some or all of these parameters that are available in the market now a days. A challenge of developing a system that will monitor some if not all of these parameters, log and save it in a database which can be remotely accessed through internet is taken into account. The system will log the data of the power parameters in real-time and the power consumption, which can be access remotely either through internet or SMS. This monitoring system will measure and monitor electrical systems 24 hours a day under any possible conditions.

II. MATERIALS AND METHODS

The goal of this study is to design, develop and implement a system that will monitor and log in real-time parameters such as voltage, current, power factor, apparent power, reactive power, real power and total power. It also monitors power consumption of electrical and electronic devices in a building at specific range of time. The monitoring device can monitor a building with an up to three phase power line not exceeding 300 A each line. It operates at the standard voltage and frequency i.e. 220V and 60Hz respectively provided by the electric power company. The device must be located near the power panel and tapped to the main line of the building to be monitored as shown in figure 1.

Fig. 1. Actual Set-up

The device which corresponds to a three AC power analyzer that compensate to the three phase line of the building. The three current transformers were clamped correspondingly to the three power lines; and the three pairs of alligator clips are attached to the lines in three watt-meter configuration to get a standard supply 220Vac which is needed for the analyzer to operate. The analyzers will output the six power parameters to the micro-controller; and the microcontroller will be interfaced to the server with the develop software to visually interpret the data. Figure 2, shows the circuit diagram of the power analyzer. It is connected to the Arduino microcontroller and Ethernet shield.

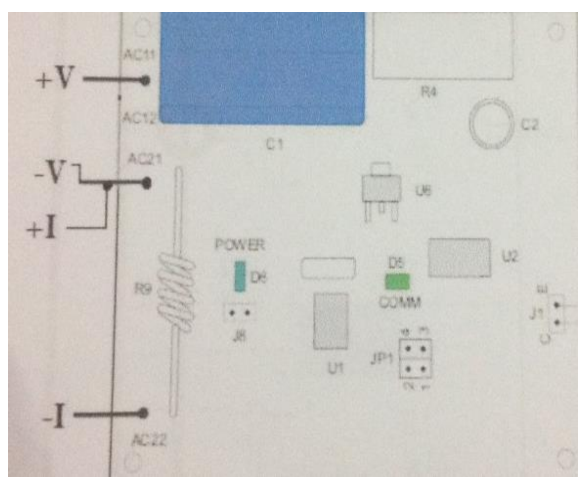

Fig. 2. Power Analyzer Circuit Diagram

The Ethernet shield allows the Arduino microcontroller to connect to the internet. There is an onboard micro-SD card slot, which can be used to store files for serving over the network. The server must have enough RAM and a fast processor to ensure no lag during transmission of data from the device. It must also have a data logger application installed where the data from the device are received before it is saved on the database.

