Palestine Polytechnic University

Collage of Engineering Department

Electrical Power Engineering Technology

Bachelor Thesis

Energy Audit of C- Building at PPU Using Smart System and its Influence on Grid

Project Team

Ali Ahmad Krajeh

Isra Radwan Al-Sharapati

Project Supervisor

Prof. Abdel karim Daud

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جامعة بوليتكنك فلسطين

الخليل - فلسطين

كلية الهندسة والتكنولوجيا

دائرة الهندسة الكهربائية

اسم المشروع

Energy Audit of C- Building at PPU Using Smart System and its Influence on Grid

أسماء الطلبة:

اسراء رضوان الشرباتي

علي احمد كرجة

بناء على نظام كلية الهندسة والتكنولوجيا واشراف ومتابعة المشرف المباشر على المشروع وموافقه اعضاء اللجنة الممتحنة تم تقديم هذا المشروع الى دائرة الهندسة الكهربائية. وذلك للوفاء بمتطلبات درجة البكالوريوس في تخصص هندسة تكنولوجيا الطاقة الكهربائية.

توقيع المشرف

توقيع اللجنة

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توقيع رئيس الدائرة

اهداء

إلى وطننا إلى قضيتنا و رمز عزتنا .... فلسطين

إلى الدم الطاهر السائل على ترابها ...شهدائنا الأبرار

إلى الحرية المغتصبة في ظلمه السجان...أسرانا البواسل

إلى ينبوع العطاء والتضحية والحنان ..أبائنا وأمهاتنا

إلى ذكريات الطفولة ...إخوتنا وأخواتنا

إلى من سكنوا قلوبنا... أحبابنا وزملائنا

إلى كل محبي العلم والمعرفة وكل من ساهم بإنجاح هذا لعمل

فريق المشروع

٢٤/٥/٢٠١٦

Dedicate

We would like to dedicate this thesis to our loving parents who gave us everything they had to facilitate our success. We are so proud of you. You trust us, and we hope that we were deserved.

Acknowledgements

In the name of Allah, Most Gracious, Most Merciful

All praise and glory to Almighty Allah who gave us courage and patience to carry out this work. Peace and blessing of Allah be upon Last Prophet Muhammad (Peace Be upon Him).

To our advisor Professor Abdul Karim Daud for their insightful inputs, valuable discussions, and the assistance they have provide throughout the lifetime of this project.

To Palestine Polytechnic University, and to College of Engineering and Technology.

الملخص

يهدف هذا المشروع الى عمل نظام تدقيق للطاقة الكهربائية المستهلكة في مبنى (C) في جامعه بوليتكنك فلسطين وذلك بهدف تحسين كفائة استخدام الطاقة الكهربائيه والتقليل من الطاقة الضائعة.

اظهر التدقيق الطاقي بان مبنى (C) يستهلك طاقة كهربائية بمقدار 308.9 (مجا واط) في السنة, حيث تم تطبيق التدقيق الطاقي على انظمة الاستهلاك الموجوده في المبنى وهي نظام الاضاءه و نظام تكيف وتبريد الهواء ونظام الاجهزه المكتبيه واجهزة المبنى و نظام التطبيقات الاخرى.

و تبين بعد الدراسة بان نظام الاناره يستهلك طاقه بمقدار 39% ونظام تكيف وتبريد الهواء يستهلك طاقه بمقدار 33% ونظام الاجهزة المكتبية واجهزة المبنى يستهلك 26% ونظام التطبيقات الاخرى يستهلك 2% من الطاقه الكهربائيه الكليه المستهلكه في المبنى.

كما وتبين بان هذه الانظمة المتواجده في المبنى تعمل على كفائة متدنية في استهلاك الطاقة الكهربائية ويعود السبب في ذلك الى ابقاء الاجهزه تعمل (تستهلك طاقة) دون الحاجه لها وعدم وجود نظام يتحكم بهذه الاجهزة لايقافها عن العمل عند عدم الحاجة لها كما وتبين بانه يوجود مجموعه من الاجهزه التي تستهلك طاقة عالية لاداء وظيفتها مع العلم بانه يوجد اجهزة تودي نفس الوظيفه تستهلك طاقة اقل.

لتحسين الكفائة في استهلاك الطاقة الكهربائية قمنا بتصميم نظام ذكي, بحيث يعمل على تقليل الخسائر في الطاقة الضائعة في كل نظام عن الطريق التحكم الاوتوماتيكي باقاف الجهاز عن العمل عند عدم الحاجه له.

ان الفوائد الجوهريه من هذا النظام سوف تتلخص في حفظ الطاقة الكهربائية الضائعة والتقليل من تكاليف الاستهلاك.

Abstract

In this project, the electrical energy audit performed for the development of the electrical energy efficiency in "C" building at Palestine Polytechnic University (PPU). The energy audit showed that the "C" building consumed a yearly electrical energy of 308.9 (MWh). The energy audit was carried out on the lighting system and Heating ventilation and air conditioning (HVAC) system and office and building equipment system in "C" building, the audit showing that the systems of lighting consuming 39% and the HVAC consuming 33% and the office and building equipment consuming an 26% and other application consuming 2% from total electrical energy.

The equipment were found to be operating at low energy efficiency, failure to switch off electrical equipment even when not required being in operation, absence of switch signage's, inadequate effective control systems, these reasons was identified to be the major causes of energy losses and wastes in the "C" building.

To improve the electrical energy performance in the building, an enhanced level of awareness to reduce energy waste, the use of efficient equipment and apply an smart system is found to be the most effective energy efficiency measures strategy, an a smart system will be designed to reduce the wasted energy in the building, thereby achieving energy saving, and costs saving.

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Abbreviations

EMO	Energy Management Opportunity
O&M	Operation and Maintenance
T&C	Testing and Commissioning
EPD	Environmental Protection Department
EUI	Energy Utilization Index
GFA	Gross Floor Area
BEP	Building Energy Performance
EMP	Energy Management Program
BEP	Building Energy Performance
M&V	Measurement and Verification
THD	Total Harmonic Distraction
RMS	Root Mean Square
PIC	Programmable Interface Controllers
RISC	Reduced Instruction Set Computer
OTP	One Time Programmable
PNA	Personal Area Network
PHY	Physical Layer
MAC	Medium Access Control Layer
OS	Operating System
RISC	Reduced Instruction Set Computer

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Chapter One: Introduction

1.1 Problem Overview

We live in a world with high consumption of energy and high costs of electricity production, with daily increasing electricity consumption and the rare of the sources that we get electricity from it, so this makes a big problem in everywhere especially in Palestine because we can't produce its energy needs.

To solve the energy problem there are many methods and techniques, but the best method is to make audit energy for building using smart system.

We want to design a smart system that auditing energy and reducing the amount of wasted energy in C building at Palestine Polytechnic University after that we are going to apply this system on the building.

1.2 Objectives

To build a flexible and reliable automation system that can be optimized for building layouts and multiple environments needs to achieve these objectives:

- The very basic goal is to find a better solution for power management.
- To offer support in the development of the system and processes which improve energy efficiency.
- Saving energy by reduction the wasted energy.
- Reduction cost of consumption electricity.
- Study the effect of energy audit on the grid.
- Design a testing mechanism to insure software and hardware components viability.

1.3 Motivation

There is a serious problem in waste energy in Palestine and this project is going to make a perfect solution to save this energy, some other reasons that motivated us to choose this project:

- The high cost of production electricity.
- High consumption of energy.
- Reducing the wasted power.
- Reducing the dangerous effect on environment.

