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GUI BASED ENERGY SAVING CONTROLLER FOR LIGHTING AND AIR-CONDITIONING APPLICATION IN LECTURE HALL VIA POWER LINE COMMUNICATION MODULE

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ABSTRACT

This paper presents a system that can control electricity for lighting and air-conditioning using power line communication (PLC) module. The control system is developed based on a case study done in UMP lecture hall. The case study has shown that numerous air-conditioner and lighting have been left on without any occupant. Thus, better control strategies are needed to reduce energy wastage. This paper will concentrate on development of Graphical User Interface (GUI) based energy saving controller and analysis of PLC module's performance for the system. Conceptually, the PLC module is used for communication between GUI to the controller. The GUI-based electricity control system is programmed as a zero-crossing switching device for the lighting and air-conditioning system. Once the GUI is connected to the PLC module over existing power cables, the GUI is able to activate and deactivate the lighting and air-conditioning remotely. It is expected that by using this software, the users can simply control the lighting and air-conditioning manually or remotely via computer. The performance of PLC is reliably enough to transfer the data with high accuracy. The system has been built and tested at wiring bay and will be install in UMP lecture room for further analysis in energy saving application in UMP lecture room. For market potential, the control system can also be used in domestics, industrial and office building.

Keywords: graphical user interface, power line communication module, microcontrollers, energy efficiency.

INTRODUCTION

Energy wasting occurrences in the campus are significant, especially in the air-conditioning and lighting system. Preliminary research on UMP buildings has shown that excessive usage of lighting and air conditioning systems are mostly due to the human factors. Lecture halls are left with lights and air-conditioning ON when they should be switched OFF. This fact has been proven from the data collections and survey that was carried out in UMP's lecture room (DK13). For the purpose of the research, a three phase data logger (Elite Pro power meter) was installed at DK13 for data collection to study the consumption and wastage of energy in the room. We found that the electrical equipment such as air-conditioning and lighting system were always left ON with no occupants. These lead to energy inefficient and energy wasting [1] – [6].

The energy wasting due to air-conditioning left ON with no occupants which lead to high energy consumption can be seen in Figure-1. The data in Figure 1 shows that energy wasting will contribute to high energy consumption occurred in DK13 lecture room. A major energy saving can be obtained if the air-conditioning and lighting systems can be made more energy efficient through better control.

With assistant from Jabatan Elektrik, Pusat Pembangunan dan Pengurusan Harta, PPH, some approaches have been developed in solving energy wasting occurrences in UMP lecture rooms. The basic concept to overcome the problem was by using the timer control. The timer controls are located at every distribution board (DB) of lecture hall and laboratory as shown in Figure-2. The significant effect of energy saving by using timer control was analyzed and it was proved that by pre-setting the timer control it could reduce the energy wasting approximately 4% per year. The return investment was about 3.2 years. There was also no maintenance required for the timer control [3].

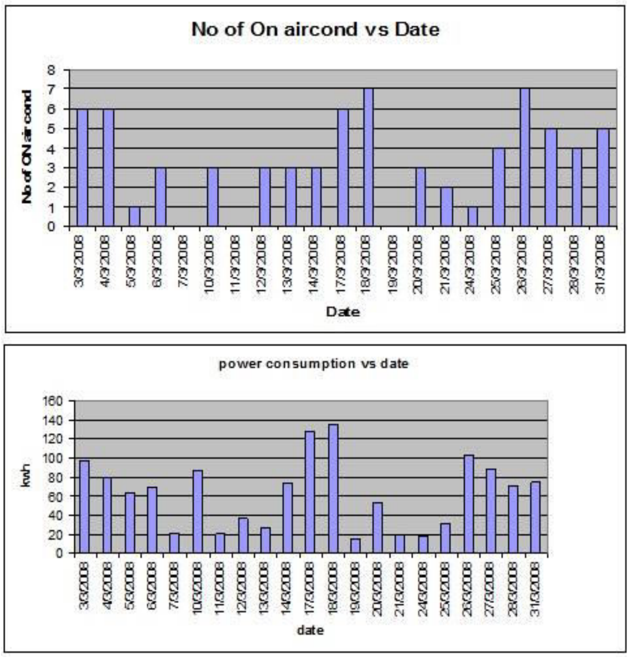

Figure-1. Case study of energy wasting occurrences in DK13 lecture room which contribute to high energy consumption [1]-[2].

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Figure-2. Timer control installation at lecture room distribution board.

