Intelligent Energy Management in Residential Building

by

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ABSTRACT

Residential building has high consumption of energy especially electrical energy. This motivates researchers to work on how to improve residential building energy efficiency. However, the improvement of energy efficiency in a building is difficult to be done for the whole building at a time. Some of the difficulty is the inefficient of energy management system in the building, but the biggest contribution to the deficiency is that there is no optimal algorithm which is suitable to the facilities in the building. An intelligent energy management system has been proposed in this paper to address this problem which include the integrated optimal control system consists of an occupancy sensor network and adaptive dynamic programming algorithm. To increase accuracy and avoid faults in available sensor technology, multiple sensors are being used in this project including passive infra-red sensors, Ultrasonic sensors and Carbon Dioxide concentration sensors have been installed to set up a hybrid occupancy detection sensor network. It is very critical to control and optimization for complex systems such as the system constituted by all electromechanical systems in a building. It learns from environment of a building and generates a series of optimal control strategies to preserve human comfort and improve energy efficiency in low cost.

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CHAPTER 1

INTRODUCTION

This chapter provides introductory information on the role of intelligent energy management in reducing energy waste, based on sensors network. The project background is briefly described followed by problem statement and objectives of this project. Finally, the scope of studies of this project is explained.

1.1 Background

Intelligent facilities of a building lead to a greater consumption of power. Hence, researchers and developers are motivated to improve building energy efficiency which resulted on the green building and technology. However, it is not easy to improve the building energy efficiency as a whole. Part of it is due to the lack of building energy management system. Most buildings' energy management systems are controlled manually and it resulted in energy wasted when energy is still consumed when not in use. To solve this issue, and integrated autonomous control system based on sensors has been proposed in this project. This intelligent system consists of an occupancy sensor network and programmed timer. To reduce the limitations in the technology of sensor, passive infra-red (PIR) sensors and Carbon Dioxide (CO2) concentration sensors has been added to the system to enhance the detection sensor network. It is very crucial for this system to control and optimize the usage of energy to reduce energy waste in a building.

1.1.1 Energy Management System

Energy management system (EMS) is frequently related commercially to any activities utilized by individual control, monitor, and measure their electrical building load. Devices such as Heating, Ventilating and Air Conditioning (HVAC) and lighting systems can be controlled centrally using energy management system. Besides that, energy management system offers monitoring, metering and sub metering functions for the building managers to be able to gather accurate information and data on energy activities at their sites. In a different perspective to define EMS, it can also be referred to as a system complied with energy efficiency standard based on standard methods and procedures, to assure continuous enhancement and increase awareness on energy efficiency.

1.1.2 Home Automation

Home automation which is similar to "smart home" technology includes the integration between electrical appliances and computers. Nevertheless, the systems can be controlled remotely using tablets, smartphones as example or any smart media. As the name suggest, most people opt for home automation for its energy efficiency, safety assurance and they find it is convenience. Home automation is complex due to the difference in patterns of energy usage and occupant usage. It can be concluded that smart home has the ability to identify environments and make decision without external (occupant) interferences to reduce the energy usage based on environmental variable. [7]

1.2 Problem Statement

One of the biggest causes of the excessive energy usage in homes comes from the amount of electrical equipment, lighting and electronics load especially when it is left on when not needed which lead to high energy cost. If everyone was just responsible and turned things off, it should not be a problem, but apparently, the conventional electrical system available at home is not efficient enough to optimize the energy. Therefore, an autonomous operating switching system is required in order to reduce energy waste if switches are forgotten to turn off when not in use.

1.3 Objectives

The general goal of this project is to develop an intelligent energy management system to reduce energy waste in home. The specific goals are as follows:

1.3.1 To develop autonomous switching system based on sensors network to control the energy consumption in a house.

1.3.2 To develop online switching controls system using Arduino board to allow the switching system to be controlled via phone using bluetooth.

1.3.3 To minimize the consumption of electrical energy as well as the energy cost due to the reduction of energy waste.

1.4 Scope of study

The scope of this project is limited to circuit design based on sensors and timers, development of online control system and fabrication of prototype. Improvement on the application and range covered by the sensors will be recommended for future and will not be covered in this research. The circuit design is based on literature reports with some basic industrial practice.

1.4.1 By using occupancy sensor which combines motion detection and heat sensing technology, all the power in the room will be switched off when no one is in the room.

1.4.2 Single phase wiring system will be used in this intelligent system.

1.4.3 Energy cost will be calculated based on how much the reduction of energy consumption has been made using this system.

CHAPTER 2

LITERATURE REVIEW AND THEORY

This chapter will include the definition of Intelligent Energy Management System, outlines brief history of technologies used in the system and their recent developments.

2.1 Definition

A smart home can be defined as an electronics technology network that is being integrated with home appliances or electrical loads which can be monitored or controlled in a centralized system. [8]

In the scope of saving the energy, the management of energy includes the process of controlling, monitoring, and conserving the energy either in a building or in an organization. This includes measuring the consumption of energy and estimate the amount of energy that could be saved.

The term “intelligence system” was added to define a smart home to manage and control the networks automatically. Smart home system can easily control and integrate the switching, house appliances, lighting, cooling features and electrical loads by using occupancy sensors as the key player of the circuit. This can be upgraded into an internet based control system by linking them to a micro controller. This allows the home owner to remotely control the systems via phone or anywhere they can access the internet. A smart home system does not only offer an improvement on safety and convenience but it also aimed to save the energy.

2.2 History of Home Automation

Despite the term of "Smart home" was used for the first time in 1980s, the concept of home automation behind it was already known before it. Disney's has increased the awareness of people on the idea of home automation in the year of 1999 through the film Smart House where it sells a story of a smart home taking care of its occupants. ECHO IV was known as a smart device where it could switch on or off the home appliances and control the temperature of the house. In the early 2000s, the application of "smart" hit the market and first model of smart home was built. With the innovation of internet, the related applications and technologies was introduced later. [9]

2.3 Research and Trends in Smart Home

The Internet of Things (IOT) has become and evolution to extend the idea of smart home. It involves the idea of connecting the hardware tools and the systems wirelessly. It also brings the idea of future smart home where the increase in number of devices that are connected to Internet defines the highly level of potential of the integration of a smart home.