1.4 Need Technology

The project will use the following list of technologies, characterized into two categories, Hardware and Software.

- Hardware Technologies

  - ✓ ZigBee Transceivers: for wireless communication.
  - ✓ PIC Microcontrollers: to control used devices.
  - ✓ Many types of sensors.
  - ✓ Power Analyzer VEGA 78.

- Software Technologies

  - ✓ C# Programming Language: for graphical user interface.
  - ✓ Matlab: to process the signal comes from the sensor.
  - ✓ C Programming Language: for PIC Microcontroller.
  - ✓ Proteuse 8 Professional: for simulate system design.
  - ✓ Vega 78 Software.
  - ✓ X-CTU.

1.5 procedure

In this project we are going to design a stand-alone system that control some application automatically, to achieve this goal we must perform the following steps:

1) **Data collection and data analysis.**

   ✓ Data collection.
   In preliminary data collection phase, exhaustive data collection was made using different methods such as observation, interviewing, key persons, and measurements using measurement device.

   Following steps were taken for data collection in our project:

   - Visited each department, we visit each floor in building C (offices, center, library, labs, classroom) and other entities of the institution.
   - We collect information about the general electrical appliances by observation and interviewing.
   - Obtained Site drawing of available building lay-out and Electricity distribution.
   - The power consumption of appliances was measured using power analyzer device and rated power that mentioned in some cases in the device (CFL and FL and LCD screen for example).

- Collect data from power analyzer device (Voltage and current and power factor) for each phase.

✓ Data analysis.
We did an analysis for the data that we collect in the previous step.

Following steps were taken for data collection in our project:

- Energy consumption per year in kWh is calculated based on the measuring value that we get by using the power analyser device.
- Determine the all loads in C building and the power consumption for each one.
- Determine the most application that wasted energy in the building.
- Calculate the amount of energy that have been withdrawn by the device in case:

  - On mode.
  - Off mode.
  - Sleep mode.

- Study the voltage and current and the power factor for each phase, and determine if the system is balanced or unbalanced.
- If this grid unbalance then we have solve this problem we are going to make grid balance.

2) **Energy audit for C building and system design**.

- Determine the all Hardwar and Software that we need to design the system in our project.
- Build and design the system.
- In this project we apply our system on this application:

  - Ligating Systems.
  - Heating Ventilation and Air Conditioning (HVAC).
  - Office and Building Equipment System.

3) **Study the grid after applied our system.**

- Build simulates surround the C building.
- Compare between grid before apply the system and grid after apply the system.
- Calculate the amount of energy and cost saved.

- Collect data from power analyzer device (Voltage and current and power factor) for each phase.

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We did an analysis for the data that we collect in the previous step.

Following steps were taken for data collection in our project:

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- Calculate the amount of energy and cost saved.

1.6 Organization of the Document

The introduction of graduation project contains four chapters can be summarized as follow:

1) Chapter One - Introduction: this chapter gives introduction and general idea about the project.

2) Chapter Two - Background: a theoretical background study on the components and technologies needs for this project.

3) Chapter Three - Measurements data and analysis:

4) Chapter Four - System design: the system design is laid out, put in two categories hardware and software, then it is dissected into group of subsystem, each with it is functionality described and detailed, finally giving a complete overview of how the system works starting from.

5) Chapter five – System Implementation.

6) Chapter Six - Energy Consumption After Apply the Smart System.

7) Chapter Seven - Testing and Performance.

8) Chapter eight – Conclusion and Future Works.

1.7 Time Plan

The Table 1.1 shows the activities that done in the project, and the time of each one.

Table 1.1: Project Time Table

weeks / Activates	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Obtaining required components																
System Design																
Recording Results																
Results analysis and conclusion																
Documentation																

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Chapter Two: Background

2.1 Introduction

2.2 Energy Audit

2.2.1 Conducting Energy Audit

2.2.2 Annual Monthly Energy Consumption Profile

2.2.3 Energy Utilisation Index/Building Energy Performance

2.2.4 Sophistication of Audit

2.3 Unbalance in Electrical Power System

2.3.1 Unbalance in three Phase Distribution Network

2.4 Hardware needed

2.4.1 Power Analyser VEGA 78

2.4.2 PIC Microcontroller

2.4.3 ZigBee Technology

2.4.4 Sensors

2.5 Software Development Tools

2.5.1 C Programming Language

2.5.2 Proteus 8 Professional

2.5.3 MATLAB

2.1 Introduction

In this chapter we are going to study a theoretical background study on the components and technologies needs for this project.

2.2 Energy Audit

An energy audit is an inspection, survey and analysis of energy flows for energy conservation in a building, process or system to reduce the amount of energy input into the system without negatively affecting the outputs. In commercial and industrial real estate, an energy audit is the first step in identifying opportunities to reduce energy expense and carbon footprints.

Energy audit is an effective energy management tool. By identifying and implementing the means to achieve energy efficiency and conservation, not only can energy saving be achieved, but also equipment services life can be extended. All these mean saving in money.

Based on the principle of "The less energy is consumed, the less fossil fuels will be burnt" the power supply companies will generate relatively less pollutants and by products. Therefore, all parties concerned contribute to conserve the environment and to enhance sustainable development.

2.2.1 Conducting Energy Audit

The following explanation of procedures that must be followed to the process of energy audits:

1. **Defining Scope of Energy Audit**

   The scopes of works and the available resources for conducting the energy audit should be determined. The available resources mean staff, time and budget. Recognising the extent of support from the building management, the audit team should then determine the scope of the energy audit such as the areas to be audited, the level of sophistication of the audit, the savings anticipated, any Energy Management Opportunity (EMO) to be implemented, the audit result to be used as reference for improvement on Operation and Maintenance (O&M), the need for any follow up training or promotion of results achievable, etc. The plan for conducting the energy audit should then proceed [1].

2. **Forming an Energy Audit Team**

An audit team should be formed by:

- Determining the members of the audit team and their duties.
- Involving the O&M personnel to provide input.
- Facilitating meeting for sharing of information and familiarising among different parties.

3. **Estimating Time Frame and Budget**

Based on the available resources, the time frame and the budget can be fixed. The budget is mainly built-up on cost of auditor hours from collection of information to completion of audit report.

4. **Collecting Building Information**

The audit team should then proceed to collect information on the building. The information should include:

- General building characteristics such as floor areas, numbers of end-users, construction details, building orientation, etc….
- Technical characteristic of energy consuming equipment, design conditions and parameters.
- Building services design report with system schematic diagrams and layout drawings showing system characteristics.
- Equipment operation records, including data logs of metered parameters on temperature, pressure, current, operational hours, etc….
- Record of EMOs already implemented or to be implemented.
- Record the maximum demand readings.
- O&M manuals and Testing and Commissioning (T&C) reports.

The audit team should consider issuing questionnaires to end-users to collect information on thermal comfort, lighting comfort, operational hours of individual floors/offices, electrical equipment and application, etc.

After having collected all or the majority of the above information, the audit team will have better understanding of the building context and it is energy consuming equipment. With this information the audit team can better plan subsequent audit activities and detect any missing important datum and arrange to obtain those [2].

5. Conducting Site Survey and Measurement

More activities should include the following actions:

- Proceed to plan the site survey for the areas and the equipment to be investigated.
- Allocate the work among the audit team members.
- Assess if separate groups are needed for the areas and the equipment. For example, the first sub-group for low floors, the second sub-group for mid floors, the third sub-group for high floors, so on and so forth. The grouping should also be based on the quantity of measuring instruments available.
- Plan ahead on the site measurement to supplement or verify the information collected. The measurement should focus on equipment that inadequate information is available to determine their efficiency and equipment that appear to be less efficient.