However, we found that energy wasting still occur in the lecture room after timer control system installation. This is due to the timer control system had been set to automatically switch-off air-conditioners and lighting after 11pm at night. The energy wasting was still occurred between 8.00am to 11pm since the energy usage was not controlled by the timer during that time. To overcome this problem, sensor based energy saving controller for air-conditioning and lighting system has been developed by N. Md. Saad *et al* [2]. The block diagram of the system is depicted in Figure -3.

The installation of sensor based energy saving control system was done at BK13 which can be seen in Figure-4 with maximum capacity of about 30 occupants (students).

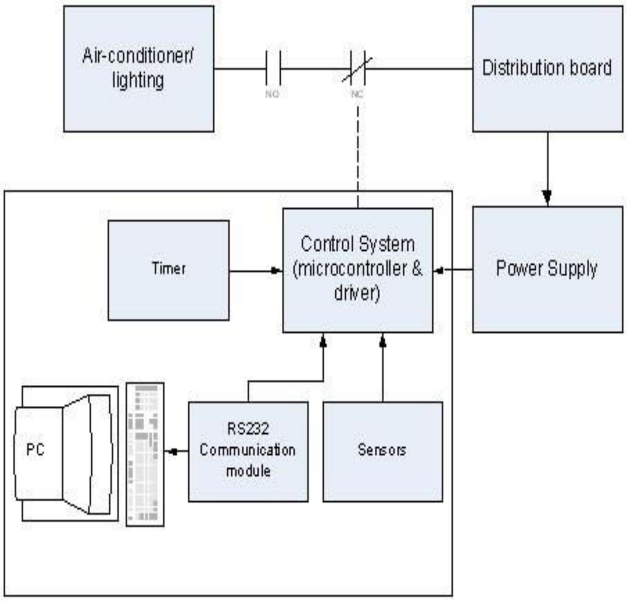

Figure-3. Sensor based energy saving control system [2].

Figure-4. Installation of sensor based control system at lecture room sub-switch board.

Figure-5 shows the data of energy consumption in BK13. The data was collected within five working days' time frame during semester session for both conditions; with and without the control system. From the graph, it shows that power saving at BK13 after installation of the sensor based control system is about 35%. The simple payback period of the control system was 0.9953 years for small classroom. The payback period will reduce for application in large area [2].

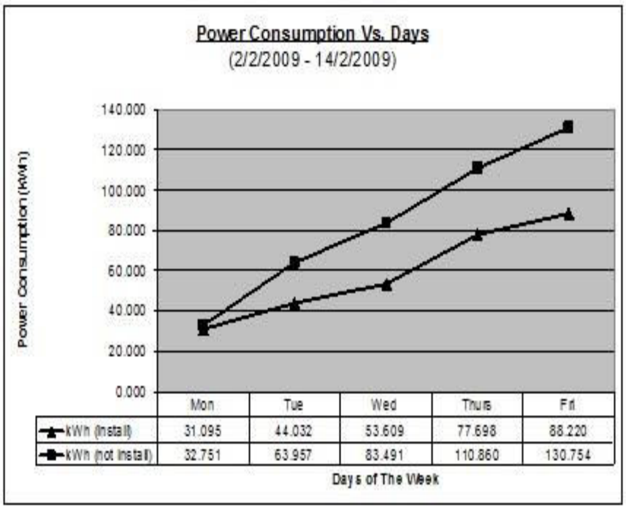

Figure-5. Power consumption at BK13 with and without controller.

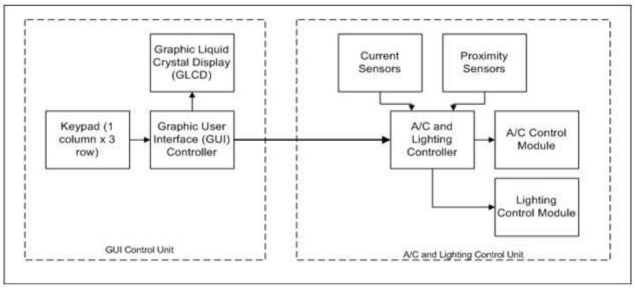

Figure-6. System block diagram.

In 2009, M. F. Abas *et al* has built the prototype of energy saving control system with GUI embedded in Graphic LCD. The control system has been developed with the following characteristics:

- User can operate the lighting and air conditioner via GUI embedded in graphic LCD and / or via common switches.
- The controller is able to source or sink a maximum current of 8A.
- Include PIR sensor to detect human presence. If there is none after a predefined time then the lighting and air conditioner will be automatically switch off for energy saving and can only be manually switch on.
- Three adjustable preset times is available to allow the controller to turn off the air-conditioners and lighting system.
- A security password for setting preset time.