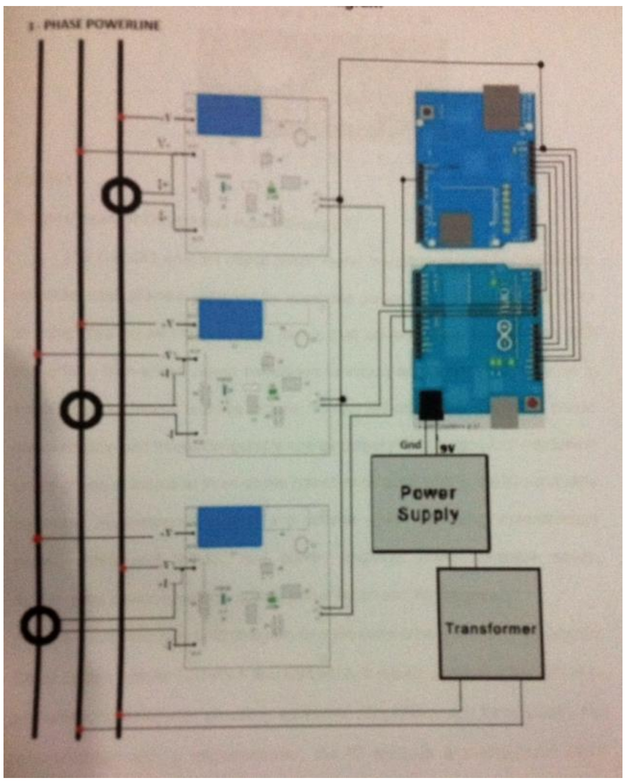

Fig. 3. Connection Schematic Diagram

The schematic diagram of the system set-up is shown in fig.3. The set-up is connected to a PC for a real time monitoring. The real-time monitoring can also be accessed remotely through internet and SMS. The remote PC has installed power quality monitoring application for internet access while a GSM modem is connected to the server for the SMS inquiry. The reply for SMS inquiry is composed of instantaneous power quality parameters such as the voltage, current, power factor, apparent power, reactive power and real power of the specific power line of the building. Inquiring of total power consumption is a day to day basis.

In the computation of total power and power consumption, the study is anchored on the following theory;

a. Calculation of the total power.

$$P_{total} = \frac{2}{3}(P_A + P_B + P_C)$$

Where:

P_A, P_B & P_C average power of each phase.

P_{total} total power of the summation of the three power lines

b. Power consumption

$$P_{consume} = \left(\frac{2}{3}(P_A + P_B + P_C) * \frac{sampling\ time}{3600}\right)$$

Where:

$sampling\ time$ is the time set of sending data.

III. RESULTS

An experimental data has been gathered to determine the system functionality. The result presented is for one school day only.

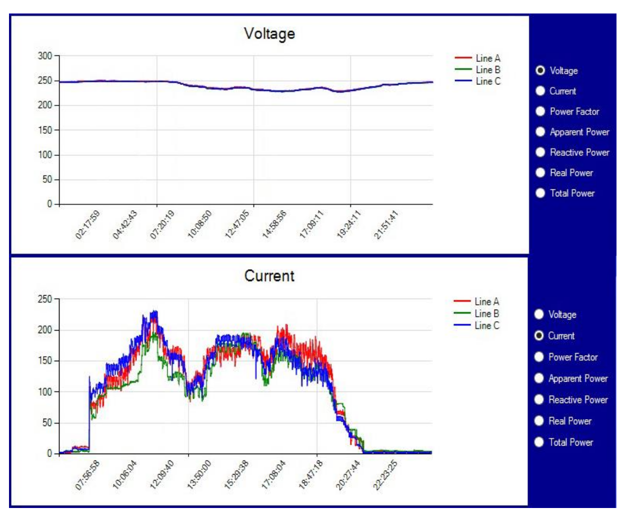

Fig. 4. Voltage and Current Reading

As shown in fig. 4, the voltages vary from 210V to 250 V for the three lines. It is considered normal and stable with a slight drop during peak hours where there are many loads. On the current data, it showed maximum current reading of 150 to 280 A between 8:00 a.m. to 11:00 a.m. in the morning and 2:00 p.m to 5 p.m in the afternoon. The peak reading was at approximately 10:00 a.m. In this hour electronics and electrical loads such as computers, air-conditioners, and other electrical appliances are functioning. During lunch break, it gradually decreases, this was due to the fact that other loads are shut or not used. While after office hours from 5pm-9pm the current slowly decreases, and beyond this time the current reading dropped at minimum range. The load of the building at this time is minimal which is electrical lighting only.