5.1 Strategic Measuring Points.

During the measurement, the sensors should be located at points that can best reflect the need or function of the controlled parameters. For example, for the office environment, a lux meter should be placed at about 0.8m above floor level (or at level of the working plane) and a thermometer at about1.1m (seating thermal comfort) above floor level and pressure and flow sensors in ductwork at points according to general engineering practice [3].

For measurement requiring interfacing with the stream of flow, the system may already have test holes/plugs or gauge cocks. However, many systems may not have such provisions and the audit team may need to install the test holes/plugs or to use the ultrasonic type meter. In fact, it is impractical in most cases to install additional flow meter or gauge cocks in water pipework. Under such circumstances, the audit team may have to make use of the existing ones available, e.g. gauge cocks before and after pump, coil, etc. to measure the pressure of the flow and to calculate the flow rate by referring to pressure/flow curves of pump, valve, pipe section, etc. If the original O&M manuals showing the pressure/flow curves are not available, make reference to those of similar size/rating.

5.2 Instrumentation

Whilst much data and characteristics on equipment can be obtained from the O&M personnel, the information may not be adequate to provide a full picture of their operation. To obtain accurate operating conditions and operating performance of equipment, the auditor should have the necessary measuring instruments to take readings of corresponding parameters such as, temperature, pressure, flow, lighting lux level, running current etc.

6. Analysing Data Collected

At this stage of the audit, the audit team has collected a lot of information on:

- Equipment characteristics obtained site surveys.
- Equipment performance data obtained from O&M log sheets.
- Equipment performance data obtained from site measurements.
- Equipment operating conditions of equipment based on design and general engineering practices.

6.1 Identification of EMOs

To identify the improvement works for the potential EMOs, calculations should be performed to substantiate the improvement works by quantifying energy savings. Some of the typical findings in an audit [4].

6.2 Costing

In evaluating the effectiveness of an EMO, the auditor has to calculate the payback period, net present worth or rate of return. Most calculations can be done using simple payback approach by dividing the EMO's capital cost by the cost of anticipated annual energy saving to obtain the payback period in years.

However, if there are appreciable deviations between the trends of energy cost and the interest rate or if the capital costs of EMOs are to be injected at different stages with different energy savings achievable at different times, the audit team may have to perform a life cycle cost assessment that can better reflect the cost effectiveness of EMOs. Some common calculations are shown in Appendix (A) [6].

6.3 Normalisation of Data

In the energy consumption bills, the measurement dates may not fall on the same day of each month. For more accurate comparison, particularly when different fuel types metered on different dates are involved, these data should be preferably normalised as figures on the common dates [6].

6.4 Maintaining Thermal and Lighting Comfort

Energy audits aim to improve efficiency but not to save energy by purely sacrificing the standard of service. An EMO should normally not downgrade the quality of service to that below common design standards. Examples of substandard level of comfort include room cooling temperature and air movement rate respectively higher and lower than the recommendations in *ASHRAE Standard 55-20044* [7], lighting level below the recommendations in CIBSE Code for Interior Lighting5, excessive noise from equipment/systems causing nuisance, etc.

In the past, energy can be saved by limiting the fresh air supply to an A/C space. With renewed concerns on good indoor air quality, consideration to provide "adequate fresh air supply" in accordance with the requirements of the Environmental Protection Department (EPD) or ASHRAE Standard *62-20016* [8] should be a foremost thought when degrading to reduce fresh air supply.

6.5 Already Scheduled Maintenance and Refurbishment work

When determining EMO, it is necessary to take into account the already scheduled major maintenance and refurbishment works. Therefore, when planning EMO implementation programme, the already scheduled major maintenance and refurbishment works may consider including some of the EMOs.

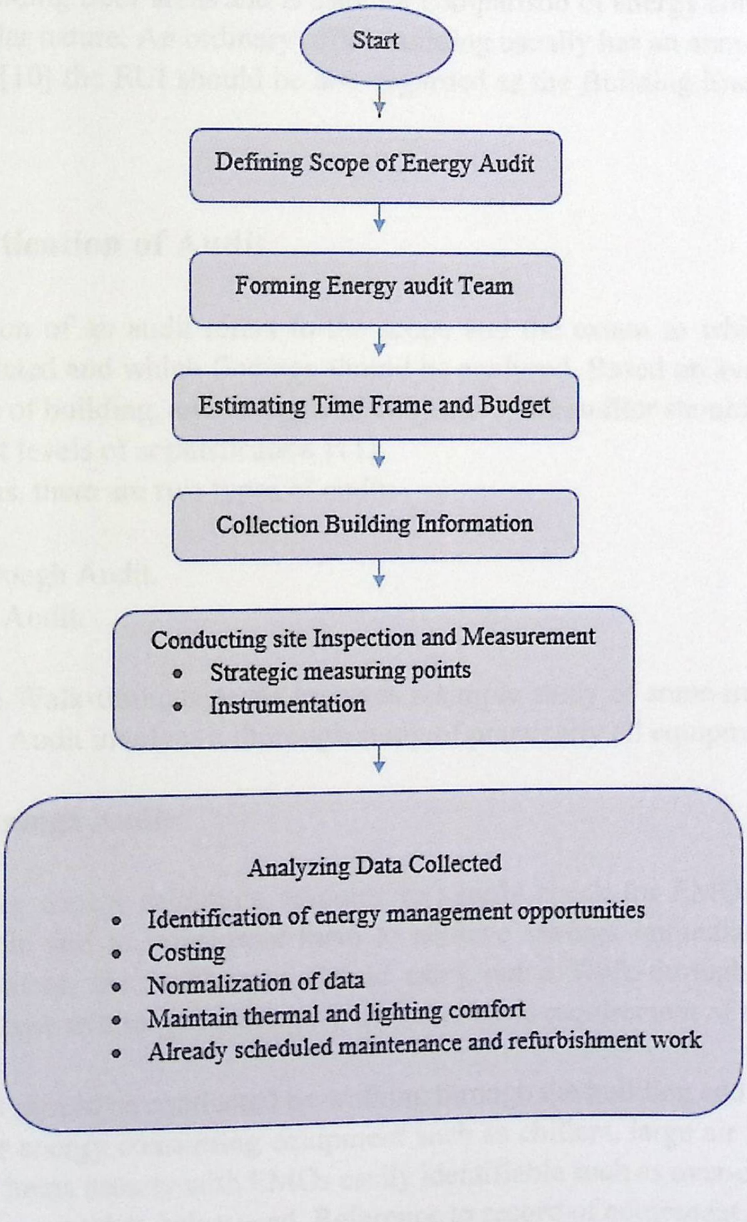


Figure 2.1: Conducting Energy Audit Flowchart

2.2.2 Annual / Monthly Energy Consumption Profile

Based on the energy consumption bills over past years, the auditor should estimate the annual energy use the building. Graphs of energy consumption against different months of the year can be plotted, from which a pattern or general trend over a number of years can be seen these graphs can show normal seasonal flections in energy consumption. More importantly any deviation from the trend are indication that some equipment had not been operating efficiently as usual which warrant more detailed studies to identify if further EMO has existed [9].

2.2.3 Energy Utilisation Index/Building Energy Performance

The Energy Utilisation Index (EUI) obtained by dividing the annual energy consumption be the Gross Floor Area (GFA) takes into account the difference in energy consumption due to difference in building floor areas and is used for comparison of energy consumption among building of similar nature. An ordinary office building usually has an annual EUI of (200 to 300) KWH/m^2, [10] the EUI should be also regarded as the Building Energy Performance (BEP).