Conceptually, the control system was design with internal timer and sensor to automatically switched off the power supply of air-conditioner and lighting units at three predefined time, or when the sensor detect no user in the room. The air-conditioners and lighting system need to be manually switched on if the room is in use again. The GUI based controller was designed for setting and switching of the control system. The setting of internal timer can be changed in GUI setting menu via a password. The block diagram and prototype of the system can be seen in Figure-6 and Figure-7 respectively [4].

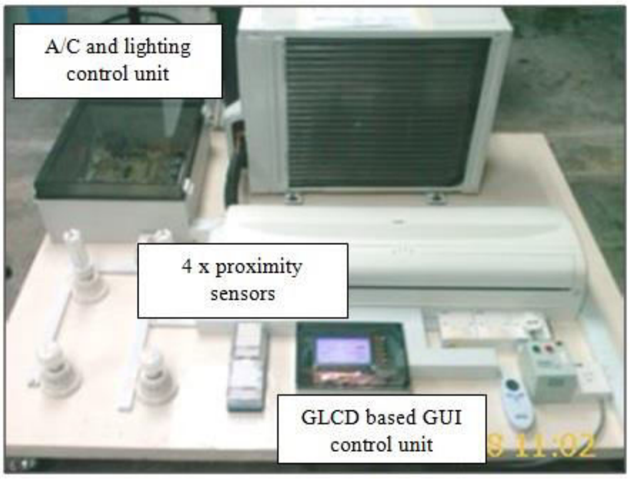

Figure-7. Graphic LCD based air-conditioning and lighting controller.

METHODOLOGY

The GUI based energy saving controller is a user friendly system that can control lighting and air-conditioning using PLC. Conceptually, the PLC module is used to connect and control between GUI to a controller and the GUI-based energy saving control system is programmed as a switching device for the lighting and air conditioning system. Once the GUI are connected to the PLC module over existing power cables, then the GUI is able to control and turn on / turn off the lighting and air-conditioning remotely. The block diagram and flow chart of the system can be seen in Figure-8 and Figure-9.

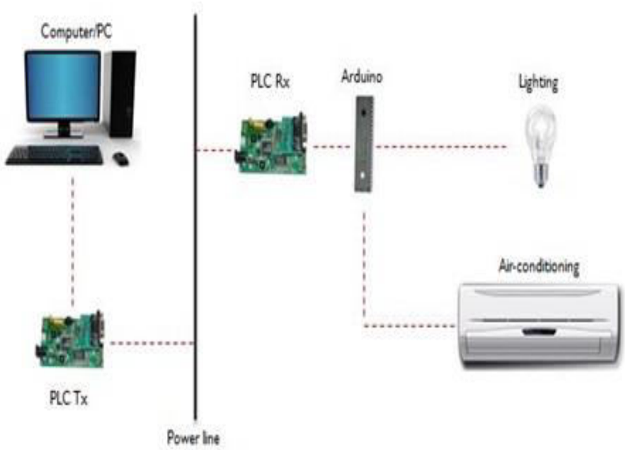

Figure-8. Block diagram of the system.

GUI is designed and connected to the control system via PLC module. This software is designed so that the users can also switch on and off the power supply of the lighting and air-conditioners via computer. In our case, the system is built for application in UMP lecture room in order to reduce energy wasting occurrences due to unattended classroom.

The PLC module is used for data transmission due to it's flexibility especially for long distance/ installation. PLC module is a communication technology that enables sending data over existing power cables. This system is simple and the settings are flexible. Otherwise, it is user friendly and can efficiently save wiring, maintenance and installation cost. If equipment has to be removed or reconfigured, it can be connected to another power line. This system also required only electricity to drive the system therefore it is protected and safely to use. Compare to the current problem, we need to control the electrical equipment manually and have remote to control the lighting and air-conditioning [8]-[10].

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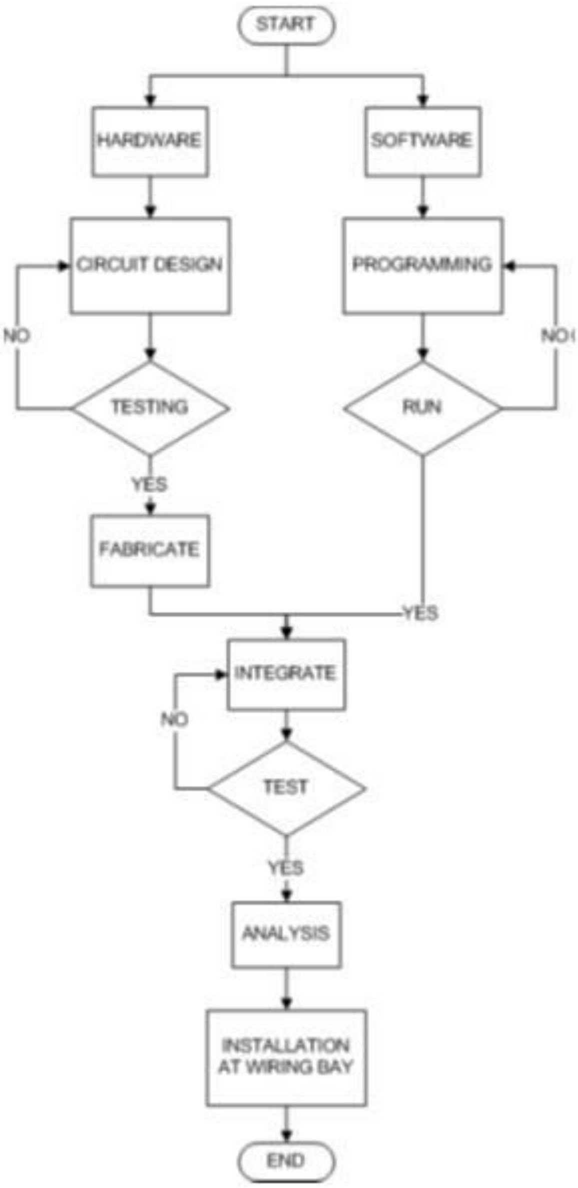

Figure-9. System flow chart.

The control system is designed with software to manually switch on and off the power supply of air-conditioning and lighting systems using computer. User can simply switch on and off the power supply of air-conditioning and lighting systems by clicking the GUI's buttons as shown in Figure-10. The software is designed to make sure that the lighting and air-conditioning units will only be used when they are needed, thus preventing energy wastage. In this system, the ON button layout indicated by green color and the OFF button layout indicated by red color. Other than that, the GUI was developed as a security concern to protect and avoid other people to access in this system. Figure 10 shows the control system setting that require user to insert the password to access the system

Figure-10. Control system with log in screen.

The control system which uses PLC communication to transfer the data was designed with zero-crossing switching capabilities. PLC communication is like any other communication technology where modulates the data to be sent, injects it onto medium and demodulates the data to read it. By linking controller together with the equipment drive models via ac 240V power line, it achieves the two-way data communication between the controller and each internal driver module. Figure-11 and Figure-12 shows the controller using PLC module.

The lighting driver circuit consists of resistors, triacs, optocouplers and connector which form two identical circuits with one connectivity. The double circuits act similar to single-pole-double-throw switches. Triac used in the circuitry could withstand a maximum current of 12A. The optocoupler with an integrated zero voltage crossing circuit is used for switching of the lighting control module. The lighting driver circuit that connected to microcontroller can be seen in Figure-13.

There are four lighting control module to cater for four lighting circuits in UMP lecture room and four sets of air-conditioning control module thus enable the controller to control up to four air-conditioners simultaneously.

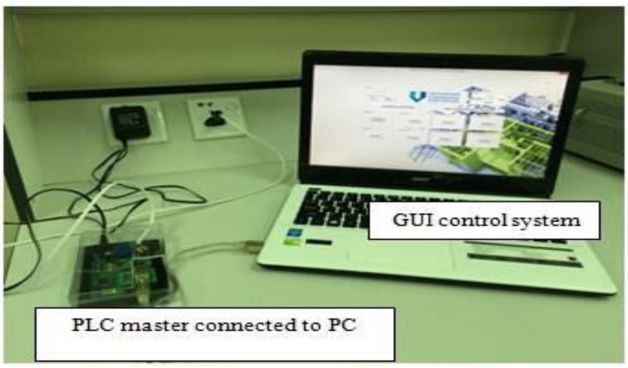

Figure-11. GUI controller module via PLC communication.

Figure-12. PLC slave connected to microcontroller.