Security has been the highest priority of a smart home system today. The idea of an advanced smart security systems that will give you a notification whenever there is an intrusion or alarm has become one of the demand nowadays.

Currently, there are less than 1% of homes apply integration of intelligent energy system. A research done by ABI has predicted the annual business of a smart home will increase to $14.1 billion by 2018. [9] Regardless the number predicted, the experts agree that the market of home automation is growing very rapidly. This growth has been in line with the growth of tablet market. Most Do It Yourself (DIY) experts found tablet is very easy to use as the remote control to manage the energy usage effectively. External factors that lead to rapid growth of home automation are the increasing of energy costs,

increasing of awareness among customers on environment, safety and also home automation.

2.4 Intelligent Energy System Network

Multi-network sensor can be designed to sense electromechanical equipment, environmental parameters, occupancy and energy consumption based on the type of sensors use. This include temperature sensors, wind speed sensors, relative humidity sensors, potential transformers, current transformers, electrical energy meters, passive infra-red sensors (PIRs), ultrasonic sensors, cameras and RFID sensors. Nevertheless, it is not advisable to integrate all these kinds of sensors in every room because it maybe very expensive at an entire building level. Hence, an integrated sensor network design methodology adopted here is considering the range covered by sensors with the considerations of the privacy, security and the deploy cost. Added features of software integrated network was designed by using the micro controller linked with the technologies of internet.[3]

There are several ways to know whether a room has been occupied or not. The usage of sensors in a given control range is one of the ways to know it. There are various options of sensors adopted as occupancy sensors such as RFID sensor, infrared sensor, ultrasonic sensor, camera-based sensor and microwave sensor. In the case where an indoor space is detected empty, some appliances, such as air-conditioner, lighting, can be turned off, which can improve building energy efficiency.

Passive infrared (PIR) sensors are the most widely used sensors to detect occupant. They detect motion by measuring infrared light radiating from objects in its range of view since all objects emit heat energy in the term of infrared light when they are above absolute zero. A PIR sensor works by sensing the energy radiated by other objects but it does not produce any energy for detection purposes by itself. That is why it is called ‘passive’.

PIR sensors work when the source of the heat is in motion. If the source of the heat stops moving, PIR will not sense it. Inversely, PIR can be triggered by moving radiated heat such as fire flames. A PIR sensor usually takes a minute or two to warm-up to allow the sensing elements works on its operating temperature.

Figure 1 below shows an example to integrate a simple PIR (this module is from Parallax) to an Arduino microcontroller. A simple program pirsensor.pde is an example of commands to allow reading of the value from the PIR and to display it on Arduino's built-in LED.

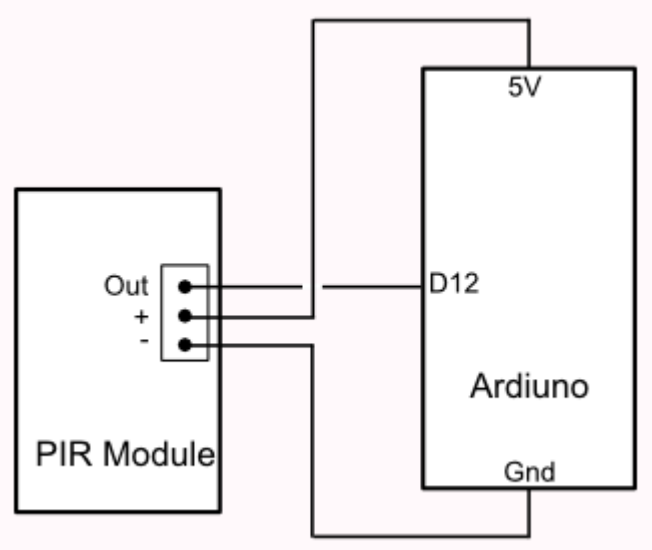

Figure 1 : Interfacing PIR and Arduino

Most of PIR sensors have numerous mirror segments, an effective range of about ten metres, and a field of view less than 180 degrees. Although a PIR sensor offer easy integration with control system, it has many drawbacks. For example, a PIR sensor is not able to detect a stationary human in a room; it also not able to determine the number of people either.

Ultrasonic sensors produce high frequency sound waves and interpret the echoes. By calculating the time interval between the signal of the wave and the echo, ultrasonic sensor will determine the distance to an object. Multiple ultrasonic sensors are needed to measure speed or direction of a person. An ultrasonic transducer typically generates sound waves in the range above 18,000 Hz. At first, the sensing system of an ultrasonic sensor converts electrical energy into sound, before the echo waves is converted into electrical energy which can be measured and displayed.

The main disadvantages of an ultrasonic sensor are clutter, no echoes occasionally and multipath because of the irregular reflection surface of an object detected. Camera-based sensors are widely used in outdoor applications and hallway detections. A camera-based sensor converts an optical image into an electronic signal, which is used mostly in digital cameras and other imaging devices.

Digital charge-coupled device (CCD) or complementary metaloxidesemiconductor (CMOS) active pixel sensors are widely used nowadays. For security purposes, most of modern buildings have a closed circuit television system (CCTV), it will be helpful if there are an additional feature of an image processing software for occupant detection and classify the number of people in CCTV system. However, a camera sensor does not offer to be deployed in private indoor spaces. What is more, a camera does not work well in a dim environment. [6]

2.5 Communication

Back to Basic of Bluetooth

Bluetooth technology is understood as one of the technology that provides wireless communication. It is secure, simple and can be use almost everywhere. Today, we can find Bluetooth technology in devices such as mobile phones, computers, cars and many more. The idea behind it is to replace the usage of cables as the communication tools between devices, yet providing high security levels for the consumers.

The highlight features of Bluetooth are their low power and low cost technology. It defines a standard specification that provides a same structure for the devices to connect to each other.