2.2.4 Sophistication of Audit

The sophistication of an audit refers to the scope and the extent to which investigations should be conducted and which findings should be analysed. Based on available resources, the size and type of building, and energy audit objective, the auditor should adopt the energy audit of different levels of sophistication [11].
Under such terms, there are two types of audit:

- Walk-through Audit.
- Detailed Audit.

In summary, the Walk-through Audit involves a simple study of some major equipment's and the Detailed Audit involves a thorough study of practically all equipment's.

1. **Walk-through Audit**

   Audit may deploy minimum resource to simply check for EMOs that are readily identifiable and to implement them to achieve savings immediately. Under such circumstances, the audit team should carry out a Walk-through Audit. It is the simplest type of energy audit and is the most basic requirement of the energy audit.

   The audit should be conducted by walking through the building and concentrating on the major energy consuming equipment such as chillers, large air handling units or common items usually with EMOs easily identifiable such as over-cooled spaces and T8 fluorescent tubes being used. Reference to record of equipment ratings, technical catalogue, O&M manuals that are readily available will be very helpful to quickly determine where equipment/systems are operating efficiently. Calculations, usually simple in nature, should be done to quantify the saving achievable from implementation of the identified EMOs.

The audit should be carried out in one day by either one auditor or one audit team, depending on the size and the complexity of the building and the scope of the audit. If the audit team wants to check more areas, more auditor-hours are required. Usually, simple instruments such as thermometer tube, multi-meters and lux meter will serve the purpose.

A Walk-through Audit should, other than fulfilling the original objectives, give an overview of other areas with potential EMOs.

2. **Detailed Audit**

Alternatively, if the building management is highly committed to energy conservation and have allowed for adequate staffing and funding, a Detailed Audit should be adopted. The audit team should check practically the majority or all equipment/systems, identify as many EMOs as possible, classify them into different EMO categories, further study if more complex items are involved, formulate a plan for implementation and finally present it to the building management. This audit goes much beyond the Walk-through Audit. The auditor has to exercise more detailed planning. The auditor-hours could be about 5 to 10 times more, depending on the complexity of the equipment involved and size of the building [12].

2.3 Unbalance in Electrical Power System

A three phase power system is called balanced or symmetrical if the three phase voltages and currents have the same amplitude and are phase shifted by 120^0 with respect to each other. If either or both of these conditions are not met, the system is called unbalanced or asymmetrical.

The unequal distribution of loads between the three phases of the supply system determines the flow of unbalanced currents that produce unbalanced voltage drops on the electric lines, as a result, the voltage system within the supply network becomes also unbalanced.

In power systems supplying asymmetrical (unbalanced) loads, appear supplementary negative and/or zero sequence currents that cause additional power losses and faults in the electric power system and the unacceptable overheating of three-phase asynchronous machines belonging to different customers [13].

Power quality has become an important issue for electric power engineering. Nowadays, the distribution electric networks have unbalanced operating regimes, mainly produced by the great number of single-phase loads. Unbalanced line currents produce unbalanced voltage drops on the three phases of the supply system. Consequently, the voltage system within the supply network will become unbalanced. Voltage unbalance influences different components of the electric networks: the effects on the motors are the growths of losses, supplementary heating, and finally, the motors life is shorted. In the distribution and transmission electric networks the main effect of the unbalanced currents is the existence of additional power losses. Taking into account the above mentioned aspects, it is necessary to study the propagation of unbalance through the electric power system, upstream from the LV distribution level. By using the symmetrical components theory, transformers with different types of connections were studied, and their influence on the unbalance propagation was analysed.

2.3.1 Unbalance in Three Phase Distribution Networks

To study the unbalanced operation of a power system, the symmetrical components theory is used. According to Stokvis- Fortescue theorem [14], every three-phase asymmetrical system of phasors can be decomposed into three symmetrical systems of positive, negative and zero sequence respectively. This aspect can be seen in figure 2.2, where every sequence system contains three phasors characterized by equal magnitudes, in the case of positive and negative sequences, components are rotated between them with 120 electrical degrees in counter-clockwise direction and negative clockwise direction, respectively. In the case of zero sequence components, there is no rotation between phasors. If an asymmetrical system of line currents is taken into consideration, the relationship between the initial system and the symmetrical sequence systems can be written as follows:

$$\begin{vmatrix} I_A \\ I_B \\ I_C \end{vmatrix} = \begin{vmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{vmatrix} \cdot \begin{vmatrix} I^+ \\ I^- \\ I^0 \end{vmatrix} \qquad (2.1)$$

Where I_A, I_B and I_C are the line current phasors, I^+, I^- and I^0 are the positive, negative and zero symmetrical system, respectively, $a = e^{j120}$ is the rotation operator [15], the relationship is:

$$\begin{vmatrix} I^+ \\ I^- \\ I^0 \end{vmatrix} = \frac{1}{3} \begin{vmatrix} 1 & a & a^2 \\ 1 & a^2 & a \\ 1 & 1 & 1 \end{vmatrix} \cdot \begin{vmatrix} I_A \\ I_B \\ I_C \end{vmatrix} . \qquad (2.2)$$

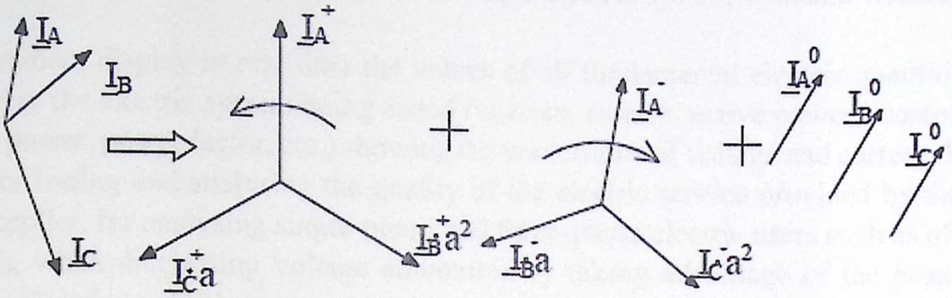


Figure2.2: Decomposition of an Unsymmetrical Phasors System in Three Symmetrical Phasors Systems

These sequence system are not only theoretical, they correspond to the reality, the positive sequence components are created by the synchronous or asynchronous generators while the negative and zero sequence components appear at the place of unbalance. Each of them can be separately measured and influences in a different way the power system. For example, in the case of motors, the positive sequence components produce the useful torque while the negative sequence components produce fields that create braking torques. On other hand, the zero sequence components is the one that get involved in the cases of interferences between the electric and the telecommunication transmission lines [13].

Other influences on balanced elements (generators and loads) connected to the power system are as follows:

- Negative sequence currents can produce the overheating of synchronous generator rotors, the transformers saturation and ripples in rectifiers [16].
- Zero sequence currents cause excessive power losses in neutral conductors and interferences with protection systems [17].
- In unbalanced electric systems, power losses grow and the loading capacity of the transmission networks diminishes.

2.4 Hardware Needed

In order to achieve the aforementioned objectives and requirements we need some of hardware.

2.4.1 Power Analyser VEGA 78

The instrument VEGA78 power quality analyser and energy logger allow carrying out analysis and tests on single-phase and three-phase electric system with and without neutral.