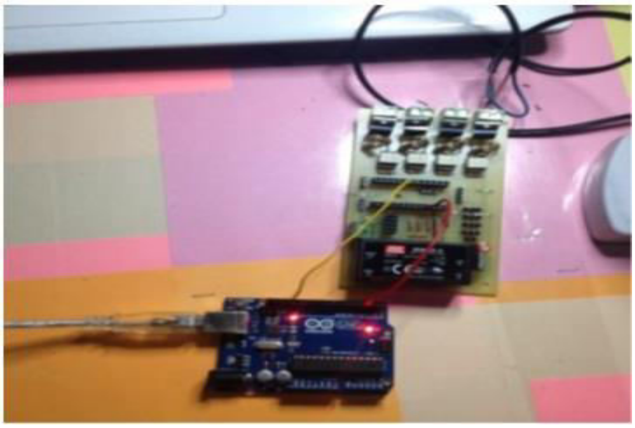

Figure-13. Lighting driver circuit connected to microcontroller.

The testing of the control system using one unit 1 horse-power air-conditioner and 4 unit light bulb rated at 2x23W and 2 x 100W is shown in Figure-14. The bulb is switch ON when the ON button layout is chosen and the bulb is switch OFF when the OFF button layout is chosen. The test of the control system for switching the lighting and air-conditioner via computer is successfully done.

Figure-14. Testing the hardware of the control system.

RESULTS AND DISCUSSION

After the control system has been tested, the experimental study was setup to analyze the performance of PLC module compared to others communication network (wireless and cables).

The transmitter and receiver are connected to digital oscilloscope to analyze the time delay and distance of output voltage for each part of the hardware circuit using different communication network. The data was collected to compare the performance of PLC, cables and wireless (Zigbee). Based on the data collected, the performance can be measured.

Figure-15 to Figure-18 show the different of time delay between 3 methods of communication network (PLC communication, wireless and cable). The results show that the cables are the fastest compare to others while the wireless is the slowest to send the data. This is because there are disturbance while transfering the data using wireless. From our case study, it was found that the network cables can disconnect or become faulty consequently causing the connection to fail. Besides that, the cost of network cable will be increased for long distance installation.

Figure-19 shows the time delay between 3 methods of communication network; PLC, cables and wireless on a different distance. Its show that the PLC and cables got the constant time delay in different distance meanwhile wireless uniformly increased. There are varieties of modulation schemes can be used in power line carrier communication. This project is using FSK modulation due to robustness and simplicity but at the same time it offers lower data rates.

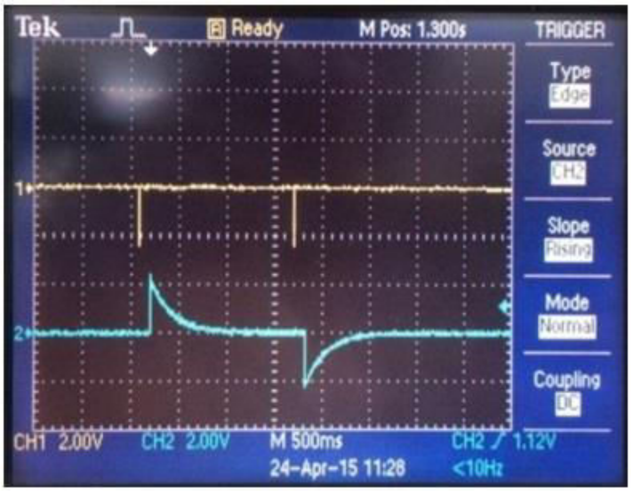

Figure-15. PLC signal.

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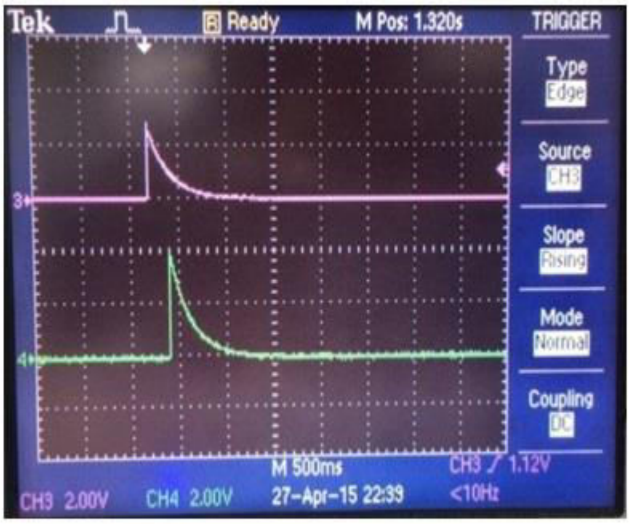

Figure-16. Wireless signal.