Pairing is done when two Bluetooth device allow their devices to connect to each other. Due to the standard structure of the Bluetooth technology that is accepted globally, this means that any devices integrated with Bluetooth technology can be paired with other Bluetooth devices nearly all the places in the world, provided that both of the devices are in the limited range.

Bluetooth technology allows short range communication and provides ad hoc networks called piconets. Once Bluetooth devices are paired or connected to each other, Piconets are establish automatically. This allows the devices to exit or enter proximity of radio easily providing easy access to connect and disconnect wherever and whenever needed.

Each device in piconet can communicate with multiple devices up to seven devices in a single piconet, and each device can be belong to more than one piconets at the same time. This provides limitless connection of Bluetooth devices.

Handling data and voice transmission at the same time is one of the core strength of Bluetooth wireless technology. This allows innovative solution such as hands-free headsets, wireless printing and synchronization of mobile phones and PCs and a lot more to offer.

Furthermore, the working range for Bluetooth technology is application specific. The fundamental specification allow the range to be of minimum 10 meters, but there is no set limit whereby the manufacturers can change the setting to provide the needed range for their specific purposes.

CHAPTER 3

METHODOLOGY

This chapter presents the methodology in developing this project. The hardware and software tools used in this project will be explained before the flow chart. Next, the project's key milestone and Gantt Chart is provided to illustrate the timeline of this project.

3.1 Hardware tools

In this step, literature review is done related to occupancy sensors. Each of the sensors are properly evaluated which lead to the selection of multi-network sensor as viable option. Each of the sensors play a different role in ensuring the energy management system in the residential building is intelligent.

3.1.1 Occupancy sensor and timer

Occupancy sensor is famously known as a lighting control device to detect the presence of a person and switch the lights on or off automatically within a specific space. The occupancy sensor are based on infrared, ultrasonic and also microwave. As for this project, it is decided that the occupancy sensors that will be use includes PIR, ultrasonic sensor. Both of the sensors are responsible to detect the presence of an occupant or occupants in a given range of space. These sensors will be integrated with a programmable timer to set the threshold time for the switch to on or off. This is to minimize the frequent spikes in energy consumption which can lead to higher energy cost.

3.1.2 Wiring system

A single phase circuit is designed to deploy the intelligent energy management system which includes the sensors, and timer, micro controller, and also electrical loads. The wiring system will not change the existing circuit of the residential building instead the sensors, timer and micro controller will be connected into the existing circuit.

3.1.3 Home appliances

Energy consumption in residential buildings mainly comes from all home appliances that uses the electrical energy to work. In other word, a home appliance is the energy consumed by any load such as television, lights, air conditioner and power supply.

3.2 Software tools

Extensive readings and gathering of all the theoretical information is studied in order to understand the mechanism of Arduino and micro controller to evaluate its performance technically.

3.2.1 Bluno

The use of Arduino with integrated Bluetooth (Bluno) board is to allow the owner to monitor the status of their energy consumption in real-time and also allow them to control the energy usage using any media (smartphones or laptop) which can have access to internet. For the purpose of project's prototype, Bluetooth will be chosen as the medium of communication between microcontroller and android phone. In real cases, wifi have a wider coverage area and faster transfer rate. Arduino board as selected due to its friendly user advantages and easy integration with hardware. It is responsible to link between the hardware tools and software.

3.3 Project Flow

The project flow gives an overall flow of the project starting from Final Year Project I (FYPI) and Final Year Project II (FYPII).

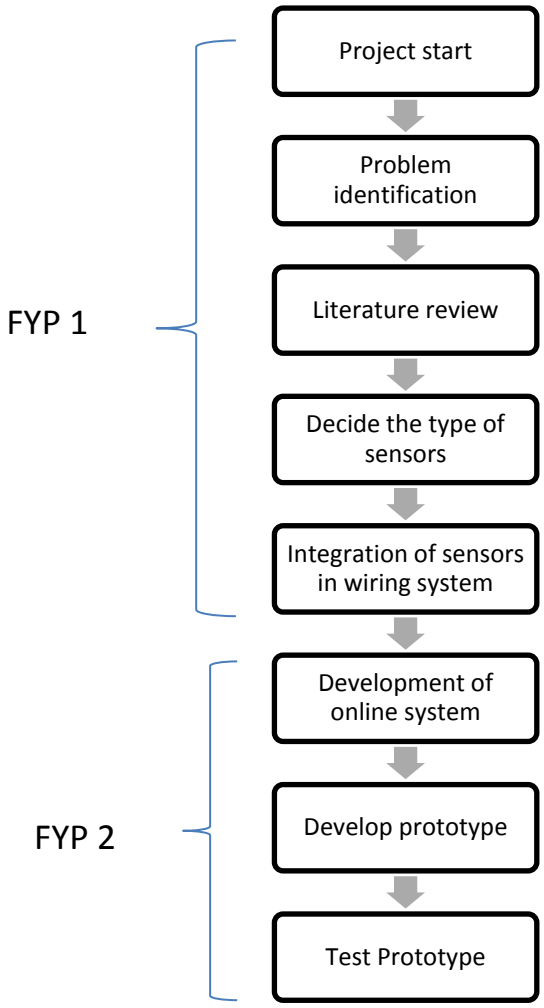

Figure 2 : Overall Flow of the project

The project started with the identification of problem related to energy management system. Issues addressed include the inefficiency of energy consumption which lead to energy waste and increase of energy cost. Intelligent energy management based on sensors and programmable timer is then identified as the best energy efficiency solutions to overcome the problems.

3.4 Project Milestone

Project milestone has been set up at the beginning of the project to allow smooth planning and progress of the project in order to complete it in the time given as shown in table 1. It was planned in monthly basis and is subject to changes depending on the future.