The instrument display in real time the values of all fundamental electric quantities which characterize the electric system being tested (voltage, current, active power, reactive power, apparent power, power factor, etc.) showing the waveforms of voltage and current. VAGA78 is used for testing and analysing the quality of the electric service provided by the electric power supplier, for analysing single-phase and three-phase electric users such as offices and industries, when diagnosing voltage anomalies by taking advantage of the possibility of recording electric quantities.

The instrument also allow evaluating the harmonic content introduced by non-linear loads such as computers, TV sets, controlled electric motor, etc. which can cause the RCD's tripping or a neutral overheating [18].

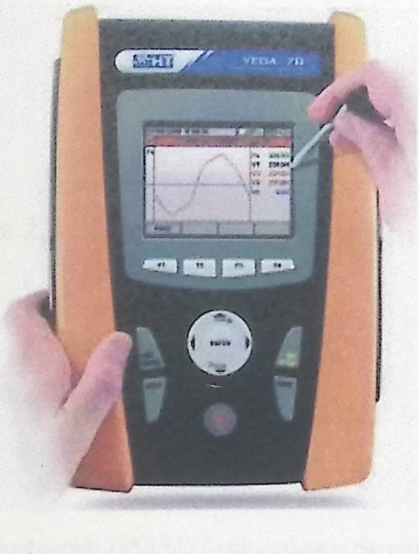


Figure 2.3: Power analyser VEGA78

2.4.2 PIC Microcontroller

The PIC microcontroller family is manufactured by Microchip Technology Inc. Currently they are one of the most popular microcontrollers, used in many commercial and industrial applications. Over 120 million devices are sold each year.

PIC Microcontroller (Programmable Interface Controllers) are electronic circuit that can be programmed to carry out a vast range of tasks. They can be programmed to be timers or

Control a production line and much more. They are found in most electronic devices such as alarm system, computer control system, phones, in fact almost any electronic device [19].

The PIC microcontroller architecture is based on a modified Harvard RISC (Reduced Instruction Set Computer) instruction set with dual-bus architecture, providing fast and flexible design with an easy migration path from only 6 pins to 80 pins, and from 384 bytes to 128 k bytes of program memory [20]. Figure 2.6 shows the shape of PIC MCU.

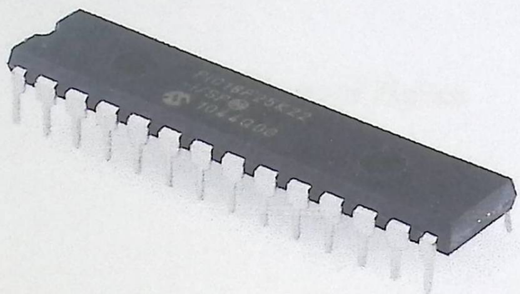


Figure 2.4: Shape of PIC Microcontroller

2.4.3 ZigBee Technology

ZigBee is a new personal-area network (PAN) technology developed by the ZigBee Alliance based on the IEEE802.15.4 standard. It is mission is to define a reliable, cost-effective, secured wireless communication, using low power consumption with the ability to operate for months or even years [21].

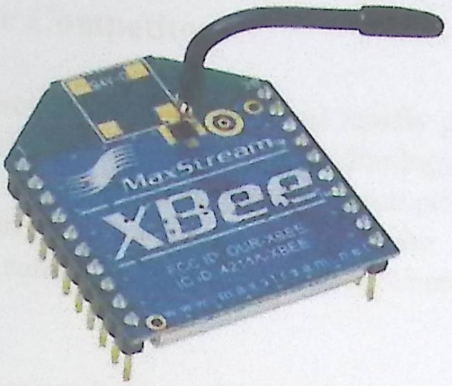


Figure 2.5: Shape of ZigBee

1. ZigBee Stack

ZigBee protocol stack is shown in figure 2.6. It extends the IEEE802.15.4 standard with two layers (Network layer and Application layer) to support additional features such as routing reliability and network security and many other features.

IEEE802.15.4 standard define two layers which are the physical layer (PHY) and the medium access control layer (MAC) [22]. The PHY layer is concerned with the interface to the physical transmission medium as well as exchanging data bits with the upper layer (MAC layer). The PHY layer specifies 27 channels distributed along three license-free frequency bands as follows: 16 channels at 2.4 GHz with data rates of 250 Kbps, 10 channels at 902 to 928 MHz with data rates of 40 Kbps and one channel at 868 to 870 MHz with a data rate of 20 Kbps. Only the 2.4 GHz band operates worldwide, the others are regional bands [23].

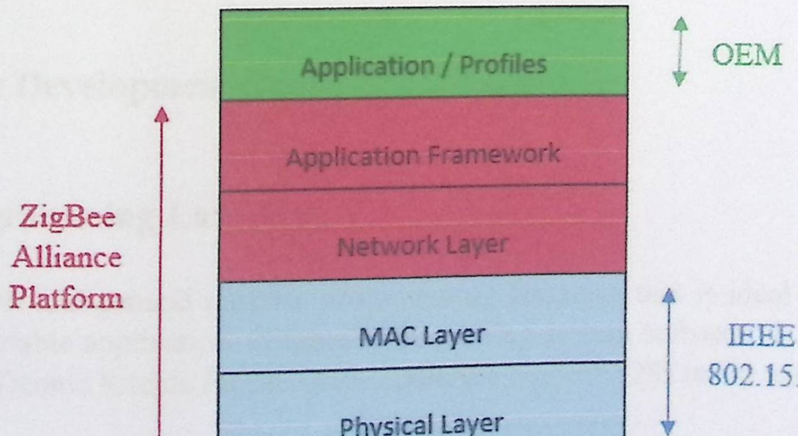


Figure 2.6: Stack of ZigBee protocol

2. ZigBee and other Competitor

Wireless sensor networks are one of the most rapidly growing technologies and has a wide variety of applications. As a wireless technology, ZigBee becomes popular in the recent years due to it is ultra-low power consumption. However, there are many wireless technologies that are competing with the ZigBee such as Wi-Fi and Bluetooth. Table 2.2 summaries the main difference between these technologies [24].

Table 2.1: Comparison between Wi-Fi, Bluetooth and ZigBee Technologies

	Bluetooth	ZigBee	Wi-Fi
Frequency Band	2.4 GHz	868/915 MHz, 2.4 GHz	2.4GHz,5GHz
Data Rate	1 Mbps	250 Kbps	54 Mbps
Nominal Range	10 m	0 – 100 m	50 – 100 m
Data Protection	16 –bit CRC	16 – bit CRC	32 –bit CRC
Power Consumption	Medium	Low	High

2.4.4 Sensors

A sensor is a device that converts physical, biological, or chemical input into an electrical or optical signal. To be useful, the signal must be measured and transformed into digital format, which can be processed and analysed efficiently by computers. The information can be used by either a person or an intelligent device monitoring the activity to make decisions that maintain or change a course of action.

A sensor is a type of transducer, direct indicating sensor, for example, a mercury thermometer, are human readable, other sensors must be paired with an indicator or display, for instance a thermocouple [25].

2.5 Software Development Tools

2.5.1 C Programming Language

C is a high-level and general purpose programming language that is ideal for developing firmware or portable application. Originally for writing system software, C was developed at Bell labs by Dennis Ritchie for the Unix Operating System (OS) in the early 1970 [26].

Ranked among the most widely used languages, C has a compiler for most computer systems and influenced many popular languages-notably C++.

The UNIX operation system, the C compiler, and essentially all UNIX application programs have been written in C. C has now become a widely used professional language for various reasons:

- Easy to learn.
- Structured language.
- It produces efficient programs.
- It can handle low-level activities.
- It can be compiled on a variety of computer platforms.