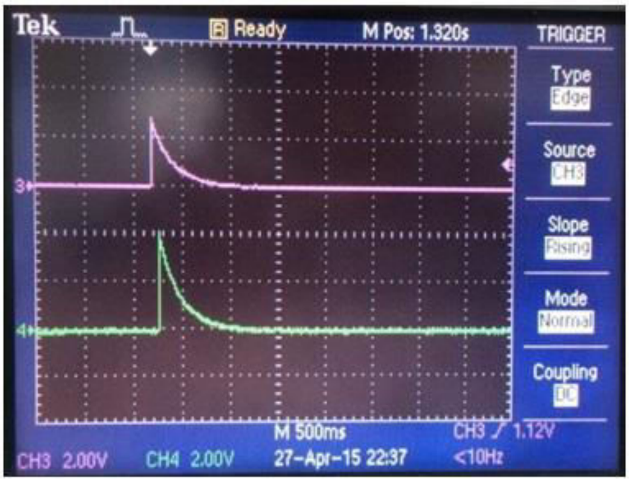

Figure-17. Cables signal.

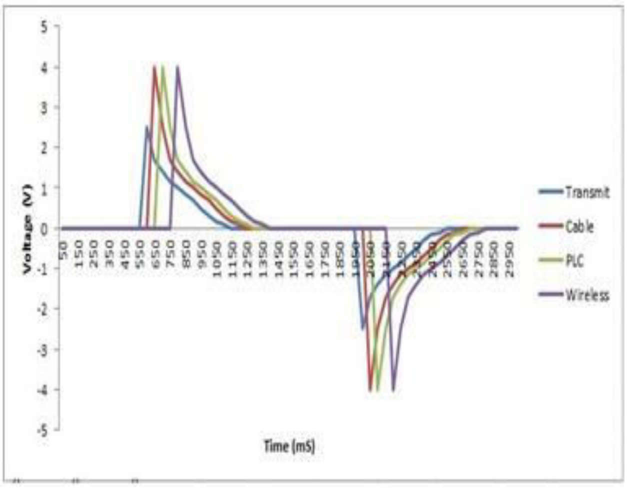

Figure-18. Voltage versus time delay between 3 methods.

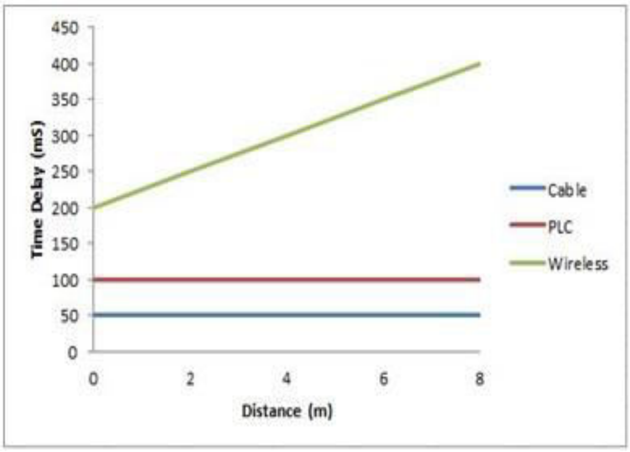

Figure-19. Time delay versus distance between 3 methods.

Based from the results we can conclude that the performance of PLC communication mainly depends on the physical parameters of the power line: attenuation, impedance and noise level. The advantages of PLC communication over cables and wireless communication are the system does not need wiring, its installation is simple and the settings are also very flexible. If equipment has to be removed or reconfigured, it can be connected to another existing power line. Thus, it can efficiently save wiring, maintenance and installation cost. This system also is friendly user and required only electricity to drive the system therefore it is protected and safely to use.

CONCLUSIONS

The presented power line communication modules have proved its functionality and capability for data communications and usability for GUI based energy saving controller of lighting and air-conditioning system. The Visual Basic software together with the hardware implementation via power lines carrier modem presented in this paper results in a flexible, inexpensive, and easy to use solution for low speed data communication. A prototype of GUI based energy saving controller for lighting and air-conditioning system has been designed and tested. Our next target will be installation of the controller in UMP lecture room for more analysis regarding the effectiveness of the controller for our energy efficiency program.

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