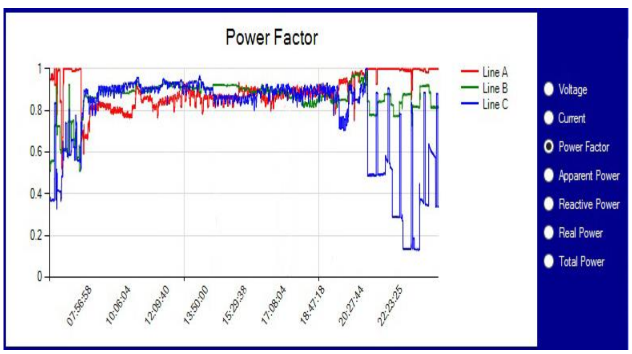

Fig. 5. Power Factor Reading

Power factor is an important aspect to consider in an AC circuits, because any power factor less than 1 means that the circuit's wiring has to carry more current than what would be necessary with zero reactance in the circuit to deliver the same amount of (true) power to the resistive load. The poor power factor makes for an inefficient power delivery system. Standard quantity of power factor acceptable to be normal is 0.8 or 80%; any amount below it needs to have some corrective measures.

Ideally, the power factor of a 3 – phase power line should be equal for all the phases for it to be balanced. If not, there would be losses. Since in actual situation, balancing the loads of the 3 lines is not possible, it is a need to have the loads an amount not far from each other to minimize energy losses.

Fig.5 showed that line C, give a very low power factor. The lowest value was less than 0.2 that occurs between 9:00 to 10:00 p.m.

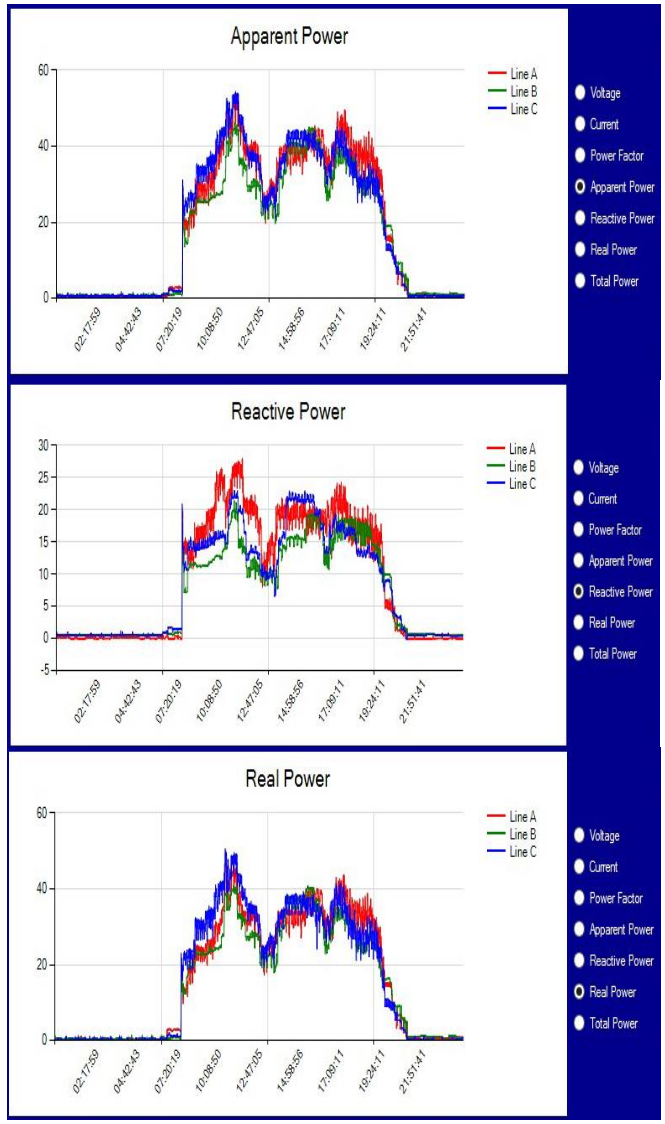

Fig. 6. Apparent Power, Reactive Power and Real Power Reading

The relationship of between Apparent Power, Reactive Power, Real Power, & Power Factor were shown through the graphs of Figure 5 & 6 were shown. Most of the time, the difference between Apparent Power and Real Power is quite big so the power factor is far from unity.