Facts about C:

- C was invented to write an operating system called UNIX.
- The language was formalized in 1988 by the American National Standard Institute [27].
- The Unix OS was totally written in C.
- Today C is the most widely used and popular system programming language.
- Most of the state of the art software have been implemented using C.
- Today most popular Linux OS have been written in C.

Why use C?

C was initially used for system development work, particularly the programs that make-up the operating system. C was adopted as a system development language because it produces code that runs nearly as fast as the code written in assembly language. Some examples of the use of C might be:

- Operating Systems.
- Data bases.
- Language Interpreters.
- Network Drivers.
- Utilities.
- Print Spoolers.

2.5.2 Proteus 8 Professional

Proteus 8 is a best simulation software for various designs with Microcontroller, it is mainly popular because of availability of almost all Microcontrollers in it. So it is a handy tool to test programs and embedded designs for electronics hobbyist. You can simulate your programming of Microcontroller in Proteus 8 simulation software.

Compared to anther similar application Proteus provides the user with various tools that work in a simple and intuitively way. Maybe that is why this tool is frequently used in the education field. It is very friendly for novice users who are interested on obtaining high level simulation, schematics and board design [28].

Proteus 8 Features:

- Proteus incorporates a tool that automatically places a component in the net list into the board.
- Make a basic simulation.
- It is possible to execute the integrated based router loading custom scripts or using an interactive mode.
- Proteus provides a 3D visualization of the board. It includes navigation and a 3D data footprints user application.
- Mange and configure dynamic teardrops.
- Proteus gives an automatic gate-swap optimization.
- Unlimited shape based power plans per layer.
- Unlimited number of pins in a net list.

2.5.3 MATLAB

MATLAB is a very powerful software package that has many built in tools for solving problems and for graphical illustrations. The simplest method for using the MATLAB product is interactively an expression is entered by the user and MATLAB immediately responds with a result. It is also possible to write programs in MATLAB, which are essentially groups of commands that are executed sequentially.

MATLAB is a mathematical and graphical software package it has numerical graphical, and programming capabilities. It has built-in function to do many operations, and there are toolboxes that can be added to augment these functions (e.g., for signal processing). There are versions available for different hardware platforms, and there are both professional and student editions [29].

3

Chapter Three: Measurements and Analysis Energy in "C" Building

3.1 Introduction

At this chapter we mention all the data that we collect include the measuring data that required in our project about "C" building in Palestine polytechnic university, then we analyze these data and do the required calculation and descript these data by a tables and figures.

3.2 Major Energy Sources and Consuming System at "C" Building

We collect the major sours of energy that used in the "C" building and the consumption rate of each one of these sources, this include the electricity consumption and diesel consumption and water consumption and the liquid petroleum gas (LPG) consumption.

At this section we mention each one of these source alone and descript its consumption rate for year, then we describe the total energy consumption from all sources in the building and show the percentage of consumption for each one, after this we make an indication for each one of these sources to show the relationship between the total energy consumption in (kWh) and the number of people (student and the Staff) that use the "C" building

3.2.1 Electricity Consumption

We want to find the total consumption of electricity in the "C" building at this stage of the project, we face a problem in electricity bills, which supposed to know the total consumption of electricity at the "C" building from the electricity bills, but these bills is not include "C" building alone it is for all the university building in Wade- Elharea branch, that mean the consumption that mentioned in the bill for more than one building not for one building alone, so we want to find the consumption of electricity in "C" building alone.

Calculate the electricity energy consumption (kWh) for "C" building:

To solve the bills problem we want to calculate the load and energy consumption in "C" building according to measuring value from the primary feeder of the building.

We use the power analyzer device (VEGA 78 power analyzer) as in picture in the primary feeder of the "C" building that located in the ground floor in a special room beside the PPU Library in the building to measuring the value of the voltage and the current and power factor for each phase for one week in two months, one week in October and one week in November, for the period between (Monday 12/10/2015 – Sunday 18/10/2015 and Sunday 9/11/2015 – Saturday 15/11/2015) then we take the recording value that saved in the device for two months using the VEGA 78 software and make our calculation according to these saved value as we describe below.

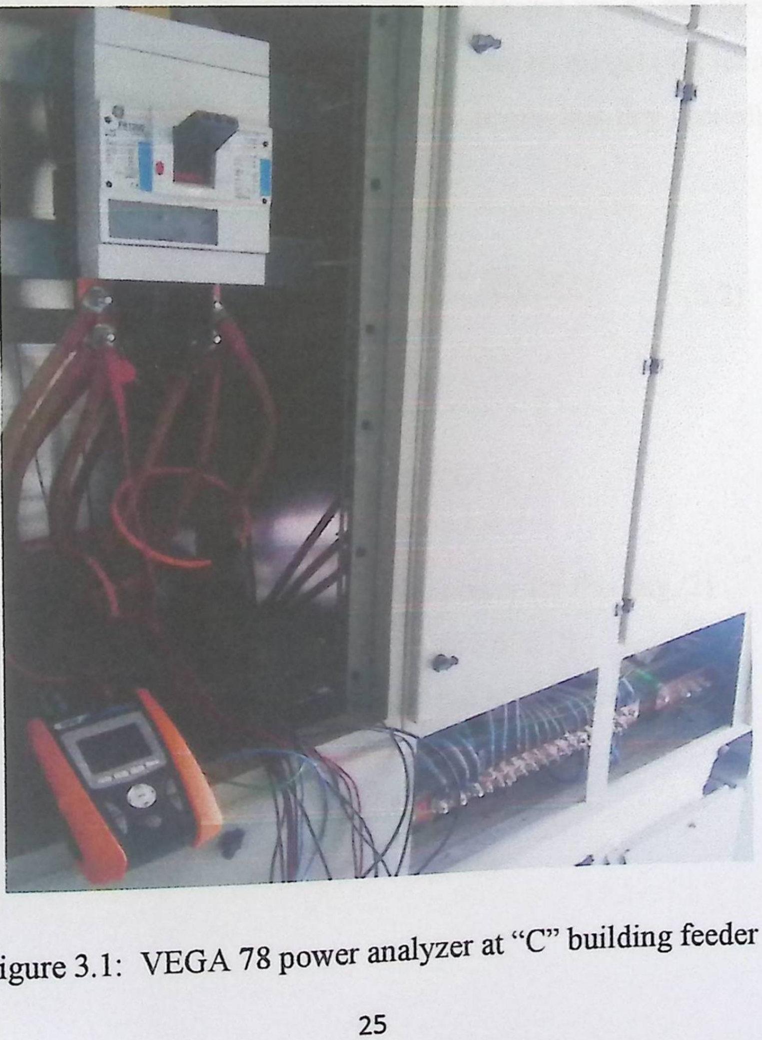


Figure 3.1: VEGA 78 power analyzer at "C" building feeder

The Calculation:

We take the value of the voltage (V) and the current (A) and the power factor from the VEGA 78 device then calculate the power on each phase for two weeks one in October and one in November according to equation (3.1).

$$P = V * I * PF \tag{3.1}$$

These calculations is shown with details in Appendix (B) at (daily consumption for October) and (daily consumption for November).

