Abstract: - This paper will concentrate on the algorithm and control strategies where the air-conditioners and lighting system can be controlled using microcontroller; a microcontroller is chosen due to its low cost and high flexibility. Conceptually, the controller is programmed with internal timer and sensors to automatically switch off the power supply to the air-conditioning and lighting units at pre-defined times, or when no user is detected in a room. The working prototype of energy saving control system is developed with graphical user interface (GUI) embedded in Graphic LCD in order to avoid the dependency of personal computer which consume a lot of energy. The system has been built and tested in UMP lecture room. Based on our case study and energy audit, the prototype can achieve 35% reduction in the energy consumption of the air-conditioning and lighting system in UMP lecture room. For market potential, the control system can also be used in other places such as domestics, industrial and office building.

Key-Words: - graphical user interface (GUI), graphic LCD, energy saving control system, microcontroller

1 Introduction

Energy is a part of everyday necessities which is proportional to the cost which the supplier has endorsed. Due to this fact, the energy usage must be used smartly and efficiently. Currently, UMP has not applied energy efficiency in its buildings. Thus excessive power usage is used and hence billing is quite tremendous. These can be seen in the monthly average electricity cost in UMP from Year 2005 until Year 2008 as shown in Table 1 [1]-[4].

<table>
<thead>
<tr>
<th>YEAR</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>RM</td>
<td>160,000</td>
<td>183,000</td>
<td>209,000</td>
<td>302,000</td>
</tr>
</tbody>
</table>

Besides that, energy wasting occurrences in the campus are significant, especially in the air-conditioning and lighting system. A preliminary work was carried out in UMP’s lecture hall (DK13) to study the consumption and wastage of energy in the room. For the purpose of the research, a three phase data logger (Elite Pro power meter) was installed in DK13 for data collection regarding energy consumption and energy wasting. We found that the electrical equipments such as air-conditioning and lighting system is always left ON with no occupants which lead to energy inefficient and energy wasting [4].

Clearly, a major energy saving can be obtained if the air-conditioning and lighting systems can be made more energy efficient through better control [5]-[8]. A smart air-conditioning and lighting controller has been developed based on a case study done prior to the development. The case study has shown that numerous air-conditioner and lighting have been left on without any occupants. Based on this 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 is 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 is designed for setting and switching of the control system. The setting of internal timer can be changed in GUI setting menu via a password.
2 Hardware Development

The hardware development comprises of two different systems. The first part is the standalone user friendly GUI embedded in the controller. Standalone means that it is not using any personal computer since personal computer consumes a lot of energy. The second part is the air conditioner and lighting control unit which controls the switching on and off of the peripheral. The block diagram for both systems can be seen in Figure 1.

2.1 Graphical User Interface (GUI) Control Unit

The schematic development of GUI control unit was made using OrCAD 10.5. The schematic involve the integration between the GUI controller (microcontroller), small keypad and Graphic LCD. The graphic LCD unit type LMG7420PLFC-X (Hitachi) is connected to the GUI controller via 12 pins and five pins for power. The intersystem communication port and programming port is used to communicate between the master (GUI Control Unit) and the slave (Air conditioner and Lighting Control Unit). The protocol for intersystem communication will be explained in the firmware development. The fully assemble of GUI control unit can be seen in Figure 2 and Figure 3 respectively.

2.2 Air-Conditioning and Lighting Control Unit

The air-conditioning and lighting control unit schematic consist of the current sensor schematic and the air-conditioning and lighting controller with air-conditioning control module and Lighting control module. The current sensor used in the system is a hall-effect based sensor ACS712ELCTR-05B-T (Allegro MicroSystems Inc.). It can detect maximum current of 5A but the device can withstand up to 60A. The connectors are used to connect in series with the power line to the air conditioners or the lighting systems. The sensor circuits are also connected to the control unit via connectors.

Lighting control module consists of resistors, triacs, optocouplers and connector which form two identical circuits with one connectivity. The double circuits act similar to a single-pole-double-throw switches. Triac used in the circuitry could withstand a maximum current of 12A. Optocoupler (MOC 3042) with an integrated zero voltage crossing circuit is used for switching of the lighting control module. There are four lighting control module to cater for four lighting circuits and four sets of air-conditioning control module thus enable the controller to control up to four air-conditioners simultaneously.

