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Automated Energy Saving System Using Occupancy Sensor

Dania Khan[1], Hasnain Sario[2,*] Fatima Riaz[2], Muneeza Sanam[2], Muzzamil Ahmed[2]

[1]Department of Electronic Engineering, Mehran University of Engineering and Technology, Jamshoro, Sindh, Pakistan
[2]Department of Electronic Engineering, Quaid-e-Awam University of Engineering, Science and Technology, Nawabshah, Sindh, Pakistan

*Corresponding Author

Abstract: Buildings consume large amount of energy in Pakistan such as: School/ University, office etc. As a result, a large amount of energy is being wasted. The largest and fastest-growing application for lighting controls is energy management. To reduce the electricity consumption in Electronic Department's building, we first measured and analyzed the energy consumption of the building before and after the implementation of occupancy based energy saving systems. Occupancy sensors are used to control various devices (like Heating, ventilation and air conditioning devices, tube lights, fans, projector etc.). After studying various research papers, we came to the conclusion that by using occupancy sensors, we can save the energy of Electronic department up to 30% for lights, fans and projector. Almost all sensors which are used with the energy saving system use timer (preset) which will produce a time delay (when the last motion is detected by the sensor, the lights/fans will be turned OFF after certain period of time which is set by the timer). If this TD set by the Arduino is long then, it will save less energy, as the load will remain switched ON during unoccupied period also. At the same time, if the TD set by the Arduino is short then it may result in false detection (false OFF) of the lights and fan when there is no motion detected. In our research, we have observed that the energy consumption of may change over the day, also the activity of different user is different. Therefore, multiple time day will be suitable based on the activity of particular user. In this paper, we propose the design of automated energy saving system in which we will can change the time delay according to the needs of user. A model is also suitable for a person who is sitting at one position and working at a computer. Automated energy saving system had understood the variations in activity level of the user with respect to their working hours. Based on this information, it can change the time delay according to the working hours of the user. We have perform an experiment that our proposed system will save the additional 5% of the energy with multiple time delay.

Keywords: Energy Saving, Energy harvesting, Occupancy Sensor

1. Introduction

The higher energy consumption may results into higher costs of bill. One of the method to reduce the cost of energy consumption for the user is to increase the efficient usage of energy, such as using energy saving systems and deactivates electrical/electronic loads when they are not in use, this can be achieved by using the sensors such as occupancy sensor [1]. Occupancy sensors are the type of sensors which has been replaced the manual light control to automatic controls the load based on the user's presence or absence in the specified area. Basically, there are there detection technologies are been used in occupancy sensors: PIR (passive infrared), ultrasonic and dual

*Corresponding author: 18es42@quest.edu.pk

(combination of PIR and ultrasonic). Passive infrared sensors (PIRs) detect the presence of human in term of infrared waves. It uses two pyro-electric sensors [2]. Infrared waves are basically the temperature. The PIR sensor compares the two temperature differences (when person enters, his room temperature is higher than room temperature) so after differentiating these two temperatures, the PIR will indicate that it has detected the presence of the person. The PIR sensor will be used with relay and Arduino module to control the state of lights [3]. If the motion detected than the lights will be turned ON. If the motion is not detected in a specified time delay that is set by the Arduino, then lights will be turned off after that certain time delay. The lighting system is turned off the time delay is given by using Arduino, we can also vary this time delay based on the user requirements. There are multiple sensors such as ceiling mount and wall mount. To get the efficient detection in larger area, multiple sensors should be installed for effective sensing and avoid false detection. If the sensor is installed near HVAC system then it may results in false detection/false triggering [4].

In this work, we made a prototype of an automated energy-saving system using an occupancy sensor that will save energy in all four seasons. It is expected to save about 12-15% of energy via adopting this proposed system in the 18ES Class room. The proposed work saves energy by detecting the presence of people in terms of temperature, heat, and motion detection, in addition with the usage of the Pyro electric sensor the more focus on the presence of people can be acquired using the light parameter. If the presence of one or more than one person is detected using the proposed occupancy sensor-based system the lights will be in usage. If there is no detection of the people is recorded via the proposed occupancy sensor-based system the lights will be turned off automatically. This will save the energy that is wasted in the department of Electronic Engineering, QUEST Nawabshah at from lecture rooms, laboratories, and offices. Each unit of occupancy sensor is based on passive infra-red (PIR) sensor that detect the motion efficiently. It has a Fresnel lens which gives it a sensor a panoramic view. There is a green LED behind the lens that will detect when the sensor heard or seen something. There are three important parameters that are important for the sensor to work properly, that are: location, type, and setup.

- Location: The sensor must be installed at the appropriate position so that it can detect the presence efficiently. It should be installed at ceiling as well as on wall.

Type: This is the most important factor that must be focused when using occupancy sensor. Based on your requirement and the environmental conditions, the particular sensor must be chosen correctly that will best suited for the application.

- Setup: Few sensor parameters must be adjusted such as: time delay, sensitivity, and switching action.

In our work, we'll use the wall mount PIR Sensor that will detect the presence of the person and automatically turn the lights ON/OFF as per detection. The wall and ceiling mount sensor are efficient for motion detection. It has a cone shape detection (360 degree view) coverage area with 2 meters distance. In office and University buildings we have noticed that people leave the building without turning OFF lights and fan, results in significant amount of energy is being wasted. We had also noticed that there are certain security issues in banks, offices, and shops. So it is necessary to implement a energy saving system in the buildings to reduce the energy consumption. This system will work by using motion detection sensors which can also be used in security system.

2. Problem Statement

The significant amount of energy is wasted in University building as we have notices that most of the students leave the classroom and laborites without shutting off the light and other HVAC system. Even after the implementation of automated energy saving system, it is difficult to

determine how much energy will be saved because it is depended on few parameters as: occupancy patterns, user preferences, seasonal variations, and/or weather patterns, which are themselves extremely variable. Therefore the energy saving systems will be installed and comparison would be taken for before and after the implementation of the energy saving system [5-7].

3. Background and Literature Review

Researchers have long been research on energy saving for buildings but it has become a necessity by the year 2050 when the European Commission formulated the idea to decrease 80% of CO2 emissions [8]. This requires the reduction in consumption of energy. The total energy consumption of offices is of lights which uses 10% of the energy, this is the case of light technology is recent developments such as solid-state lights [9]. In modern sources of light, automatic energy control techniques are being applied to provide real-time energy control systems for offices. The main factors that determine the needs of offices are:

The period in which sunlight is available, and

The presence of user in the predetermined office area [10].

These factors can be obtained by daylight and by using occupancy sensors, respectively. Automated energy saving systems based on occupancy sensors have been used in offices to provide the energy saving up to 20-30%. Occupancy sensors are used in combination with daylight controls to provide maximum energy saving [11]. In recent time, light bulb and fan uses smart technologies to use occupancy sensors in smaller control zone that gives maximum energy saving in comparison of tradition light control systems. Optimally, lights are used in small control zone, since it is based on the occupancy sensor detection patterns of individuals. In North America, research have analyzed that, at the desk level, energy saving of light bulb and fan is about 40 to 42% compared to patrician office cases, where lights has been used according to the routine work and where lights are been turned ON and OFF manually [12]. In addition, some other researchers found that the energy saving percentage is different for different office cases and for different seasons. Consequently, as discussed by Chew et al., the results achieved are greatly different. The achieved results might be due to the different job timings and types of the users e.g., secretary or manager differing across the studies. Research found that, among other factors, different job timing and type cause a differ in occupancy pattern. Chang et al., presented the occupancy patterns for users could be classified into five different types, and argued that job characteristics are likely to underlie these distinct types. Hence, in office cases with users who differ in job type, energy savings might varied by number found [13]. And it is also noted that the energy saving system for desk level is difficult to implement. Instead, in particular cases, this system is suitable to achieve efficient light control in large zone, for example in subgroup or room. For example, in office area where all the users have the same type of job, therefore, maximum similar occupancy patterns achieved, at the desk level it might not be possible to get maximum energy savings compared to energy saving of room. To further analyze, the research is focusing on the influence of occupancy pattern variance on relative energy savings of various lighting control strategies that differed in control zone granularity.

In their work, Chew et al., argued that there may be variations in the achieved results of energy savings from occupancy-based lighting control might impede widespread implementation of smart lighting, in part, because of higher implementation cost of energy saving system. Therefore, it is necessary to find the no. of office employees where fine-grained lighting control will reduce installation costs. Moreover, in office buildings, it is necessary to compare the energy consumption of smaller area with larger area it is difficult to install a sensor network in smaller area . However, even in those cases when such a sensor network is present, control at a granularity level lower than the desk level might be preferred; at the desk level, further assessments and modifications in the

system will be required to work properly. As we know that, in rooms, the usage is almost constant throughout the day as compare to desk level when energy consumption is based on the job function time. In open plan office, the use of occupancy sensors might not be efficient; when the illuminance of the sensor is decreased then the lights will become dimmer and the user will be discomfort by this effect of sensor. Different researches have been used to develop the energy saving system that are mentioned as following:

Abidin et al. were among those 11 universities who have revealed that U.S. colleges Boston University adopted the installation of occupancy sensors to reduce energy consumption and energy efficiency initiatives, reducing the costs. Further research on energy reduction by energy control mechanisms can be concluded as Jeong and Seo developed an occupancy sensor based energy-saving system by using PIR sensor technology which detects presence of a person with the help of a Fresnel lens and a smart plug capable of measuring current consumption, resulting in savings of about 25% of electrical energy by eliminating the unnecessarily operated appliances. Hong et al. developed a system which saves the energy up to 65.2%. He develop this system by using occupancy sensors to reduce the energy consumption. In order to reduce light energy usage, Nam et al. perform an experiment in which they receive the 10% reduction in energy consumption by installing a PIR sensor in the classroom walls. After the detailed study, it has been found that the most efficient and accurate method for energy saving is achieved by using Occupancy sensor. In these papers, a solution has been proposed to prevent the wastage of energy.

4. Research Methodology

The university classes are held on a daily basis and offices are occupied as well on regular basis. The consumption is recorded for both winter and summer seasons. It was considered that there is no energy saving mechanism is installed at our university. The occupancy sensor-based system can adjust the lights when you're not present in the specified area this can be achieved by using Movement- and photo-sensors, timers and other smart technology. Motion sensors and other features will be the key techniques to cut electricity use and address inefficient and unnecessary lighting in and around the department. They are based on three motion detection techniques to detect presence due to Passive infrared (PIR), Ultrasonic detection, Microwave detection. After recording the energy consumption of our Department, we'll implement the occupancy based system to our department that will be able to sense the presence of occupant and automatically turns "ON" the light, and will turns OFF the light when the specified area is vacant. In our work, we want to implement the prototype of Automatic energy saving system by using occupancy sensor. At First, when energy saving system is not implemented we will record the usage of energy of our Electronic Department on daily basis. In second step, we will implement the occupancy sensor based energy saving system at our department. The occupancy sensor-based system also requires the dc power to run but that power is minimal and using the proposed occupancy sensor-based system the energy saving can be reached up to 30%. After the implementation of energy saving system, the energy which were wasted, will be saved by using the occupancy sensors. The occupancy sensor turns ON the light when specified area detect the presence and automatically turns OFF the light when the area covered is empty.

In the last step, we will compare the usage of energy before and after the implementation on the energy saving system. The whole mechanism of our work is shown in schematic diagram in the Figure 1

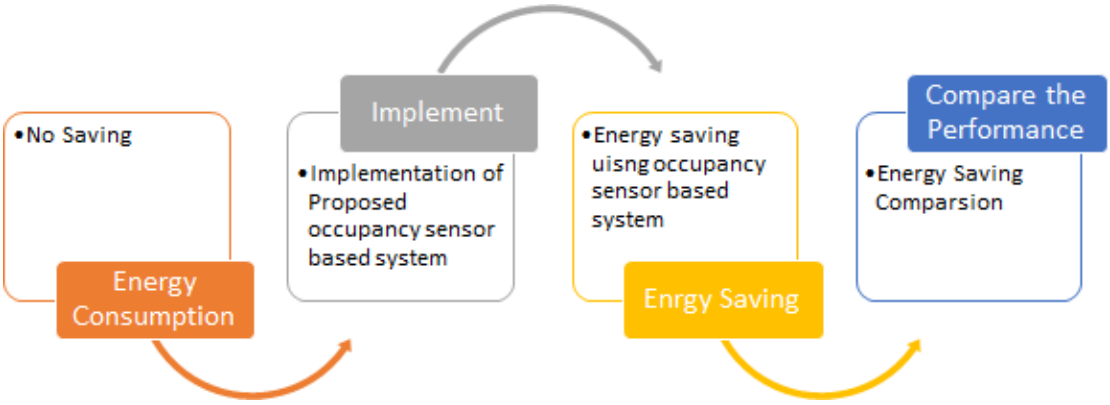


Fig. 1 – Design Methodology

Our work of energy saving is mainly based on three main components: PIR, Arduino NANO and relay module. PIR sensor will be used to detect the presence of a human. Arduino will be used to control the relay and set the time delay of relay to avoid false detection. The relay module is act as a switch. It will control the light bulb based on the state of PIR sensor. In electronics, transistor can also be used as a switch but here we use relay. As we know that the relay is a mechanical switch so it is used to isolate the main supply with the Dc supply of Arduino. Our work is based on occupancy sensor which will sense the presence of the person and control the lights to be turned ON/OFF. The state of the lights will be controlled through the relay module. Relay module will be act as a switch in the circuit. If PIR sensor detects the presence then a HIGH input signal will be sent to Arduino NANO and then Arduino will send a low signal to relay module which will turn on the lights ON. If there is no motion detected in specified time then after 5 minutes the relay will turn OFF the lights.

4.1 Hardwar Design

The circuit diagram of the work entitled energy saving system based on occupancy sensor is given below. This circuit is made by using Arduino Nano, Four channel relay module, PIR sensor and light bulb as shown in Figure 2.

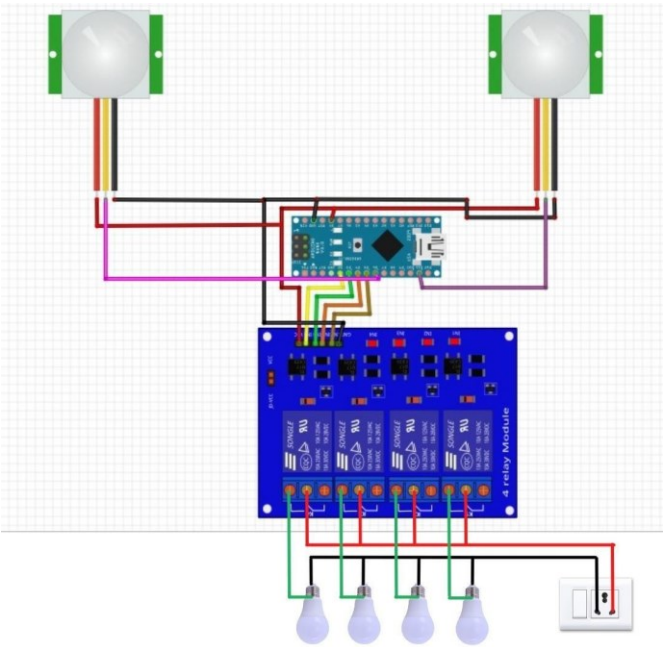


Fig. 2 – Hardware Design

This is main circuit diagram of our work, this is actually one prototype of work but we will use in our class room multiple types of this prototypes for better sensing and for better result. This makes our class room automatic which is sense reduces energy wastage and saves energy up to desired level. The work involves connection with 220V direct AC Mains (or 110V, depending on area where you live). Be extremely careful while connecting the bulb and Relay to mains supply. If you are not familiar with the connections of main AC supply then don't do connections by yourself, I strongly recommend you to work under the supervision of any expert.

4.2 Hardware Components Description

The components that are used in work hardware are PIR sensor, Four channel Relay Module, Arduino Nano and 9v Adaptor.

4.3 PIR Sensors

Two PIR sensors are used here. PIR Sensor's Data OUT Pins is connected to Arduino's Digital I/O Pin 9 and 11. The relay module's Pin IN1 is connected to pin 2 of Arduino board. A bulb is connected to mains supply through relay. One terminal of the bulb is connected to one wire of the mains supply. The other terminal of the bulb is connected to the NO (Normally Open) contact of the Relay Module. COM (Common) contact of the 4xRelay is connected to the other wire of the mains supply. Be careful when connecting this part of the work. A passive infrared sensor (PIR sensor) is a motion detection sensor that measures infrared (IR) light radiating from objects in its surrounding. Applications where PIR sensors are used is: security purpose and automated energy saving system as show in Figure 3

Fig. 3 – PIR Sensor

This PIR sensor module model no. HC-SR501 is consists of three output pins which are: Vic, Output and Ground as shown in the pin diagram above. Its output pin as 3.3TTL clock which can be used with microcontrollers like Arduino, Raspberry, PIC, ARM, 8051 etc. PIN description of PIR sensor is described in Table 1

Table 1 – PIR Sensor Module Pinout Configuration.

Pin Number	Pin Name	Description
1	Vic	Required input voltages are +5V
2	Output (Doubt)	3.3V required when motion detected and 0V for no motion detected
3	Ground	To ground the connection

Specifications of per sensor is discussed in table 4.2.1, in which input voltage range is 5V ~ 20V, power consumption 65mA, sensing range 7m and all other specifications are shown in given Table 2.

Table 2 – PIR Sensor Specifications

Features	Specification
Input	5- 12V
Consumption of power	65mA
Transistor to transistor logic (TTL) output	3.3V, 0V
Operating temperature	-15ºC to +70ºC
Delay Time	Adjustable (.3->5min)
Sensing Range	Less than 120 degree, within 7meter
Applied Triggering methods	L- Disable repeat trigger, H- enable Repeat trigger.

4.4 Four Channel (5V) Relay Module

In electronics, a relay is a mechanical switch that can open or close the contacts of a switch when the current will flow through it. The single-channel relay module is significantly more than simply a plain relay, it is based on the components which will indicate that the relay is powered or not. It make the easier connections. COM: Stands for common pin. NO: Stands for Normally open, when we trigger the COM pin, then the connections will be made between COM and Normally open and the load will be powered up. NC: Stands for Normally closed, When the relay is turned off, there is always a connection between NC and COM pins. There is no supply is provided to the load when you trigger the relay and the circuit is still remain open. In our work we use four channel relay module. It is consists of four 5V relays isolating components and associating switches to make the easy connection between the microcontroller and PIR sensor. Each relay is specifically used for 250VAC and 30VDC and 10A in each output load as show in Figure 4

Fig. 4 – Four Channel 5V relay module

The working principle of relay is based on electromagnetic force of attraction. When current flows from the relay it will energizes the surrounding electromagnetic field and produce a temporary magnetic field. There are different working operations of the relay so the relays are classified according to their mode of operation which are: Electro thermal relay, Electromechanical relay, Solid State relay, Hybrid relay.Relay module consists of six pins such as normally open pin, normally closed, common, signal, Vcc and ground pins as shown in Table 3

Table 3 – Four Channel Relay Module Pin Description

Pin Number	Pin Name	Description
1	Ground	Ground reference for module
2	IN1	To activate input 1
3	IN2	To activate input 1
4	IN3	To activate input 1
5	IN4	To activate input 1
6	VCC	Relay module power supply
7	VCC	Power supply to select the jumper
8	JD-VCC	Power pin will be altered

Module connection of 4 channel relay module with Pin Configuration:

- GND PIN = used to provide ground
- IN1 PIN = This is active low pin which is used to energize input 1 when low signal is applied.
- IN2 PIN = This is active low pin which is used to energize input 2 when low signal is applied.
- IN3 PIN = This is active low pin which is used to energize input 3 when low signal is applied.
- IN4 PIN = This is active low pin which is used to energize input 4 when low signal is applied.
- Vcc = Used to supply 5V Dc power.

Relay are the electronic switches which are used to operate the load through the help of microcontroller/ Arduino or the sensor. The circuit diagram of relay module is given below in Figure 5

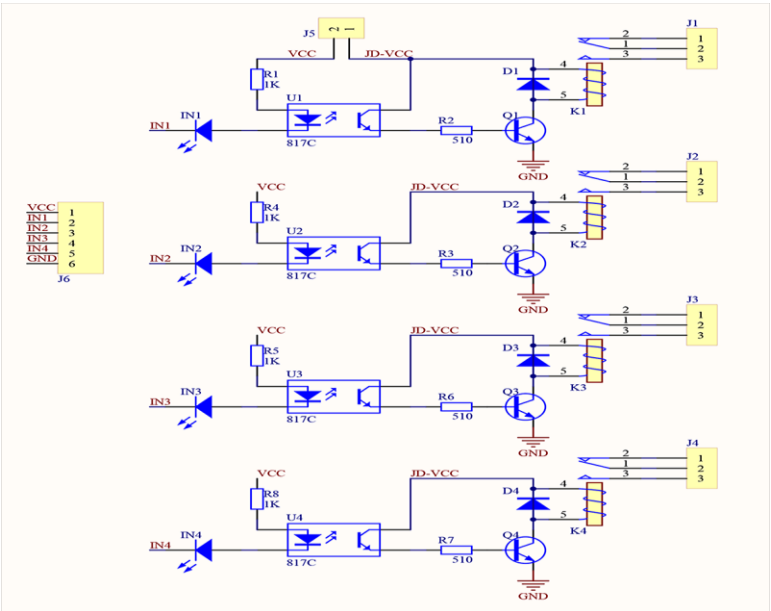


Fig. 5 – Circuit diagram of 5V four channel relay module.

As we know that the switches are used in turn ON/OFF applications so the relay module will be used to turn ON/OFF the loads by using above connections. Depending on the requirement that the load should be turned ON/OFF, one terminal will be connected to the common pin and the other will be connected to NC or NO pin.

4.5 Arduino Nano

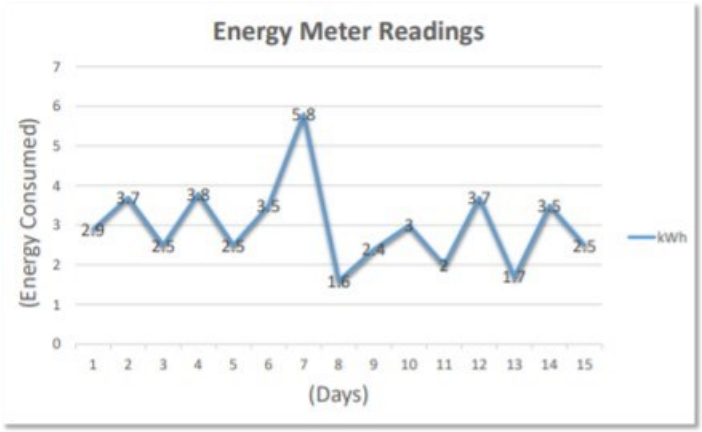
In 2008, the arduino.cc developed the Arduino NANO microcontroller which is flexible and easy to use for breadboard connections. It is small in size and has 30input/output pins, and is designed in DIP30 fashion. It is based on ATmega328p processor. It has a frequency crystal of 16MHZ, which uses constant voltages to produce the clock frequency. Every components has a limitation, so Arduino NANO also has a limitation that it does not use DC power jack to connect to the power supply, a mini jack will be used to power it up as shown in Figure 6.

Fig. 6 – Aurdino Nano.

Arduino is used in many applications and become very much popular in past few year. It is considered as the brain of the IOT based works. It is used worldwide by professionals, teachers, students, programmers and etc. to make their works on Arduino software. Ivrea Interaction Design Institute designed the Arduino software for people which are not even relative to the programming and electronic background to ease them in making their works. It is user friendly software. When this software become popular worldwide, then it was further modified so that it can be used in other industrial applications such as IOT, embedded system etc. The Arduino software and board is user-friendly that everyone can easily use it without the background knowledge of electronics and make their works based on their needs. Software is available on internet as open-source, anybody can download it and use it without any difficulty. The Arduino IDE stands for Integrated Development Environment. It is consists of a text area to write the program for the work and also a message area where an error will be shows up if there is error detected in a work code, a toolbar which have number of options to select the desired options according to the requirement. The program which you write on the Arduino IDE will be used to connect the Arduino board with the hardware circuit of the work to respond according to the requirements. The program which you write for your work is called as sketch, which are to be saved with file extension. You can edit, replace or search your code in text editor. The console contain the entire information of the code including code errors and displays the output of the code. The bottom right-hand corner of the window displays the configured board and serial port. The toolbar buttons allows you to verify your code, upload programs to the Arduino board, create the code for the work, open the recent one program, and save sketches, and open the serial monitor to monitor the analog data. In the next, results achieved form the designed work are discussed.

5. Result and Discussion

To determine the total amount of energy consumption of our final year class, we install the energy meter at the main power supply unit. The below shows the total energy consumption of 15 days as show in Figure 7.



Analysis	
Total Energy Consumed	43 kWh
Total Consumption Time	62 Hours
Avg. energy Consumed per day	2.86 kWh
(EC/h) Energy Consumed Per hour	0.697 kWh

Fig. 7 – Energy Consumption Graph.

The results achieved from the analysis of automated energy saving system is sensed by using the PIR sensors. According to the status of sensor the lights will be turned ON and OFF through relay module. If the sensor detect the presence then lights will be turned ON automatically. And when the person leaves the room, the sensor will detect that no presence is detected at occupied area, after 5 minutes it will turn OFF the light. The sensor only detect the presence, it will send the signal to relay module, and then relay module will turn ON and OFF the lights. According to our research we assume that our proposed system will save the energy up to 15%. To control the sensor and relay module we need a controller so we use Arduino Nano microcontroller in our system. The complete designed of hardware is show in Figure 8.

Fig. 8 – Automated Energy Saving System

When the PIR sensor detected the presence, it send the HIGH input signal to relay module and it turns On the light bulb as shown in our project prototype in Figure 9

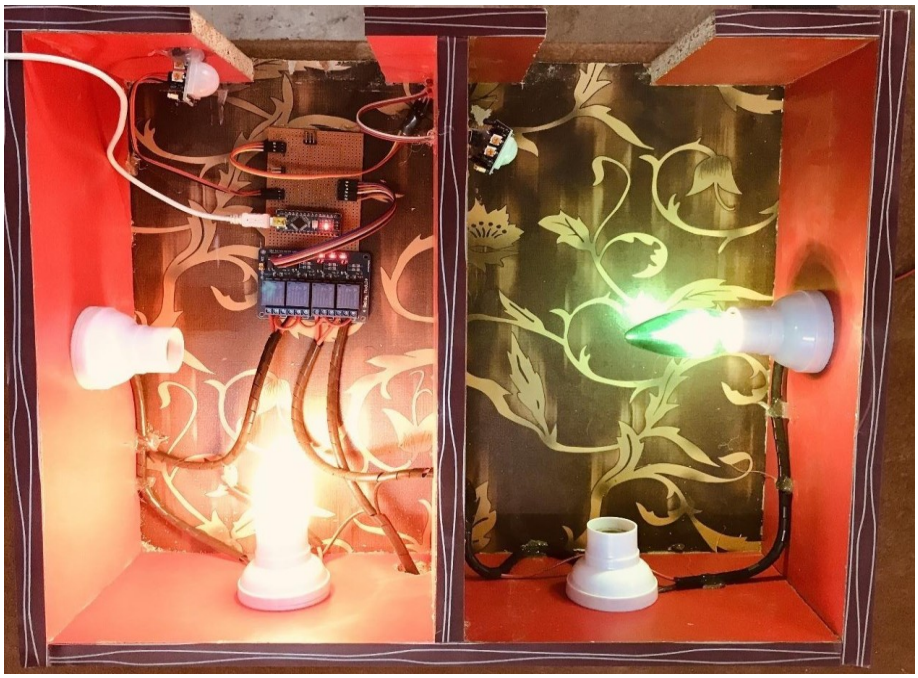


Fig. 9 – When the present of persons is detected in the room

When the PIR sensor does not senses the presence then low signal will be sent to the relay module and the lights will be turned OFF. Here we also set the timer, to avoid the false detection problem. After 5 minutes of sensing that no one is present in the room, the bulb will be turned off through relay module as shown in Figure 10

Fig. 10 – When the absence of persons is detected in the room.

To analyze that how much amount of energy is being wasted at our department, we perform an experiment for 15 days that can determine the approximate energy wastage.

- Analysis of Experimental based observations.
- Time Duration of Energy Consumption without presence of students.

Analysis	
(TTC) Total Time of Consumption	12 hours
Avg. Time per day	48 m
(EC/h)x(TTC)	0.697x12 = 8.364

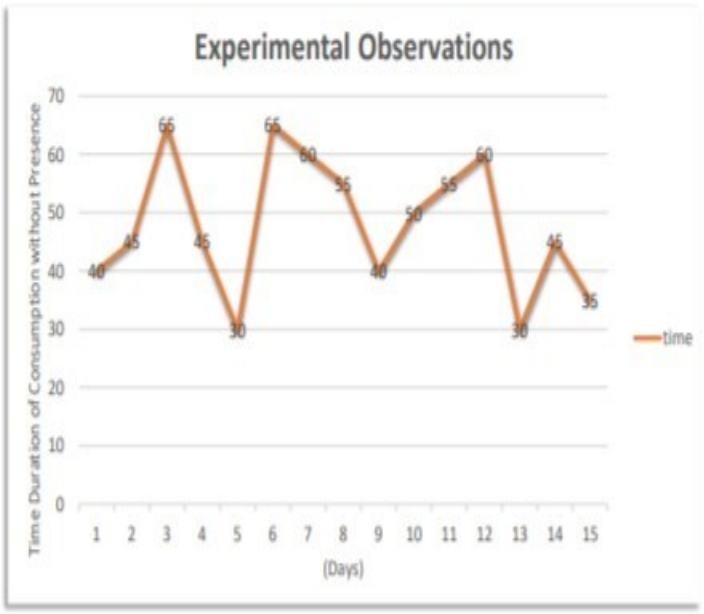


Fig. 11 – Experimental Results.

We found that the total hours in which energy wasted in 12hours when no one were there in the class. And determined that daily 48m the class were empty and energy were being wasted approximately. After that we determined that the total 8.364KWH energy were wasted in 15 days. After mathematical calculations, we found that, by implementing our proposed system, we can save the energy up to 12- 15% of the energy.

6. Conclusion

In this work, we proposed an automated energy-saving system using an occupancy sensor system for Electronic department that will save energy in all four seasons. It is expected to save about 12-15% of energy via adopting this proposed system in the University Building. A vast amount of power could be saved by using an automated energy saving system based on occupancy sensors. Unlike the other traditional lighting system which can waste large amount of energy, occupancy sensor based system is able to minimize the costs and yearly energy consumption. By using occupancy sensor, we can make an energy efficient system and also minimize the overall yearly expenses. Occupancy sensor-based system has long life and consume less energy. The initial installation cost for such systems are higher but other normal systems but, the maintenance is easy which make it best choice to implement such systems.

The prototype of energy saving system project saves energy by detecting the presence of people in terms of temperature, heat, and motion detection, in addition with the usage of the photo-electric sensor the more focus on the presence of people can be acquired using the light parameter.

This will save the energy that is wasted in the department of Electronic Engineering, QUEST Nawabshah at from lecture rooms, laboratories, and offices. It is expected that the proposed project will save about 12-15% of the energy that is wasted before implementing this proposed occupancy sensor-based system. The project is considered to be cost effective and has replaced the traditional lightening system which produce the higher costs and energy wastage other planned

refurbishments, which could remove existing constraints such as ceiling type or height, space, layout for improved future gain.

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