Table 1 : Project Milestone for FYPI and FYPII

No	Plans of action	Months							
		1	2	3	4	5	6	7	8
1	Extensive research on intelligent energy management system and the components in it.	●	●						
2	Design a sensor system for autonomous energy management system.			●	●				
3	Software & Hardware Development integrated with Arduino board.				●	●			
4	Develop application of online system for controlling and monitoring through internet					●	●		
5	System Implementation & Prototype Fabrication					●	●	●	
6	System Troubleshooting							●	●
7	System Functionality test								●

● : Key Milestone

3.5 Gantt Chart

Table 2 describes in details on the Gantt Chart of the project in weekly basis for FYP I only.

Table 2 : Gantt Chart for FYP1

TASK \ WEEK	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Briefing of the course by coordinators														
Selection of Project Topic • 1st meeting with supervisor • Understanding title of project • Understanding project requirement and challenges														
Preliminary Research Work • Problem statements identification • Prepare Literature Review • Proposal of possible approach solutions • Planning of the project flow in Gantt chart (to evaluate progress)														
EXTENDED PROPOSAL • Submit extended proposal to SV						★								
Preparing for proposal defense • Research for related papers, articles and journals to retrieve idea and enhance knowledge • Prepare literature review • Decide on the sensors and timers required to make necessary purchase														
PROPOSAL DEFENCE • Present the proposal defense review to SV • Submit the related slides and documentation to SV									★					
Project work continues • Design the circuit integrated with the sensors and timers														
Interim Report Drafting • Consult SV for the Interim report progress														
INTERIM REPORT • Hand in Final Technical Report 1 to SV/Course Coordinator														★

Table 3 describes in details on the Gantt Chart of the project in weekly basis for FYP II only.

Table 3 : Gantt Chart for FYP II

WEEK / TASK	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Briefing of the course by coordinators														
Continue on Research Work • Weekly meeting with supervisor • Purchase components and equipment for prototype • Start to integrate a small scale smart-home														
PROGRESS REPORT • Submit progress report to SV								★						
Preparing for ELECTREX • Troubleshooting prototype • Prepare poster and relevant slides for presentation.														
ELECTREX • Present the poster presentation review to SV • Present at the Electrex to internal examinor • Submit the related slides and documentation to SV											★			
Project work continues • Improvise on the system based on comments.														
Final Report Drafting • Consult SV for the Final report progress														
FINAL REPORT AND TECHNICAL PAPER • Hand in Final Technical Report to SV/Course Coordinator														★
VIVA • Hand in Final Technical Report 1 to SV/Course Coordinator														★
FINAL REPORT (Hard Cover) • Hand in Final Technical Report (Hard Cover) to SV/Course Coordinator														★

CHAPTER 4

RESULT

This chapter will further discuss on the preliminary results that have been obtained through extensive research and the circuit simulations of an intelligent energy management system in a simple residential area.

4.1 Components in Intelligent Energy Management System

To be qualified as an Intelligent Energy Management System, all the technologies used in the system must comprise home automation, intelligent control and internal network, as illustrated in figure3.

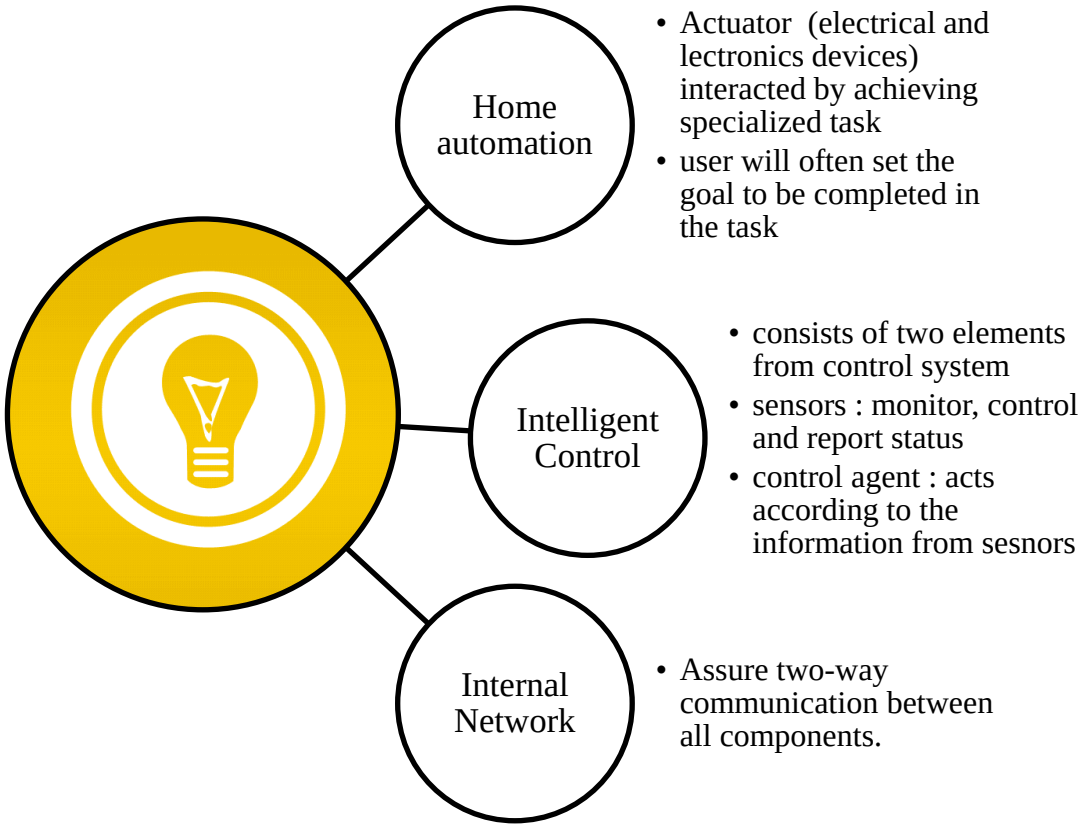

Figure 3 : Intelligent Home System Components

4.1.1 Control Systems

Control system is a vital part in an Intelligent Energy Management System because it confirms the effectiveness and reliability of the solution provided. These systems are software-based systems that run on any electronic device such as computer or phones. The software provides the power to control the status of electrical appliances from a centralized spot. Most of the systems include macro command which allow user to execute a command at pre-scheduled time.

4.1.2 Actuators

Household appliances or electrical load are controlled by electrical or electronics devices which is known as actuators. There are cases where they are available in separate device and need to be coupled with the appliances electrically. A simple command such as turning it on or off can control the actuators. If they are already embedded inside the appliances, it is more sophisticated and more valuable to the user.

4.1.3 Home Network

Intelligent Energy Management system consist of three main subdivisions, subject on the communication media used which is Powerline, Busline or Wireless.

Powerline systems involve a direct connection into the home network without having to add supplementary cable. This system is cheap and has a simple configuration than other solutions besides being the oldest system among three. However, the disadvantages of this technology include vulnerability to electrical interferences which makes it less reliable. Furthermore the earlier protocol only allows devices to receive information which means that it only support one-way communication.

Upgraded **Busline** systems allow two-way communication using separate media typically twisted-pair cabling where usually found in network and phone services. Although it requires expensive installation cost, it is more reliable as the separate cable

provides positive note and higher bandwidth. Basic knowledge in networking are needed for configuration as this technology is more complex.

Wireless systems as the name suggest does not need any wire to functions. It is divided into two subdivisions which is Infrared (IR) and Radio Frequency (RF). This technology is the newest among three and the cost per unit was decreased making it more popular nowadays. Wireless system offer easy installation, allows two-way communication although with lower bandwidth compared to Busline. Nevertheless, this system also is vulnerable towards electrical interferences and triggers a privacy alarm where it can involve unauthorized access. This has led to the introduction of authentication instruments and data encryption. Adding the features to ensure privacy issues guaranteed has make the system more complicated to configure.

4.2 Hardware Integration in Circuit System

4.2.1 Operation of Ultrasonic Sensors

Ultrasonic sensors operated in similar way that sonar and radar work based on Doppler Effect principle. Ultrasonic sensors works in which a piezoelectric transducer will convert electrical energy received by the sensor into an ultrasonic wave (40-50kHz) which will then be transmitted as a high frequency wave sound. If there is an object in front of the sensors, the wave will hit the object and being reflected back toward the sensor. The reflected wave will then be converted back from sound wave to electrical energy. Once the reflected wave is received, the distance of the object from the sensors can be calculated using the following equation :

$$d = \frac{t \times c}{2} \quad ,$$

Where d = distance , t = time , c = speed of light 340.29 m/s.

The change in frequency of motion can be evaluated and determine whether the object is moving or not via the control circuitry.

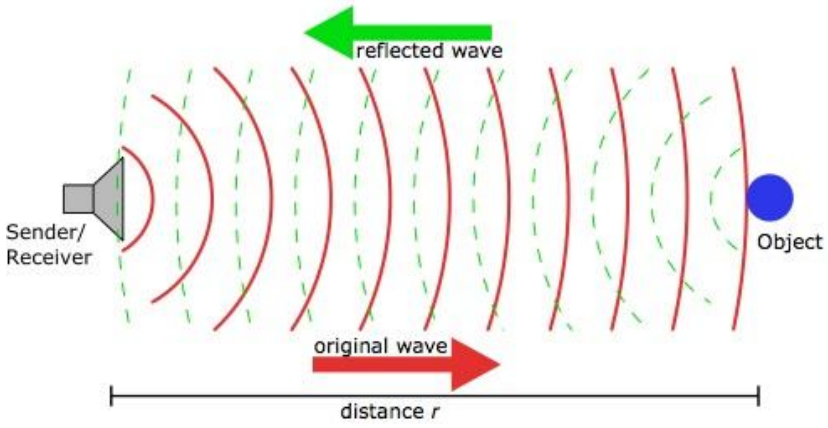

Figure 4 : Doppler Effect of Ultrasonic Sensor

4.2.2 Operation of Passive Infrared Sensors

Passive Infrared Sensors works in which the sensors will emit an electromagnetic radiation (wavelength ranging between 300 μm and 700 nm). It is not in the range of spectrum of visible light but it is radiated to the surroundings. When there is a change in level of infrared radiation, the sensing element Pyroelectric device will generates an electric potential. However, it is a temporary electrical potential which will then disappear once the relaxation time is finished to allow continuous sensing. A false trigger is prevented by Fresnel lens to ensure extension of field of view and even sensitivity supplies.