The air-conditioning control module consists of resistors, diode, optocoupler, relay and connector. Here, the optocoupler used are 4N25 which is not identical to MOC3042 since it can only be used for dc voltage circuitry. Connectors will be connected to the controller of the air-conditioner. This will enable the system to operate the air-conditioner safely without damaging or reduce its life span. The full assembled of the control unit can be seen in Figure 4.
2.3 Smart Air-conditioner and Lighting Controller

The fully developed smart air-conditioner and lighting controller is setup on a test bed inclusive of a single-phase one horse-power air-conditioner and four light bulb rated at 2 x 23W and 2 x 100W. The full system can be seen in Figure 5 and Figure 6.
3 Firmware Development
The firmware for the controller consists of the main program with a number of subroutines to operate the main program and link to each of the GUI windows. The flow diagram of the program can be seen in Figure 7. The full program and subroutines will not be explained in this paper.

4 Graphic LCD Based GUI Control System
User can switch on or switch off the lighting and air conditioner via the GLCD based GUI controller and/or via common switches. The controller includes four PIR sensors to detect human presence. If there is no user after a preset delay time then the lighting and air conditioner will be automatically switch off. The auto off subroutine will send a command to the A/C and lighting control unit to turn off all peripheral. Besides that, three adjustable predefined timer can be set at the GLCD based GUI controller to turn off the air conditioners and lighting system at the setting time. For security, user needs to enter the password for setting predefined time. The introduction window is depicted in Figure 8.

The main window consists of the ALL section which enables the user to turn on or off all the air-conditioners and the lightings. Besides that, the main window also consists of an AIRCOND, LIGHTING and CONFIGURE sections which if the user selects it, the window will change to air-conditioners window, lighting window and configuration window respectively. These can be seen from Figure 9 to Figure 15.
The window in Figure 13 can only be accessed via a password. This page consists of the CHANGE CODE, CHANGE TIME, SET PRETIME1, SET PRETIME2 and SET PRETIME3. CHANGE CODE if selected will bring up the change code page which allows the user to change the password. CHANGE TIME if selected will bring up the change time window which will enable the user to change the real time clock which is visualized on the bottom left of every page. PRETIME1, PRETIME2 and PRETIME3 if selected will bring up the respective pre-defined time page which will allow the user to change the predefined time to automatic turn off of all peripherals.

5 Analysis of energy consumption at BK13

After the control system has been fabricated and tested, it is installed for further analysis at UMP lecture hall (BK13) which has maximum capacity of about 30 students. The energy consumed with and without the control system is compared by using data logger (Elite Pro power meter). Based on the data collected, the energy saving can be measured.

The data was collected within a five working days time frame during semester session for both conditions; with and without the controller which was taken from 2nd February to 6th February 2009 (with control system) and 9th to 13th February 2009 (without control system). Figure 16 shows the installation of the controller at sub-switch board. The data of energy saving in BK13 is depicted in Figure 17.
From the graph, it shows that power saving at BK13 after installation of the control system is about 35%. The calculation of power saving and simple payback period (SPP) by using Malaysian low voltage industrial tariff is shown below:

Simple payback period (SPP):
Cost of controller = RM 700.00

Saving per month (RM):
\[ = (\text{kWh (not install)} - \text{kWh (install)}) \times 0.38 \times 4 \]
\[ = (130.754 - 88.22) \times 0.38 \times 4 \]
\[ = RM 64.65 \]

Operation cost per month:
\[ = \text{kWh} \times 24 \text{ hours} \times 30 \text{ days} \times 0.38 \]
\[ = 0.02 \times 24 \times 30 \times 0.38 \]
\[ = RM 5.47 \]

Saving per year (RM):
\[ = (64.65 \times 12) - (5.47 \times 12) \]
\[ = RM 710.16 \]

SPP = Cost of controller / Savings per year
\[ = 700.00 / 710.16 \]
\[ = 0.986 \text{ years} \]

The simple payback period of the control system will reduce for application in large area compare to small area since the savings per year will increase if the control system is install in large area.

6 Conclusion
A working prototype of smart graphic LCD GUI based air-conditioning and lighting controller for building energy saving has been designed, fabricated and tested. Our achievement in this project is 35% reduction in the energy consumption of the air-conditioning system in small UMP lecture room with capacity of 30 students. The controller can also be used for domestic application as well as industrials and offices applications. The simple payback period of the controller is less than one year and for application in large area it will reduce since the savings per year is increase.

References: