ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY

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PROGRAM OF ELECTRONICS AND COMMUNICATION ENGINEERING

Design and Implementation of Automated Electronic Switch for Electrical Energy Saving

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Abstract

Electricity was one of the most important discoveries in science. Humanity in this generation depends much on the usage of electricity. The modern technology cannot exist without electricity. Even though there is large production of electricity in our country from different sources (such as hydropower, solar, wind and geothermal), there is a large wastage due to the way we manage the produced power and the equipment we use in our day today life. It is very frequent to see a power fluctuation in every side of the country. We have investigated that most of the electrical systems in the country are controlled by manual controllers which may cost us for unwanted energy consumption by different electrical loads including lighting systems.

The use of automated controllers is more efficient as compare to manual controllers. In the design consideration of automated controllers, the power management of the controller itself was necessary in order to minimized fire caused by appliances. Most of the available design of the automated controllers in the market had a standby power that may cause electrical power consumption and fire. As the appliance become older some of the parts may produce heat and when this heat is accumulate, it may generate fire. For this reason, most of the consumers unplug the appliance from the wall outlet. The result is very significant in reducing fire hazard caused by electrical appliance due to un attended use, reducing electrical energy losses by 300% due to unawareness of the status of manual controllers. The system functionality was tested by PROTUES and Micro_C in addition to this, a prototype is developed and tested for its functionality.

Keywords: microcontroller, automated switch, energy saving, automated switching system, energy loss

List of Symbols / Acronyms

A	ampere
AT	ampere trip
AWG	American wire gauge
CO	convenience outlet
E	energy
I_{max}	maximum current
kΩ	kilo ohms
KW	kilowatt
KWh	kilowatt-hour
LED	Light Emitting Diode
LO	lighting outlet
Ω	Ohms
PCB	printed circuit board
PIC	programmable interrupt controller
P	power
sw	switch
TW	twisted wire
V	voltage
AES	automated electronic switch
SSR	solid state relay
PIR	passive infrared
AVR	Automatic Voltage Regulator

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1. Introduction

One of the biggest challenges of electrical engineers of the country is designing a system that disconnects the appliances connected from the line in the absence of users in the area. Many automated switches are available in the market today, but these available automated switches consume power even when the appliances are already turned off. Thus, these switches consume a standby power. The most common switch is the occupancy switches. This switch detects the presence of people inside the room and turn on the appliance automatically. Using this type of switches are not 100% safe in terms of fire because it always requires power in order to detect the presence of users inside the room.

According to the fire protection agency (FPA), the most causes of fire in buildings or homes are those appliances which are unattended.

According to Mekonnen Kassa of the Ethiopian Rural Energy Development and Promotion Center, there are lots of energy losses based on the un-attended uses of electricity [1]. The consumers may always leave the room or offices without switching off the lights or other electrical consuming devices.

In order to ensure that all lights are switched off and the appliances are disconnected from the outlet, automated switches are used to control the lights and appliances. Research shows that most common available automated controls in the market require power in order to sense the occupancy of the certain room. The aim of this study is to design an automated switch that will also switch off all the lights and disconnect the appliances from the outlet from the room including the controller. When the power is off from all the connected appliance load, the automatic electronic switch is also turn off. And no power is flowing from the system. Thus, in this way all the loads in the room are totally disconnected from the power source.

Figure 1 shows the block diagram of AES (automated electronic switch). The controller is the heart of the circuit. Embedded programs are stored in the controller. Even though any microcontroller can be used,an 8 pin microcontroller is preferred in the study in order to minimize the size of the hardware. The controller controls the solid state relay by giving some voltage across its control input. The solid state relay (SSR) used to connect from the power source to the load and to power the controller. The low voltage power supply gives power to the controller. The SSR supply power from the source to the controller via low voltage power supply. Room sensor is used to detect whether the room is occupied or not.

The sensor gives signal to the controller to activate the SSR. It is known that the only way to access the room at normal procedure is through the door. The sensing of the occupancy of the room is based on the opening of the door. Power sensor detects the presence or absence of the power from the system. The power sensor activates the other SSR when the circuit is turned off. These give an alternative power for the controller during the total shutdown period of the system and regain the power from the power source. The operation of the said SSRs follows the logical OR gate function in the digital system.

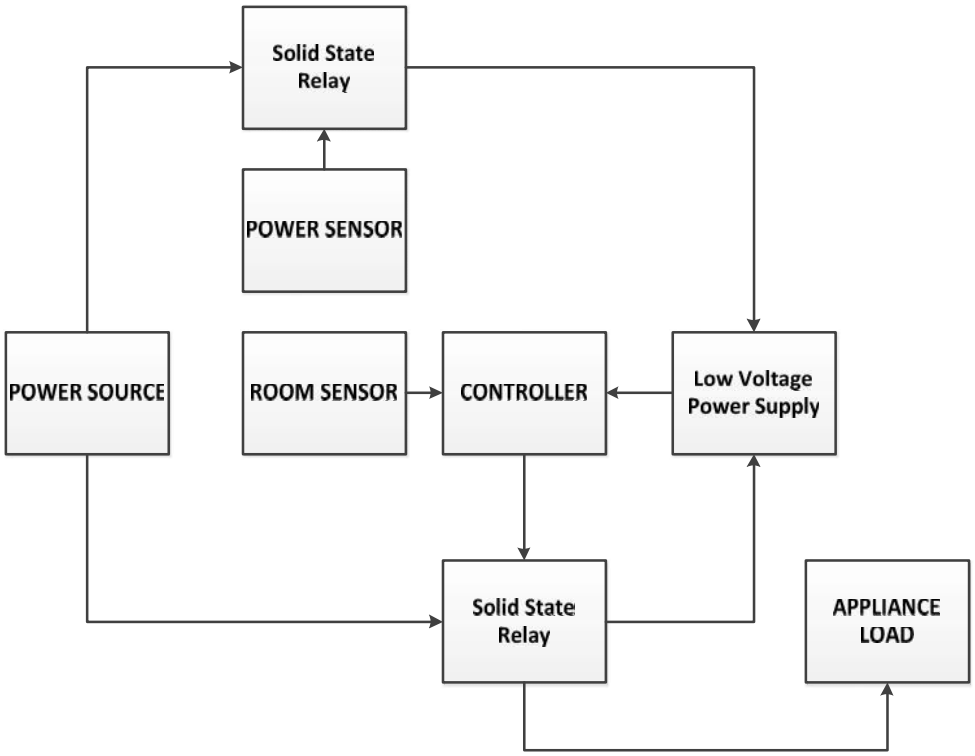

Figure 1.1 – Block Diagram of Automatic Electronic Switch (AES)

1.1 Background

Ethiopia is Africa's oldest independent country and it is second largest in terms of population.It served as a symbol of African independence throughout the colonial period, and was a founder member of the United Nations and the African base for many international organisations [2].

Different universities and colleges are established in this country owned by private or government.

Some advanced countries like USA, Germany, Britain, Korea and even China starts introducing different technologies to improve the lifestyle of the people. And most people in this country are adopting these technologies. But this technology requires power in order to operate. Due to these requirements of technologies, people around the country in the offices or even homes plug-in the appliances unattended. Some office workers both in private and government institutions left their lights and electrical appliance switch-on even when they are not using it. But the problem isseverin the classrooms for which students and teacher may forget to turn-off the lights when they are out of the room. Most of the classrooms are being left by not switching off the lights. Some of these classrooms are being locked without inspecting whether the lights are switch-off or not especially during night classes. This may results to the lights to stay switched-on over the nights. These things are common attitude of most of the users. Due to this attitude, energy consumption is increasing without knowing the reason of the increase.

1.2 Statement of the Problem

Even though most electrical appliance Manufacturers stateas their products cannot cause fire, the experience of most fire investigators is that electrical appliances frequently do cause fire. One of the most common reasons for fire is through misuse by the owner; however from experience another prevalent factor is component fatigue. Design faults are also a common fire cause and this is reflected by the significant number of recall notices issued for television sets, heaters and cooling fans in recent years [3].

According to Charles Dawes, Energy consumption is the product of the power of the load and the time it is being used [4]. In order to save energy, the time usage must be reduced of the certain equipment. Thus, controlling the specific equipment and light when not in use is the best way to reduce electrical consumption.

From the latest news on the internet, many appliances were burn while they are being used. This may lead from burning the house or building if it will be left unattended. Thus; for some advices from the fire protection authority, if those appliances are not being used it should be disconnected from the outlet.

The Automated Electronic Switch will automatically switch off the appliances when the user is not around in the room or office. The circuit is designed to consume a minimum current in order to save energy from the system.

1.3 Objectives:

1.3.1 General objective

The main objective of this project is to develop an automated electronic switch that can be used to disconnect the appliance load when the room is not occupied to minimize the cause of fire and save energy.

1.3.2 Specific Objectives

- To assess the existing electrical system.
- To design the electronic circuit for the automated control switch.
- To simulate the design model circuit.
- To develop the prototype hardware circuit.
- To test the efficiency of the automated electronic switch
- To calculate the energy saving with the automated electronic switch and the efficacy of the system.

1.4 Significance of the Study

The significance of the project includes but not limited to the following.

- Save energy consumption.

  From the California Energy Commission, “Lighting is one of the largest users of energy in the classroom. By turning out the lights when a classroom is unoccupied, the school can save money. The school may also want to consider "occupancy sensors" that detected whether there are people in the room. If no one is there, the switch turns off the light” [6]. Classroom plays one of the major energy consumption especially when the lighting used is not the energy saving lights.

- Reduce the causes of fire.

  Study shows that major causes of fire in homes, offices or buildings are due to electrical failure. But the most significant reason for this causes are on the appliances which are connected to the outlet unattended.

  Lamps, toasters and even baby monitors can short out. Strong care should be given to older appliances and extension cords. Even new appliances can be the source of a home fire. To be safe, appliances should be unplugged when not in use. Unfortunately, not all appliances can be unplugged, leaving your home at risk 24 hours a day [5].

  Unplugging appliances in rooms and offices when it is not occupied is the best way to reduce the causes of fire. But it needs dedicated individuals to do such things. Not all users in the rooms and offices have such dedicated attitude to perform such. Most users just only turn off the appliances without unplugging from the outlet. These appliances still consumed electrical energy from the outlet. Thus; it tends to generate heat while nobody is in the room or office. And it will cause fire at the long run.

- Automate the electrical control at minimal cost.

  Essential actions such as switching off computers and all electrical equipment will make a significant difference immediately [7]. Because the best way to save energy is not turn off appliances when not in used. The world is promoting energy saving devices in homes and offices. Most of these devices use complicated technologies that are used to save energy. But the main goal of these devices is to turn off automatically the appliances by means of timers and other programmable controllers. But some of these devices are expensive that to the extent that it is only available in advance countries.

  Low cost production and quality assured devices are necessary in order to achieve the goal. The installation of the automated switch must be minimal in order all people around the globe can use it.

- Use the available resources for developing the hardware.

  Designing without actual materials and components to be used is useless. The country always imports materials from other advance country. Some materials maybe available in the country but not the same materials as what is found in advanced country. It needs some modification and innovation in order to use these available materials. The design of the circuit follows the availability of materials. Reverse engineering design was used in order to achieve the goal.

2. Literature Review

Energy saving is one of the most burning issues in the world today. Advanced countries invest millions of dollars for research and development on energy saving appliances.

Electrical lighting plays important role in every buildings and homes [8]. Lighting is also one major area of electricity consumption and it is estimated that about 19% of global electricity is consumed for lighting. This comprises of both indoor and outdoor lighting [9]. Unmanaged lighting system may increase energy consumption. Aside from increasing energy consumption, it may contribute the cause of fire in the buildings or home. Lighting fixtures are one of the most accounted causes of fire [10].

"A lighting control system is an intelligent network based lighting control solution that incorporates communication between various system inputs and outputs related to lighting control with the use of one or more central computing devices. Lighting control systems are widely used on both indoor and outdoor lighting of commercial, industrial, and residential spaces. Lighting control systems serve to provide the right amount of light where and when it is needed" [11].

Turning off the lights when not in use is energy conservation. But replacing the old lamps with low power consumption with the same effect of lights is energy efficiency [9]. Unplugging appliance can save energy consumption and prevent the cause of fire [12].

Common attitude of people is to leave the room by not switching off the lights. But sometimes switching off the lights manually seems forgotten by common people. An automated control that will automatically turn off the lights when nobody is around the room can help resolve this problem [13]. Manually controlling the lights are laborious and are prone to errors.

According to Lutron Company, "Lighting accounts for 39% of building electricity usage (Energy Information Administration, 2003, Commercial Buildings Energy Consumption Survey, released September 2008).Lighting energy savings exceeding 60% is frequently reported by customers using automated control solutions as part of an overall energy-savings design program" [14].

The lighting automation offers different scope for conservation[15]. There are different designs which lighting automation control can be applied. Most common designs are by using PIR sensors that detect any motions and then sends some signal to controller circuit for turning on or off the lights. The controller is the heart of the automated control.

Computers are the basic controllers that can be interface to the lighting control circuit. It will allow the designer write programs instruction to either turn on or off the lights [16].

Using computer for controlling lighting system for room is not cost effective. Computer consumes lots of energy and is more sensitive in power fluctuation. Today most home automation uses embedded controllers for automated actions. These embedded controllers are similar to computer but the power consumption is less than 0.3 watt. This controller contains RAM, ROM, microprocessor, and interface for the lighting system [17]. The embedded program is installed in the controller chip itself. This program is the instruction sets for the embedded controller hardware. The ability of the automated control depends on the programs installed in the controller chip.

The use of interface hardware play important role in the automated controls. The embedded controller uses 5V output and input DC voltage. The lighting system uses 220Vac. In order to interface the low voltage to high voltage, SSR must be used as interfacing. According to STMicroelectronics, "the TRIAC is the least expensive power switch to operate directly on the 110/240 V mains. Thus it is the optimal switch for most of the low-cost power applications operating online. The logic level or snubberless TRIACs can operate with low gate current and can be directly triggered by the MCU" [18]. This TRIAC usually used as solid state relay to interface the microcontroller to high voltage system. Using this solid state relay controlled by microcontroller, the loads can be turn on and off immediately.

Unplugging the appliances from the outlet is the safest way of preventing fire caused by the appliances. Some appliances consumes power even it is turn off. Due to the period of time, these appliances will deteriorate and eventually starts the fire. The best way to protect appliance from heating is to unplug it when nobody inside the room.

A solution to automated control system is an embedded control system. It consists of sensors and actuators. It is like a computer built-in with different interface [19]. Using this type of system the application to the control system became easier. Embedded programs are written for the instruction of the controller. The sensor can be connected to the controllers and instructions set are easily being written to interact with the sensors. A close loop system can be adopted in automated system. The sensor can serve as the feedback to the embedded controllers.

There different types of embedded controller available in the market. Among the leading embedded controls are PIC microcontrollers, AVR, and ATMEG. Arduino controller is

one of the most easily used in most of the automated control system. It is an open source embedded controller that can sense from the environment and perform specific action [20]. Another microcontroller that can suite in any application is the PIC microcontroller. It can be customized easily based on the required application. It can operate at high speed and low cost in implementation. The power consumption for this type of controllers is very much lower as compared to the other controllers [21].

Automated control system design uses lower power consumption cause it run at 24/7 without interruption. Using system with high power consumption may add the cost of operation of the system.

3. Methodology

This section describes the methods that shall be used to conduct the study. It is composed of the following major activities namely:

- Conducting an assessment to the existing electrical system of every classroom. The purpose of this activity is to determine the standard electrical connection and assess whether the existing connection conform to the electrical code of Ethiopia. And also this will give an overview on the actual load in the specific area.
- Designing the electronic circuit for the automated control switch. There are different types of design for automated control switch which are available in the internet. But these designs are based on the area which the design will be implemented. Designing electronic circuit includes the verification of the available materials and component in the area to be implemented. This activity includes verification of the availability of the different materials and component. This ensures that the design model is suitable for the Ethiopia.
- Simulating the design model circuit. In order to come up with a good design and lower the production cost of the prototype hardware, some simulation software are used. The PROTEUS software is used for simulating the output of the circuit. This activity includes the simulation of the design of the actual prototype printed circuit board (PCB). The said activity is used for verification of the results of the design. Error correction prior to the implementation of the actual hardware can be seen in this activity.
- Developing the prototype hardware circuit. The development of the prototype of the automated electronic switch includes some activities:
  - List of materials needed.
  - Purchasing the materials and component.
  - PCB layout
  - Soldering the component in the PCB
  - Assembling the hardware
  - Writing the program into the microcontroller

  In this activity the design circuits are converted into actual hardware based on the available materials and components in the country in order to minimize the cost of importation.

- Testing the efficiency of the automated electronic switch. Actual test are conducted to ensure the efficiency of the prototype hardware. Using different electrical instrument to measure the different electrical parameters of the prototype hardware. Some quality assurance standards are followed during the testing of the prototype.Performance evaluation will be done by some selected authority by the university to test the efficiency of the said project. Some criteria will be provided by the researcher during the performance evaluation of the project to ensure that the project pass the international quality standard.
- Calculating the energy saving and efficacy of the automated electronic switch. In order to fully test the system, some sample computation regarding the energy savings of the system. The computations are based on the data gathered without using the system comparing its results to the data gathered using the system.

4. Results and Discussion

This section presents the results of the research project. The discussions on the results of the research project are presented in this section.

4.1 Assessment of the existing electrical system in the room

The Ethiopian Electrical Code was used to standardize the electrical installation in every building throughout the country. The said code is used to determine the sizes of conductor for every wiring installation that is made in all the building for commercial and residential establishment. And it is mandatory that all buildings must follow the electrical code to maintain electrical safety in the building.

Table 4.1 – Conductor Sizes and Protection Used in the building

Conductor Size	Circuit Protection	Purpose
TW, AWG#14, Solid Wire	15 AT	Lighting Outlet
TW, AWG#12, Solid Wire	20 AT	Convenience Outlet

Table 4.1 shows the conductor sizes used in one of the buildings of ASTU. It was shown that AWG #14 and AWG #12 with 15AT and 20AT circuit breakers were used for light outlet and convenience outlet respectively. This room follows the electrical code.

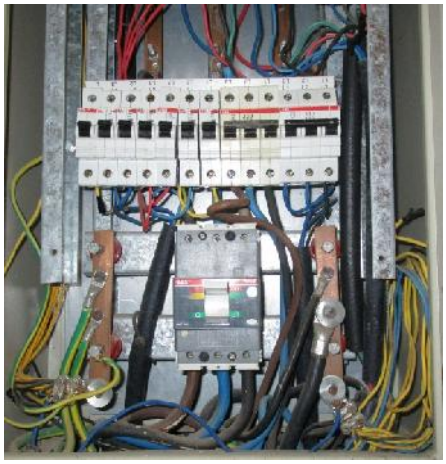

Figure 4.1 – The Main Board

Figure 4.1 shows the main breaker connection in each building. The main board consists of the branch breaker and the main breaker. The main breaker used for this building was 100 AT. The branches consist of 15 AT for the lighting circuit and 20AT for the convenience outlet. The main panel board consists of 6 branches used to protect every

room. The electrical system of each office room was directly connected in one main panel board in each building. The one sub-circuit was assigned to each circuit breaker as protection for every room. The control of power in each room was through the panel board.

Each room has SPST switch to turn on and off the light manually. The outlet in each room was used for some office equipment. Some of the rooms use extension wire to extend the outlet with other equipment like for charging mobile phone and etc.

Table 4.2 shows the typical load for one small office which is composed of room light, appliances such as computers and other small load equipment. This includes the mobile phone chargers, small power supplies, and small portable gadgets connected to the outlet.

The time hour used refers to the official time for the office staff using the room. And it is excluded when the staffs goes out the room to have some meetings or other office business outside this room. The total required watt-hr is about 6080 watt-hr.

Table 4.2 – Common Load Usage in a Minimal Room Office

No	Load Description	Watt	Time Hour Used	Total Watt -Hr Used
1	Light	160	8	1280
2	Appliances	500	8	4000
3	Small load equipment	100	8	800

Some of this appliance load stays connected in the outlet consumes power even it is turned off.

Figure 4.2 – Common Small Appliances

Figure4.2 shows some commonly known small appliances used for testing. It was found out that the mobile charger consumes power even if it was not charging the mobile phones, and was found out that it consumes 158.4 watt-hr per day.

Some of appliances when always connected increased thermal temperature of about 40 degree centigrade. Others more than the thermal limit of the appliance.

Sometimes the appliance load may not be disconnected when the users went out the room. It was a common practice by the staff users not to disconnect those small appliances from the outlet when it was already turned off. Sometimes during weekends these small appliances were still connected leaving it unattended.

According to Bruce Nordman, an energy efficiency researcher at the Lawrence Berkeley National Laboratory, as a general rule of thumb, the bigger—and older—the device, the more power it sucks up while it's off. So it's much more effective to unplug the decade-old TV in your guest bedroom than the phone charger that you bought last year [22].

Although the room electrical system follows the electrical code of the country, the fault may occur from this appliance connected to the outlet.

4.2 Designing the electronic circuit for the automated control switch

The design of the automated control was divided into hardware and software design.

4.2.1 Hardware Design

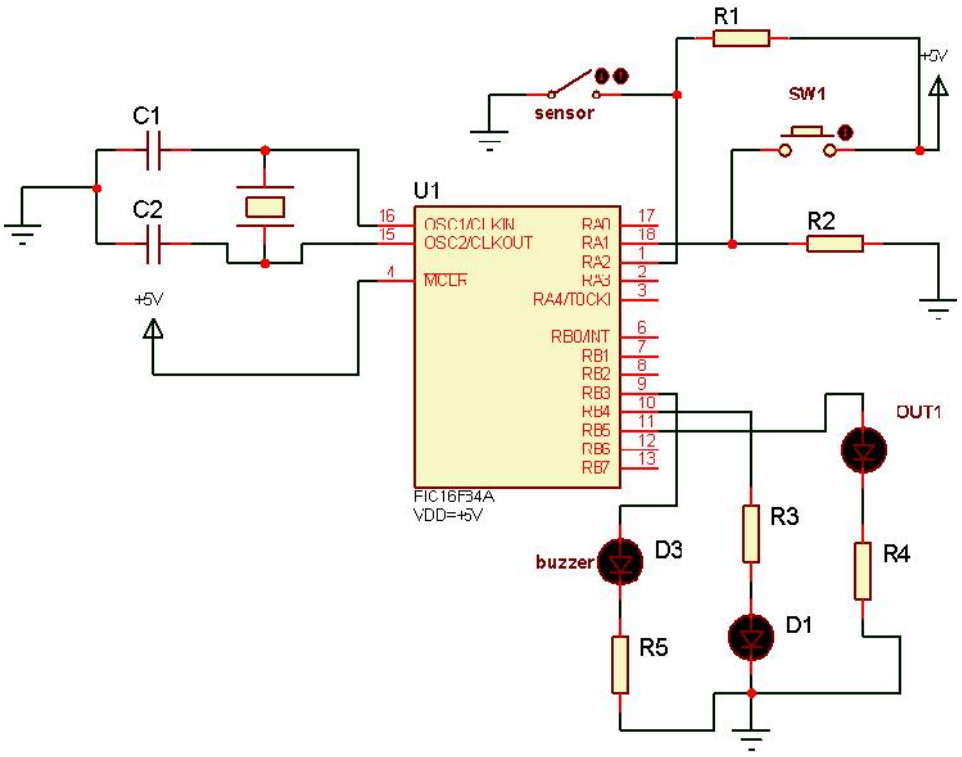

Figure 4.3 – Controller Circuit

The hardware design of the controller circuit was shown in figure 4.3. The circuit uses PIC16F84A as main controller with 4 MHz crystal oscillator. Based on the datasheet of PIC16F84A, the manufacturer recommends a 22 pF ceramic capacitor as filter capacitor in the crystal oscillator, and 10 kilo ohm resistance for the pull down resistor in the input side of the microcontroller.

The occupancy sensor for the room used in the design was a reed switch which reacts with magnet. It is placed in the door of the room. And the other side of the door was a small magnet. The reed switch detects the door status. The normal procedure of entering the room is using the door. Thus, the proponent decided to use the door also to monitor the occupancy of the room. The buzzer in D3 was used to trigger the alarm informing the occupant that the door was open and closed. The SW1 was used as the reset switch to turn

off the alarm. The output of the microcontroller was connected directly to the SSR driver circuit. The SSR circuit was shown in figure 5.

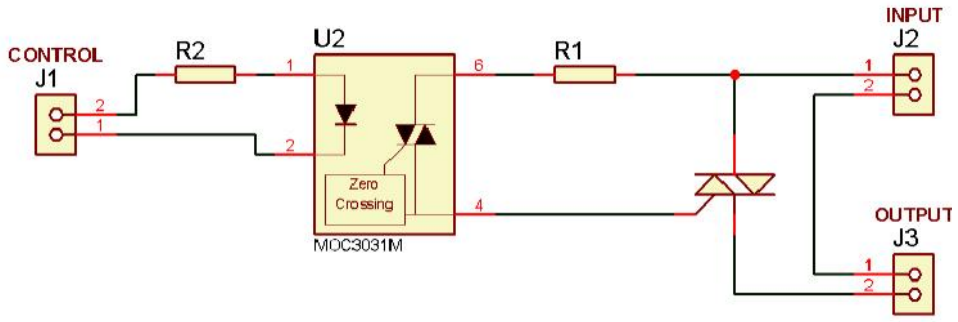

Figure 4.4 – Solid State Relay (SSR)

The SSR was used to minimize the arcing effect of the electromagnetic relay. The proponent design uses the MOC3041 as the driver to the triac. The triac serves as the switching mechanism in turning on and off the loads. The value of R1 was based on the datasheet of the manufacturer. The value of R1 was 180 ohm as per recommendation of the manufacturer. The input side was directly connected to 220Vac and gives an output of 220Vac likewise. The value of R2 was computed using the equation below.

below.

$$R_2 = \frac{E - V_d}{I_d} \qquad \text{(1)}$$

Where:

R_2 = the series resistance of the opto-coupler

E = the source voltage, normally the voltage output of the microcontroller which was 5V

V_d = the maximum voltage of the LED inside the opto-coupler, normally it was found out equal 1.7 V

I_d = the current for the LED inside the opto-coupler, basically the design uses 10mA as the working current of the opto-coupler.

Using the above equation, the value of R2 is equal to 330 ohms.

4.2.3 Embedded Software

The embedded software was written in C, and then compiled to machine language using mikroC compiler.

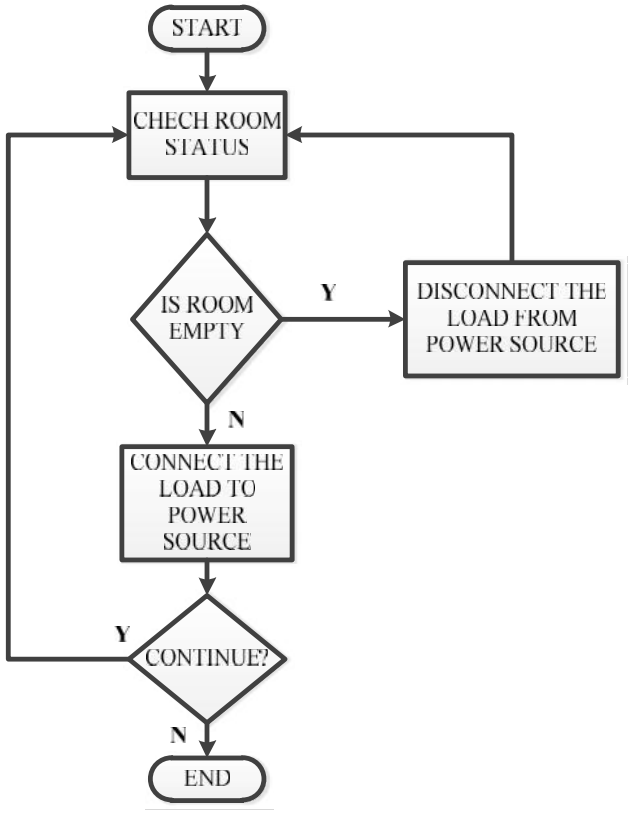

Figure 4.5–The Program Flow Chart

Figure 4.5 shows the program flow chart for the automated switch. The primary aim of the program was to determine wither the room was vacant or not. And when it was vacant it automatically disconnects the load and including the system from the power source. And it continues until the user terminates the system.

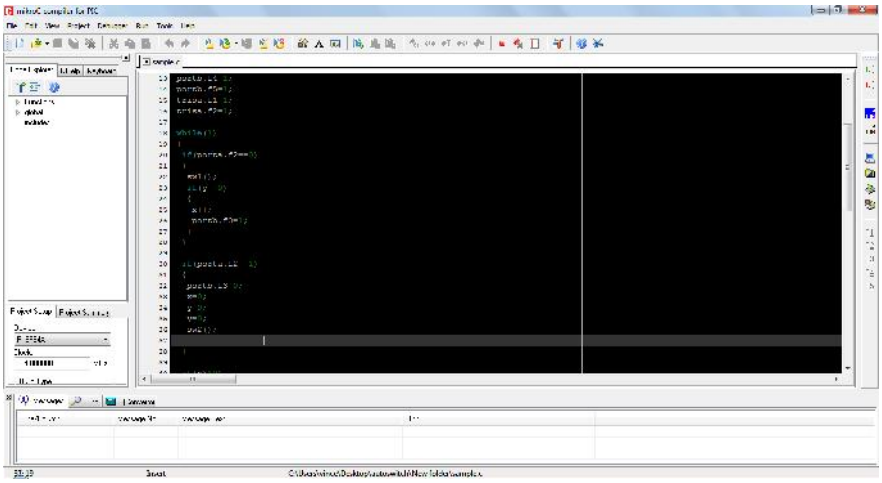

Figure 4.6 – The MikroC Environment

Figure 4.6 shows the mikroc compiler environment. The software automatically compiled the output program to hexa files. This hexa file was used in the microcontroller.

4.3 The simulation on the design model circuit

The design hardware and software were simulated in PROTEUS. And the results show in figure 4.7 below.

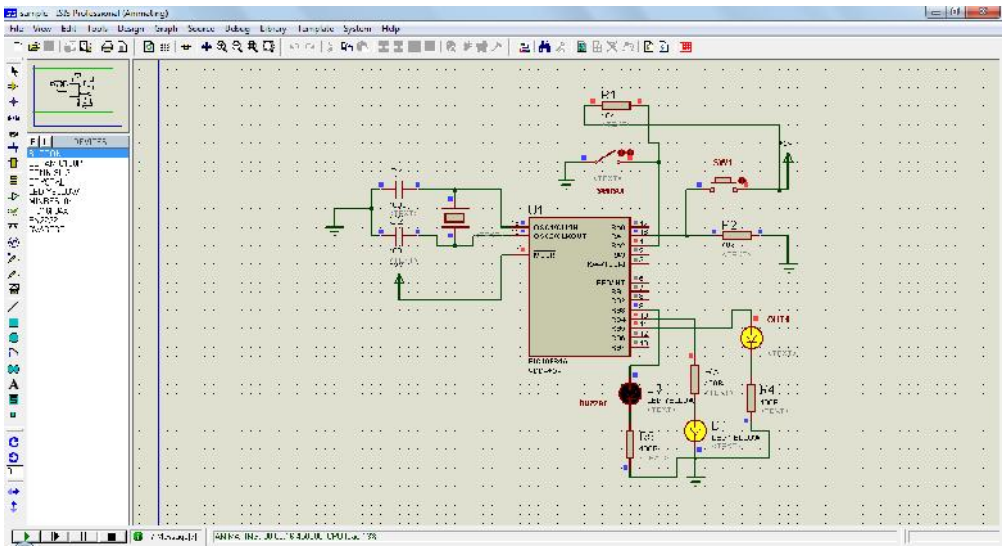

Figure 4.7 – Simulation of the Circuit Model

The simulation works as it was expected. The switch sensor works after some debugging in the embedded program.

Table 4.3 – The Output of the Controller

SENSOR	SW1	ALARM	OUTPUT
0	0	0	1
1	0	1	0
0	1	0	1
1	1	0	1

Table 4.3 shows the logic output of the controller. The '1' and '0' represents the on and off state of the controller. The sensor represents the opening and closing of door. This also identifies the occupancy of the room. The value '0' from the sensor means that the room was open and there is a person inside the room. The value '1' from sensor means that the room was closed and there is nobody inside the room. The SW1 represents the reset switch. This allows the microcontroller determine that the room was not empty. The value of '0' from the SW1 means that nobody inside the room. The value '1' from the SW1 means that someone inside the room. The alarm was only activated when the door was closed and nobody inside the room. The alarm turns on for 10 seconds and turn off. The output value of '1' means that the microcontroller trigger the SSR and '0' means turn off the SSR. This allows the load be connected and disconnected from the power source.

4.4 The development of the prototype hardware circuit

After simulating the circuit using PROTEUS software, the circuit board was prepared. Figure 4.8 shows the PCB layout of the controller circuit. The layout was developed using ARES software. It uses single sided PCB.

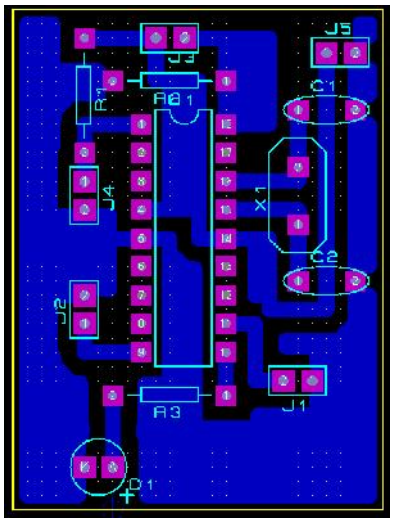

Figure 4.8 – Controller Printed Circuit Board Design

The prototype controller circuit was shown in figure 4.9. The board size of the controller circuit was 1.3 in x 1.7 in. The PIC16F84A was used in the controller. The LED 3.5mm was also used as the power indicator for the circuit.

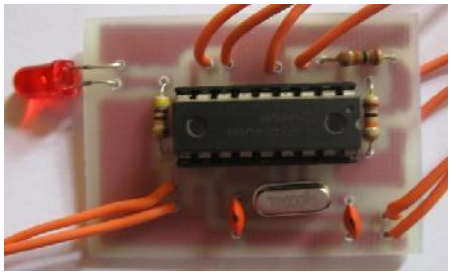

Figure 4.9 – Prototype of Controller Circuit

Figure 4.10 shows the PBC layout for SSR (solid state relay) for the interfacing circuit. Single sided PCB was also used in the prototype.

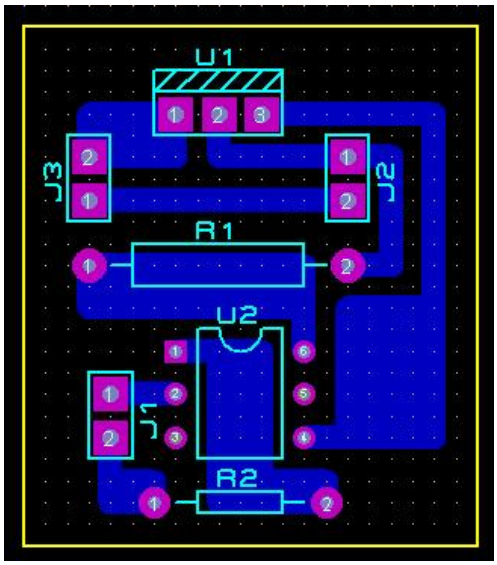

Figure 4.10 – Solid State Relay Printed Circuit Board Design

The prototype hardware of the SSR was shown in figure4.11. The board size was 1 in x 1.15 in. The circuit uses a zero crossing opto-isolator to interface with the AC source. The TRIAC was controlled by the opto-isolator.

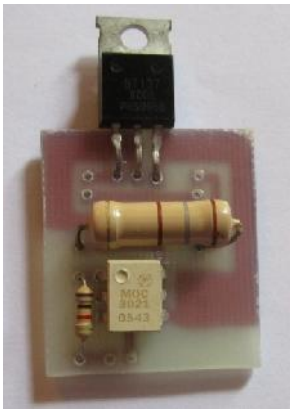

Figure 4.11 – Prototype of Solid State Relay

The TRIAC was connected directly to the power source and to the load. The power going to the load was being controlled by the TRIAC as per instruction of the controller.

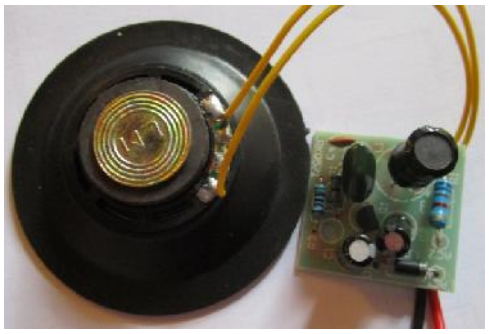

Figure 4.12 - Alarm Circuit Module

The alarm circuit module was shown in figure 4.12. The alarm module generates a ‘birdy” sound. The said module was used in order not to disturb the room. The module was directly connected to 220 Vac via SSR. This was used to generate sound to alarm the occupant that the door was open and closed.

Figure 4.13 – The Reset Switch

Figure 4.13 shows the reset switch. The reset switch was developed by modifying internal structure of the push button switch. The push button switch used was a normally open type. A 10 KΩ resistor was connected in the switch as pull down resistor. The other terminal of the switch was directly connected to the +5V supply on the controller.

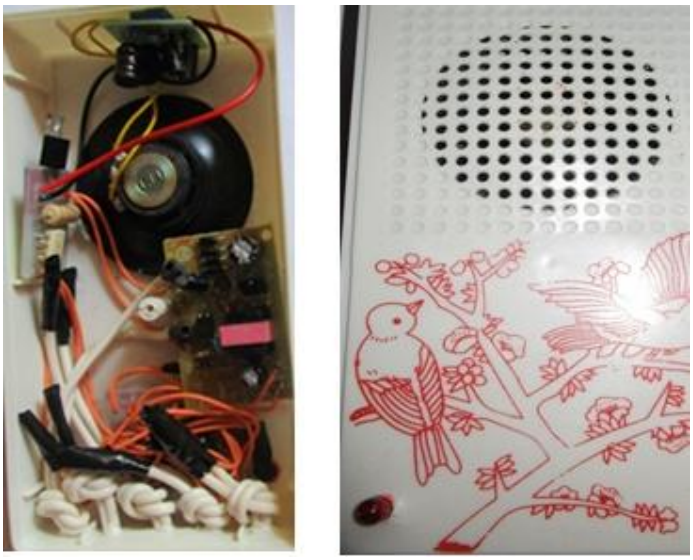

Figure 4.14 – Prototype of the Controller Switch

The final prototype of the controller was shown in figure 4.14. The box was made of the electronic chime which was available in the area. All the parts and components in this project were available in the area. The box was modified in order that the other entire module can be placed.

4.5 Testing the efficiency of the automated electronic switch

The prototype hardware was tested for two months. And it was found out that it works as what it was expected. During the testing stage, the project seems to work on and off. There are cases that the output seems intermittent fault occurs. The table 4 shows the test results.

The table 4 shows that the test conducted for 10 days. The hardware was operated for 24/7 without interruption. The hardware was also experienced the power failure due to power interruption in the area. This was used to test its functionality even in most critical cases.

Table 4.4 – Hardware Test Results for 10 days testing

DAY	SENSOR	OUTPUT
1	1	1
2	1	1
3	1	1
4	0	0
5	0	0
6	0	0
7	1	0
8	1	0
9	1	0
10	1	0

LEGEND:

1 Working

0 Not Working

And it was found out that during the first three days of operation, it works fine. The sensor and the output works as it were expected. But after three days, the sensor and the output were not working. It was found out that the sensor had a thermal breakdown. This was the cause of transient effect of the load. Since the load was an inductive load, a transient current was very high. This current was being absorbed by the sensor. The correction was made by using a sensor that can handle 80 percent of the current passing to it.

$$I_s = \frac{I_{max}}{0.8} \quad \text{---------- 2}$$

The current rating for the sensor was increase by 80 percent of its maximum current. This was made in order to protect the sensor. According to some experts, all components must have a safety factor as an allowance of its current carrying capacity. In this case, 80 percent safety factor was used.

After the correction was made, the output still not working as it was expected. Until the ten days testing was conducted. It was found out that the solid state relay was not working

as it was expected. The solid state relay composed of opto-coupler and triac. The triac input and output was being interchange. That causes the thermal break down also of the triac. The calculation of the triac current missed the safety factor of the component. The 80 percent safety factor was also applied on the triac current carrying capacity. After all the adjustment the project works as being expected.

The test results after 10 days were shown in table 4.5. It shows that the hardware works continuously without any failure. The hardware was been continuously connected and operated until this day.

Table 4.5 - Hardware Test Results for 20 days testing

DAY	SENSOR	OUTPUT
11	1	1
12	1	1
13	1	1
14	1	1
15	1	1
16	1	1
17	1	1
18	1	1
19	1	1
20	1	1

LEGEND:

1	Working
0	Not Working

The operating current of the system was measured 1 mA. And when it shut down the load, the system also automatically shut off with the load. The input current to the hardware was measured 1.001 mA.

$$E_{ff} = \frac{Power\ Output}{Power\ Inout} \text{x } 100 \text{ ----------(3)}$$

The equation for calculating the efficiency was used. And it was calculated that the efficiency of the hardware was 99 percent.

4.6 The calculation of the energy saving with the automated electronic switch and the efficacy of the system

The energy saving of a certain load was computed based on the equation.

$$Energy\ saving\ =\ Total\ Energy\ Consumption\ -\ Energy\ losses\ \ ------(4)$$

The energy loses was the term used as the energy consumption that was not actually used by the consumer. But still the consumers pay for that consumption. Not all of the total consumption was the actual used by the consumer. Most cases the energy losses were higher as compared to the used energy. One specific sample was the room that has a manual control and the room that had an automated control.

Table 4.6 – Official Time Usage of Room Lighting

Day	**Time**	**Hour Used**	**Lighting Outlet (Watts)**	**Type of Light**
Monday	8:00-5:00	8	1280	FL, 40W bulb, 40W ballast
Tuesday	8:00-5:00	8	1280	FL, 40W bulb, 40W ballast
Wednesday	8:00-5:00	8	1280	FL, 40W bulb, 40W ballast
Thursday	8:00-5:00	8	1280	FL, 40W bulb, 40W ballast
Friday	8:00-5:00	8	1280	FL, 40W bulb, 40W ballast
Saturday				FL, 40W bulb, 40W ballast
Sunday				FL, 40W bulb, 40W ballast
TOTAL HR USED:		40		
TOTAL Watt-hour/Week:		256Kw		

Table 4.6 shows the office time usage room lighting of one office room in ASTU. It was found out that the said room had 4 sets of 40W fluorescent lamp and a corresponding ballast of 40W. Each set had 2 lamps with corresponding ballast.Each set had a total power consumption of 320 watts. The total power consumption of the said room per

official day was calculated of 1280 watts for lighting alone. The total energy per week based on the official time was calculated 256 kW-Hr. This was only based on the official time of the office.

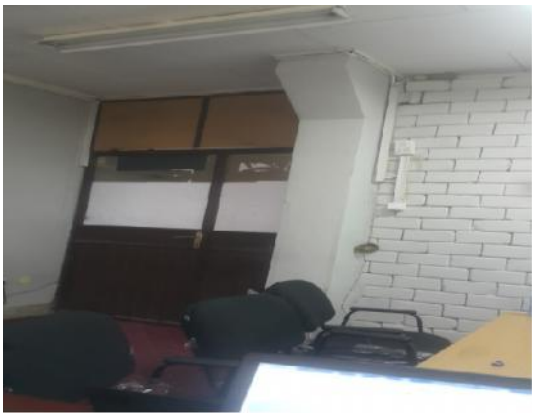

Figure 4.15 – Office Room in ASTU

Figure 4.15 shows one of the office rooms that uses manual control for the lightings. Most cases power interruption occurs in the buildings and all the rooms in those particular buildings had no power. The staff assigned to that room suddenly leave the room without checking the switch if it was already turned off. Table 7 shows the occurrence of the said room that was left for a long period of time while the switch was not switch off.

Table 4.7 shows the most cases of room lighting utilization in one of the studied area. One building was randomly checked and the total number of hours of lighting operation in every room was recorded. One of the rooms had a greater number of utilization of lighting. The said room was not merely switched off the lights when there was no power within the week. There were cases that every Friday the power failures mostly occurs around 3:00 pm or sometimes 4:00 pm. The staff usually went out during that time. They usually don't checked the switch wither it was turned off. When they don't switch off the light before going out, and the power came back after

2 hours and the room was already empty, the tendency the lights are switch on for 24 hours on Saturday and Sunday. In this case it was known based from the study. One office room was constantly observed that during Saturday and Sunday all the lights in that particular room was switched on. Since the room was locked, it can't be switch off unless the staff member who was assigned in that room came and do that turning off the lights.

Table 4.7 – Cases of Room Lighting Utilization

Date	Without Power (HR)	With Power (HR)	Light Operation	Lighting Outlet (Watts)	Type of Light
Monday	2	22	8	1280	FL, 40W bulb, 40W ballast
Tuesday	1	23	8	1280	FL, 40W bulb, 40W ballast
Wednesday	2	22	8	1280	FL, 40W bulb, 40W ballast
Thursday	2	22	8	1280	FL, 40W bulb, 40W ballast
Friday	2	22	16	1280	FL, 40W bulb, 40W ballast
Saturday	0	24	24	1280	FL, 40W bulb, 40W ballast
Sunday	0	24	24	1280	FL, 40W bulb, 40W ballast

TOTAL HR Lighting Usage: 96

TOTAL Watt-Hr: 860160

The data gathered shown in table 4.7, was only sample data that happen for one week. It was found out that for a one week time there was a big difference on the power consumption.

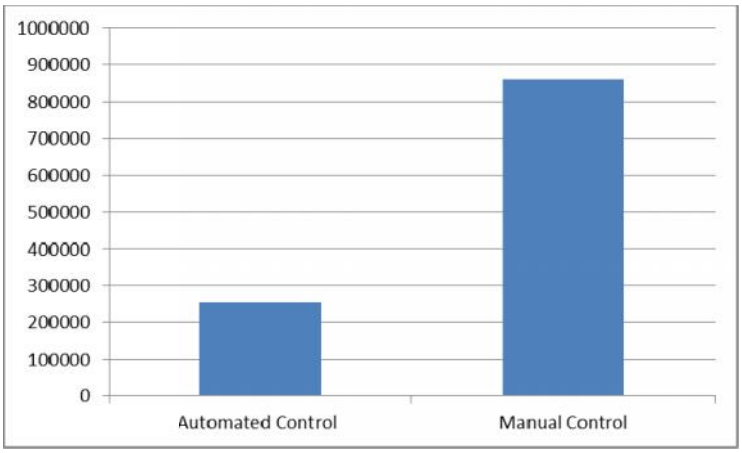

Figure 4.16 – Automated Control vs. Manual Control

Figure 4.16 shows the comparison of the power consumption with the use of automated control and manual control. The graph shows that the losses for 2 days had a great effect on the power consumption on the room. With the automated control the losses were minimized and it was found out that almost the same with the official time power consumption. While for manual control it was found out that more than 300% of the power consumption in two days losses.

$$Power\ Losses = \frac{Total\ Power\ Consumption - Official\ Time\ Power\ Consumption}{Official\ Time\ Power\ COnsumption}\ x\ 100 \text{---------(5)}$$

It was found out from the specified room 834560 kW-Hr in per week within two days the switch was not switch off during weekend.

5. Conclusion and Recommendation

Based from the gathered information and different experiments conducted,the following conclusion and recommendations were formulated.

5.1 Conclusion

Intensive research shows that using manual controls when the switch was forgotten to switch off especially during weekends in the office, can increase the energy consumption up to 300% of its total energy consumption with the official expected power consumption. And it was found out that using automated electronic switch power utilization in the room was more secured in terms of fire safety. And it was concluded that the rooms were following the Ethiopian Electrical Code and National Electrical Code based on the electrical wiring. The design of automated control hardware and software were based on the requirement on the electrical code of Ethiopia. The switching off the power in the room including the system controller itself was included in the designed. The availability of all the parts and components of the hardware were included in the designing of the hardware. The prototype of the hardware was tested for more two months and after series of adjustment and modification it was successfully working based on the requirements. And the efficiency of the project was calculated after the series of test conducted and it was found out that the hardware has 99 percent efficiency. Using automated electronic switch was more energy efficient as compared to manual control in terms of managing the energy consumption.

5.2 Recommendations

After the series of test and implementation of the Automated Electronic Switch in one of the pilot room in electrical and computer engineering department, the implementation of the automated electronic switch is highly recommended in all offices and rooms in both government and private sector.

For the future advance researchers, the ideas gathered in this projecthashelpful inputs to those who study on automated controllers for energy regulation. Upgrading some features that were not included in the studyis also recommended.

The result of the research is earnestly recommended to be incubated and commercialized. In this regard, potential companies in the area are highly requested to look for ways of fabricating the product.

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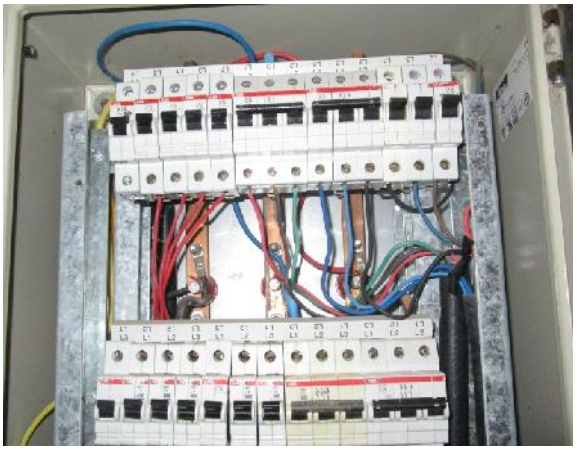
Appendices

APPENDIX A

The actual panel board of the building



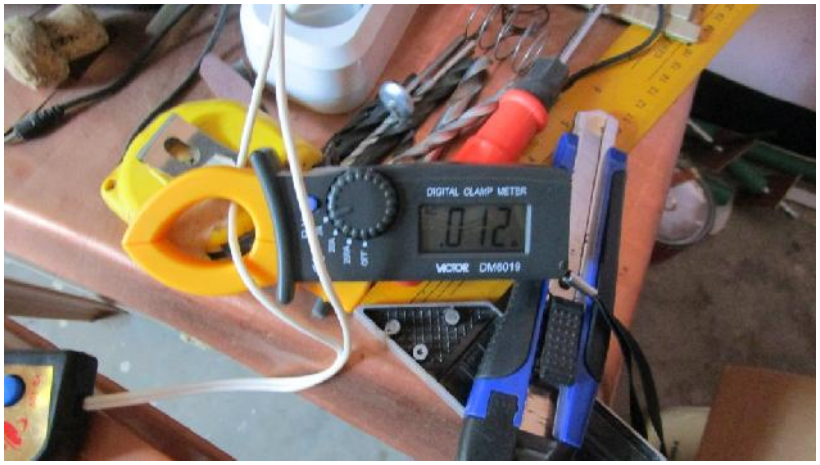
APPENDIX B

The wiring connection

The existing switch

APPENDIX C

The test for current for project efficiency



APPENDIX D

The prototype finalization and testing of project

APPENDIX E

The main controller implementation