Then, we calculate the total power for each day by summing the instantaneous power that calculated in the day. After this, we calculate the energy consumption for each day by dividing the total power that calculated in the previous step on (2) and we do this because the device recording one value (instantaneous value) for each half hour so we get (48) recording value and the day is (24) hours, so we divided on (2) to get (24) hours- one day according the equation (3.2).

$$Energy\ consumption\ \left(\frac{kwh}{day}\right) = \frac{total\ power\ for\ this\ day}{2} \tag{3.2}$$

For example in October:

- Energy consumption for (Monday-12/10/2015)

Energy consumption (KWh/day) = {total power for this day /2}
= {2176836.696/2}
= 1088.418348 KWh/day.

For example in November:

- Energy consumption for (Monday-9/11/2015)

Energy consumption (KWh/day) = {total power for this day /2}

= {2151537.247/2}

= 973.54809 KWh/day.

Then, we do all calculation of the Remaining days as showed before.

These calculations are shown with details in Appendix (B) at (daily consumption for October) and (daily consumption for November).

After this, we calculate the Energy consumption for week on October and week on November according to equation (3.3).

$$Energy\ consumption\ for\ week\ \left(\frac{kwh}{week}\right) = total\ energy\ of\ the\ 7\ days \quad (3.3)$$

For example weekly Energy consumptions for October:

Energy consumption (KWh/week) = Energy consumption (KWh/day1) + Energy consumption (KWh/day2) + Energy consumption (KWh/day3) + Energy consumption (KWh/day4) + Energy consumption (KWh/day5) + Energy consumption (KWh/day6) + Energy consumption (KWh/day7).

Energy consumption (KWh/week) = (1088.418348) + (1138.745809) + (1020.642044) + (515.772316) + (458.0393495) + (553.1528625) + (1128.384952).

= 5903.15568 (KWh/week).

All calculation is shown with details in Appendix (B) at (weekly consumption for October) and (weekly consumption for November).

After doing all these calculations we find that:

For October:

The below table and figure are explain the weekly energy consumption for October.

Table 3.1: Weekly Energy consumptions for October

Weekly Energy Consumptions	
Day	Energy (KWh/day)
Saturday	553.1528625
Sunday	1128.384952
Monday	1088.418348
Tuesday	1138.745809
Wednesday	1020.642044
Thursday	515.772316
Friday	458.0393495

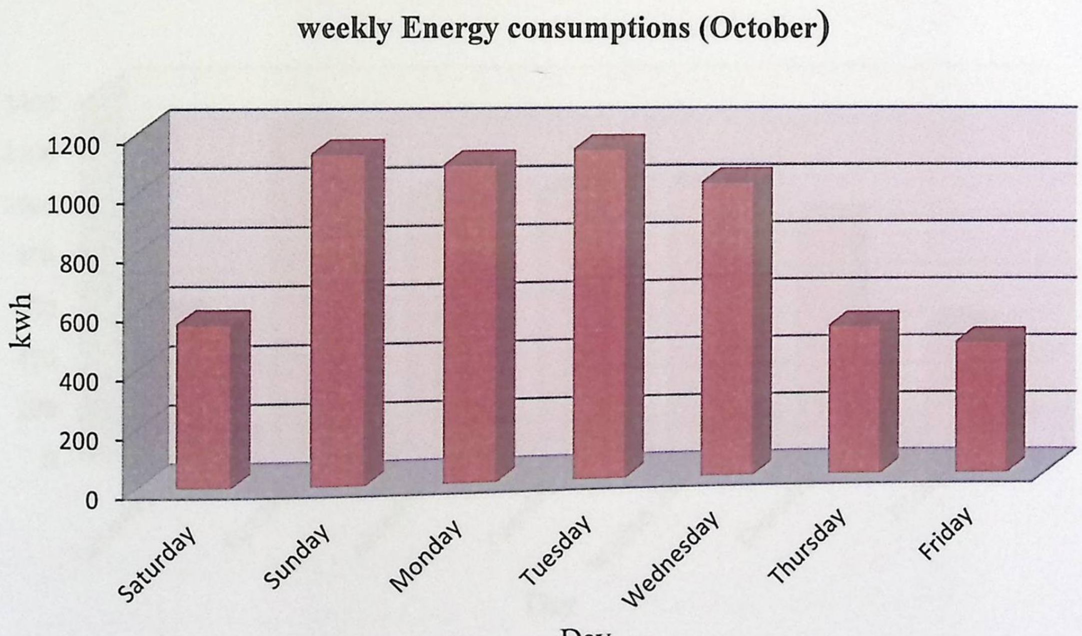


Figure 3.2: Energy consumption per day (KWh/day) for October

For November:

The below table and figure are explain the weekly energy consumption for November.

Table 3.2: Weekly Energy consumptions for November

Weekly Energy Consumptions	
Day	Energy (KWh/day)
Saturday	520.2091
Sunday	1231.4833
Monday	973.54809
Tuesday	993.5489
Wednesday	1020.642042
Thursday	876.9770453
Friday	445.35392

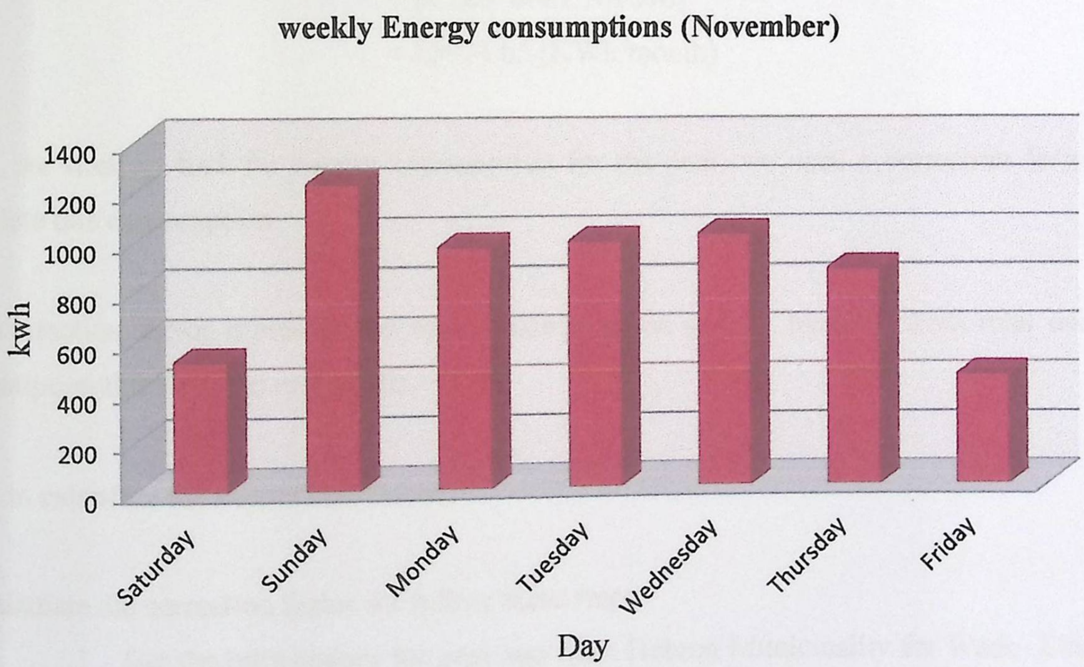


Figure 3. 3: Energy consumption per day (kwh/day) for November

Then, we calculate the energy consumption for each month by multiply the energy consumption for week that calculated in the month in the previous with the number of weeks in this month according to equation (3.4).

$$Energy\ consumption\ \left(\frac{kwh}{month}\right) = [number\ of\ weeks\ in\ this\ month] \times [energy\ consumption\ \left(\frac{kwh}{week}\right)] \quad (3.4)$$

For October:

Energy consumption (kwh/month) = [Number of weeks * Energy consumption (KWh/week)]

= [4.428*5903.15568]

= 26139.17 (KWh/month)

For November:

Energy consumption (KWh/month) = [Number of weeks * Energy consumption (KWh/week)]

= [4.285*6061.762098]

= 25974.65 (KWh/month)

Now, we want to find the energy consumption for the year, we used a correction factor to calculate this consumption.