4.2.3 Technical Specifications of PIR and Ultrasonic Sensors

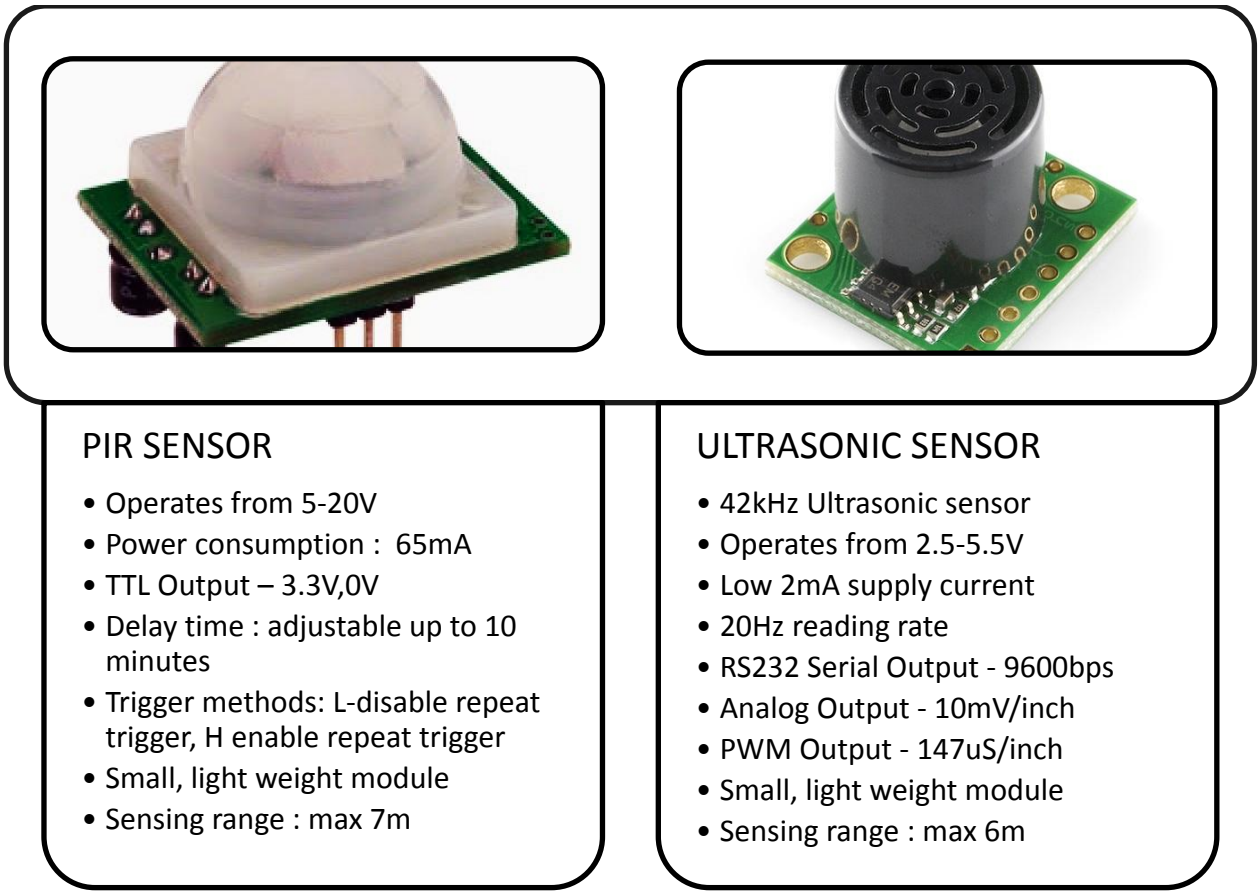

Figure 5 : Comparison between PIR Sensor and Ultrasonic Sensor

Figure 5 simplifies the technical specifications of both PIR sensors and Ultrasonic sensors to be used in this project. This is to ensure the correct calculations to integrate the existing circuits. The range of sensitivity is very important in the project to assure that all range of a given space is being covered by the sensors.

4.3 Software Integration in Circuit System

Bluno is the first innovation of integrating Bluetooth 4.0 (BLE) module into Arduino Uno, offering a perfect platform for a prototype in terms of hardware and software usage to go BLE.

Many innovative solutions such as smart pedometer, smart bracelet, smart home can be developed using Bluno. With the low-power technology offered by Bluetooth 4.0, is is really easy to establish a real-time low energy communication.

Figure 6 : Bluno

Bluno is basically Arduino UNO board integrated with a TI CC2540 BT 4.0 chip. This enables wireless programming via BLE, configuration of BLE via AT command, supports Bluetooth HID, and BLE firmware can be upgraded easily. Bluno allows all Arduino based projects to go wireless because it is compatible with all Arduino Uno pins.

Android and ios applications are also available to drive the sensors and actuators through BLE, allowing controlling the LED, switch on buzzer, and many more.

4.4 Preliminary Block Diagram

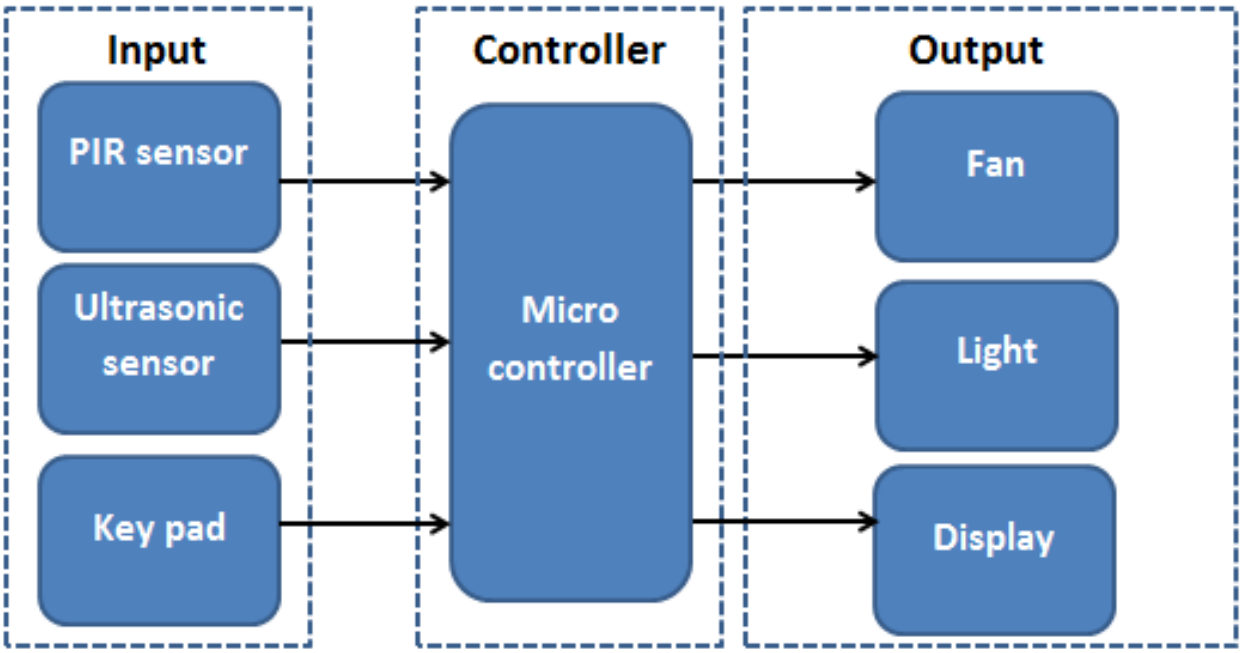

Figure 7 : System block diagram

The system block diagram consists of 3 parts of functions which are input, controller, and output below is the description lists of these functions:

1) Input:

a. Passive Infrared Sensor (PIR)

- Detect the presence of a person through infrared radiaton

b. Ultrasonic sensor (HC-04)

- Measures the distance of the obstacles when encountered through Doppler effect

c. Keypad

- User interference is allowed as the input to the system through the internet software where they can manually change the status of the energy usage from a centralized port.