Fig. 7. Total Power

Figure 7, is the total power which is two-thirds of the summation of power from the three power lines. Maximum total power is measured at around 10:00 a.m. to 11:00 a.m. Peak loading was at this time where current was high as shown in fig. 4. The total power corresponds to the power consumption of the entire building. The building used for testing is the ICT building of MUST where server for IT system, computers, air-conditioning devices, lights, etc, are installed.

Fig. 8. GUI for Power Consumption Calculation

Visual Basic.Net is the programming language in data logger. The data logger includes the graphical user interface (GUI) of the system. The GUI showed the power consumed at specific day and time, the building being monitored and the devices in that building. Part of system is the design of the data base. MySQL is used in the design. The data base includes the logged data of the parameters being monitored, the date and time. Also for easy monitoring, these data can be accessed remotely either through internet or cellular radio using SMS as shown in fig. 9.

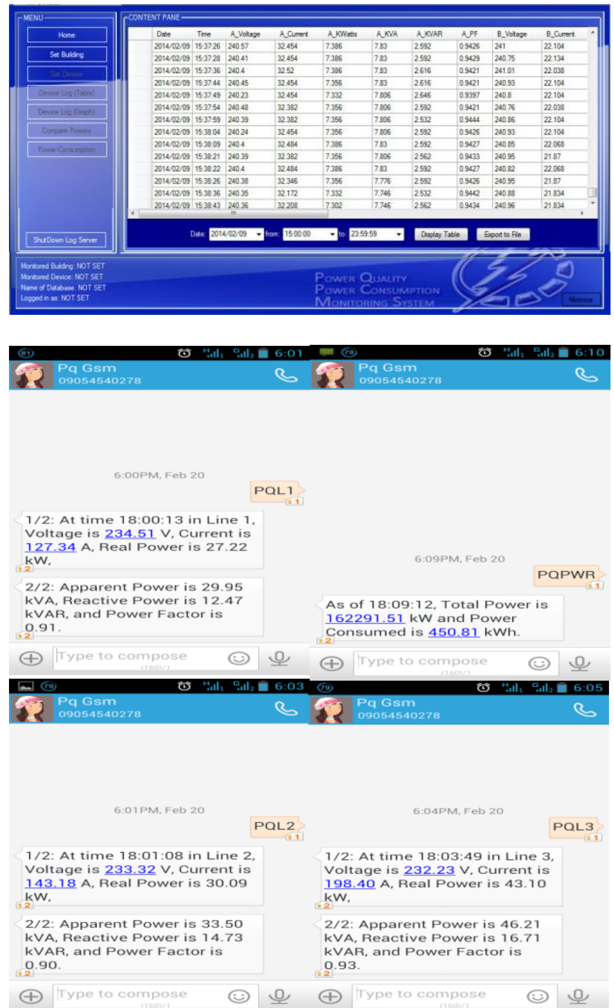

Fig. 9. Graphical User Interface for Remote Accessing via Internet or SMS

Top table of fig. 9 is the GUI for the internet remote accessing. Table showed the monitored parameters in real time. While the bottom showed the monitored application in SMS application. These data showed that the software developed was functional. The data can be accessed either through internet or SMS.

IV. CONCLUSION

The study attempted to develop a power quality monitoring system that can be access remotely. The result showed the power quality parameters in Information Communication Technology (ICT) building of Mindanao University of Science and Technology. The voltage is constant for the times when no one is using the building specifically on non-class hours. It becomes below 220 V during class hours. The current, same with the apparent power, reactive power, real power and total power rises during class hours, lowers on lunch breaks and after 6 o'clock in the evening. The power factor during non-class hours vary in every line and during class hours, it is near to unity. Also, the study has developed application software that process the raw data extracted from the main power line. The study can be improved by including the parameters such as waveform distortion, frequency and voltage flickers to comply with all the specifications demanded for such systems by national norms and regulations.

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