2) Micro-Controller:

a. Arduino MEGA

- Main microcontroller that stores and executes the main algorithm.
- Read the ultrasonic sensor data.

3) Output

a. Home appliances

- Electrical load such as fan and lamp will act according to the command from microcontroller.
- Software based control system will display the current status of energy usage of all electrical appliances at that time.

4.5 Implementation

This section describes the actual implementation of the Proof-of-concept (POC) system. Firstly, it will introduce the hardware and software integration with the technology that will be used and then the actual system's outline of inner workings.

Since Energy Management is understood as a new term and conceptually accepted that it integrates both power management and control, also taking into account the total energy conservation and not just the efficiency of specific system component. One of the objectives of this project is to save energy and thus the cost which need this system to be energy efficient. It is opt to intelligently optimize efficiency and overall performance while operated by Information and Communications Technology (ICT) equipment.

The intelligent system was designed with a holistic approach and performs in optimizing Energy Management for the consumer. Small improvements in power dissipation efficiency of a power system can give a significant change to the system in terms of energy cost and environmental impacts.

The POC system was designed to proof that the algorithm used in it is working, but in a very limited and small scale. One of the success measures of the system energy efficiency is how it will save the energy and thus save the cost. This will be explained later in this section.

A Graphical User Interface (GUI) has been chosen as the communication tools to connect with the evaluation system power management bus. This is needed in the system to ensure that the power supplies in the system can be easily programmed and the operating conditions of the system can be easily changed. This is also needed for the evaluation of Energy Management techniques.

The Androids' phones will run the GUI and will communicate with the Arduino board using Bluetooth interface. Bluetooth is capable of providing a peripheral interface, universal way for existing data networks and a mechanism to communicate a group of connected devices from a fixed network infrastructure.

The GUI will read the input from Android's phone and will send the signal to Arduino board to be processed. The Arduino board will decide to trigger the relay or not depending on the instructions given provided the conditions were met.

Conditions	Requirement	Actions
1	• Switch is on AND both of sensors triggered • Android's touchpad is high	Load turned on
2	• Switch is on AND PIR sensors not triggered • Android's touchpad is low	Load turned off

A screen photograph of the GUI build with Android Studio is shown in figure below.

Figure 8 : Android Application

Figure 8 shows the display of POC's Android GUI showing the status of Bluetooth connected to the Arduino board and the status of the load which currently lamp 2 is turned on while lamp 1 is turned off. The numbers of the load depends on the numbers of load connected to the system. As for the POC, only two loads are connected to the system.

The software and hardware part is being implemented to become a whole new system. The connection of the circuit is shown as below in Figure 9.

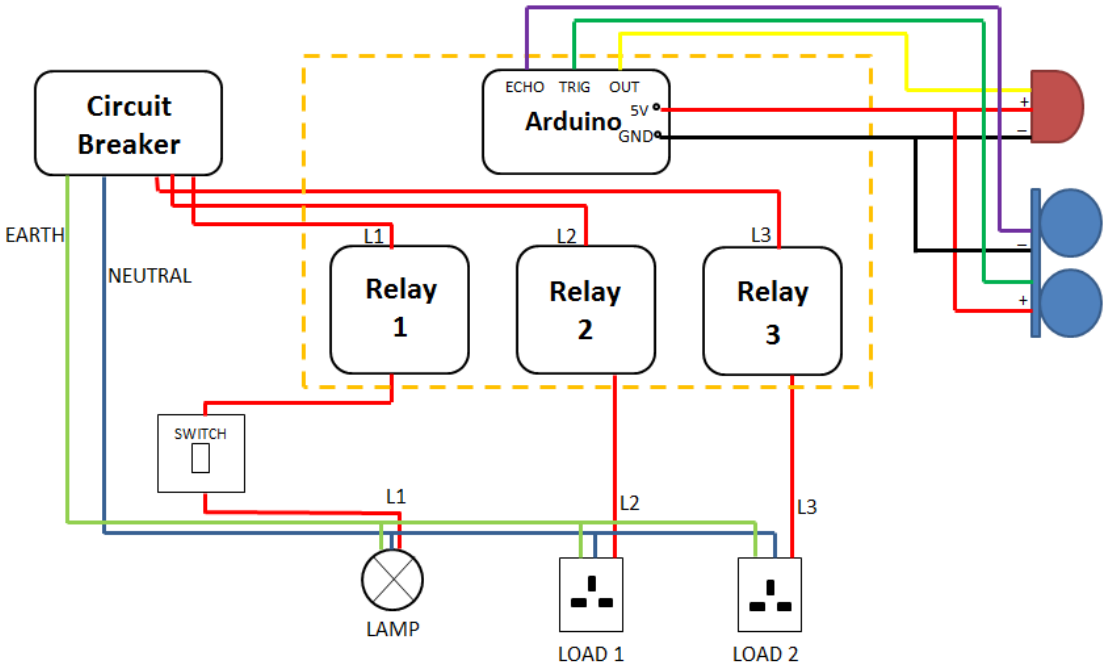

Figure 9 : Circuit diagram of intelligent system

4.4 How it can save cost?

The idea of high efficiency and energy saving has become one of the desire for everyone but often we do not often measure our desire to achieve them with their quantifiable benefits.

Assuming 10W can be saved in one load, if the operation is continuous and the energy rate is RM0.218 per kWh, the cost saving would be RM9.54 over a 5 year operating period. The example is only applicable for the power dissipation on one load. Due to the series inefficiencies of components such as battery backup, cooling hardware, AC/DC conversion, a single watt of power at the board will most likely resembles 2 to 3 watts at the input of total system. This will make 1 watt on a board to save RM28 over 5 years. A typical system will contains more than one unit of load, so the cumulative effect is significant for most of the consumers.

Looking at the environmental side, electrical energy is definitely not free of charge. It is estimated that on average, each kWh of electrical consumption and generation will affect 0.7kg of CO2. Ten watt of power saved on a load is translated into a reduction of over 61kg per year of CO2 released. With more than 400 loads connected to the intelligent system, imagine how many CO2 emissions can be reduced.

High efficiency and energy saving result in longer lifespan, higher reliability and easier thermal management conditions. The important techniques to achieve these goals are to use minimum number of power conversion staged and high efficiency power supplies.

CHAPTER 5

CONCLUSION

This chapter outlines the conclusion drawn from the work in order to complete the project. It provides a summary of the main findings, work performed, and personal suggestions for future work.

5.1 Summary of Progress Work

Chapter 1 has defined the initial objective that was aimed for this project. The aim was to develop a prototype as the proof-of-concept that would address the challenges that we aimed to solve in this project. The intellectual challenge was to investigate how an Intelligent Energy Management system could be made more cost-effective.

Chapter 2 has provided the fundamental towards the existence of a Smart Home by explaining the Smart Home system's formal definition and outlined a history of it and home networking technologies and identified appliances. This chapter has also provided a synopsis of current research projects and recent development.

Chapter 3 has investigated in more detail the methodology that is used to complete this project. The methods are divided into two parts which is hardware tools and software tools. Flow of the project was also identified and the project key milestone has been provided to give brief understanding on the flow and timeline of the project throughout completion.

Chapter 4 has dealt with the actual development of the prototype of a Smart Home system. The system and sub-system requirements were outlined in details providing specifications and knowledge behind every components used in this project. In this chapter, the basic blocks of a Smart Home system was explained and has provided an overview of home network communication protocols.

5.2 Recommendations for future work

One of the main challenges in this project is to provide a web-based application for the Intelligent Energy Management System. Future work should develop a web-based User Interface and offer the implementation of fundamental web service because this will give support to various web-based clients which will allow mobile and remote users to connect.

Besides that, general recommendations on the design of Smart Home systems can also be provided. First, it is suggested that the user's need should be the ultimate priority for producers of Smart Home technology as they should extra time and effort to try and understand users' needs before developing new product. They should also assure full understanding from their potential users of the capability of their solutions.

Second, high implementation costs and ineffective solutions were due to the lack of expertise available in the industry. On the other hand it is believe that this technology can satisfied many needs and fulfill most of the concerns. All the challenges that encountered can be reduced by implementing the precise methodology and using the correct approach. Smart Home systems can be more effective with cost-effective and reliable if supported technology is available and tremendous research fields are done to give a contribution.

CHAPTER 6

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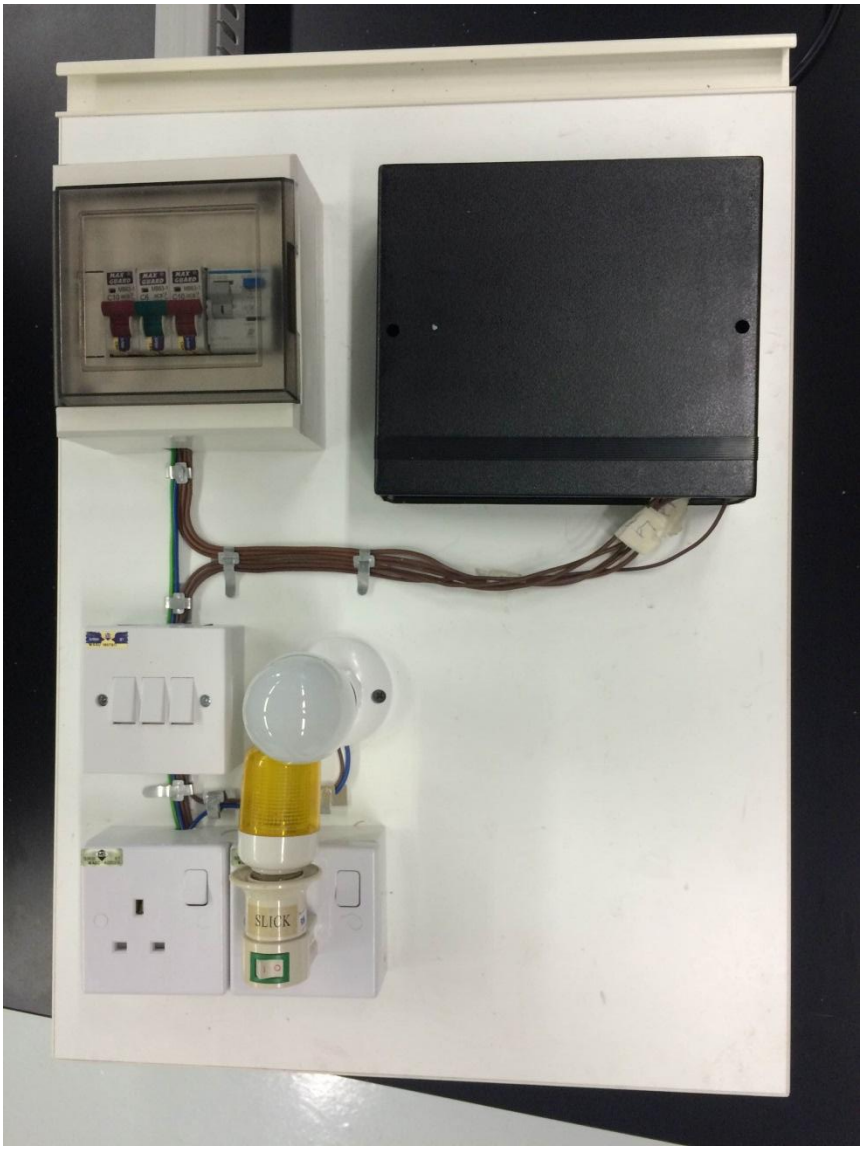
APPENDICES



Prototype of Intelligent Energy Management System in a Residential Building