The correction factor represent the energy consumption of "C" building from total energy consumption that mention in the bills.

How to calculate the correction factor:

To calculate the correction factor we follow these steps:

1. Get the bills history for year ago from Hebron Municipality for Wade- Elharea branch and from this history we know the total cost (NIS) for October and November for all buildings in Wade- Elharea branch.
2. Knowing the tariff (NIS) of one (kW) and its 0.71224 (NIS).

3. Calculate the total consumption for October and November by dividing the total cost (NIS) of each month that we get from bills history on the tariff (NIS) of one (KW).
4. Calculate the correction factor from each month using (3.5) equation.

$$Correction\ factor = \frac{calculated\ energy\ consumption(\frac{kwh}{month})}{energy\ consumption\ from\ bills\ (\frac{kwh}{month})} \quad (3.5)$$

5. Calculate the average correction factor from the correction factor of October and November

Table 3.3: Correction Factor

Correction Factor	
Correction Factor from (October)	0.444
Correction Factor from (November)	0.461
Average Correction Factor	0.452

These calculations showed in details in the Appendix (B) at (correction factor calculation).

Then, we calculate the energy consumption for each month using the correction factor that we calculated in previous.

Table 3.4: The Energy Consumption for Each Month

Monthly Energy Consumptions			
Month	Correction Factor	Energy Consumption for Bills	Energy Consumptions of "C" Building
January	0.452486969	56506.23385	25568.33448
February	0.452486969	56003.59429	25340.89663
March	0.452486969	61216.7247	27699.77021
April	0.452486969	71303.2124	32263.77446
May	0.452486969	54959.00258	24868.2325
June	0.452486969	58439.57093	26443.14432
July	0.452486969	36188.64428	16374.88996
August	0.452486969	43145.56891	19522.8077
September	0.452486969	51484.05032	23295.86188
October	0.452486969	58786.36415	26600.06373
November	0.452486969	55307.19982	25025.78721
December	0.452486969	79296.30462	35880.54453

The all calculations for monthly energy consumption are showed in details in the Appendix (B) at (bills analysis) and (monthly consumption).

The figure3.4, shows the energy consumption per month (KWh/month).

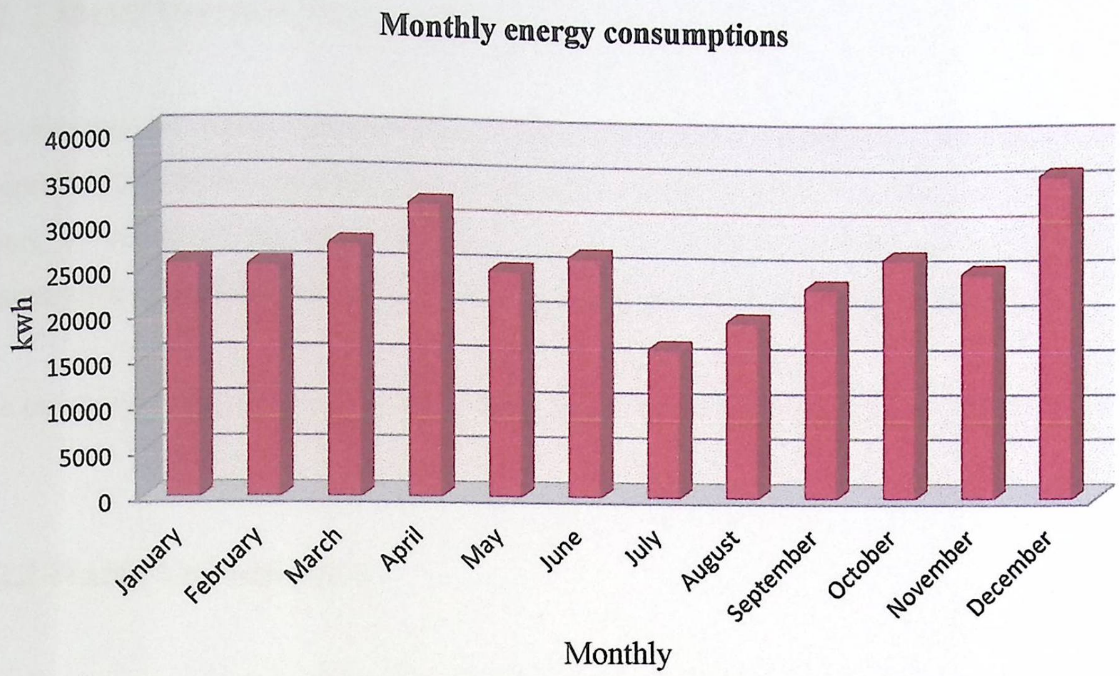


Figure 3. 4: Energy Consumption per Month (KWh/day)

At the end, we can say that the total electricity consumption of the "C" building in the Palestine polytechnic university is 308.88 (MWh) in 2014, now the energy utilization index (EUI) was calculated using (3.6) equation.

$$EUI = \frac{energy\ consumption\ (kwh) for\ year}{\text{FTE student,staff}} \quad (3.6)$$

Where:

EUI: energy utilization index.

FTE (student, staff): number of student and staff in "C" building at full time equivalent.

The energy utilization index (EUI) for electricity is 523.52 (KWh/FTE student, staff).

3.2. 2 Diesel Consumption

The other type of energy source which is consumed by the "C" building is diesel fuel, that use to operate the standby generator, the diesel consumption in the "C" building in 2015 is: 500 letters, to converter the consumption of diesel in letters to (KWh) we multiplying the consumption on letters with 9.95 and after this calculate the (EUI) using (3.6) equation.

The energy utilization index (EUI) for diesel fuel was 8.4 (KWh/FTE student, staff).

3.2.3 Water Consumption

We also use the water in "C" building for kitchens and bathrooms and other regular uses, water consumption in the "C" building for 2015 is : 480 cubic meter (m^3) the energy utilization index (EUI) for water is 0.7(m^3/FTE student, staff).

3.2.4 Liquid Petroleum Gas (LPG) Consumption

The "C" building also use the (LPG) that mainly uses in the kitchens, the consumption in the "C" building for 2015 of gas is: 60 Kg ,to converter the consumption of gas in kg to kwh we multiplying the consumption on kg with 12.91 and after this calculate the (EUI) by (3.6) equation.

The energy utilization index (EUI) for (FTE, student) is zero because there is no student using LPG.

For the staff the energy utilization index (EUI) for (FTE, staff) is 8.6 (kwh/FTE staff) so the total energy utilization index (EUI) is 8.6 (KWh/FTE student, staff).

3.2.5 Summary of Energy Consumption

After we collect and analyze data for the energy source that used in the "C" building we concluded these source and the consuming system as below.

Table 3.5: Major Energy Source and Consuming Systems

Consumption	Electricity	Diesel	Water	LPG
	Lighting	Standby Generator	Kitchens and Bathrooms	Kitchens
	Heating Ventilation and Air Conditioning (HVAC)		Regular Uses	
	Office Equipment and Other Application			
	Other Application			
2014	240120.481 KWh	500 Letters 4950 KWh	480 (m3)	60 kg 774 KWh

The below figure shows the total energy consumption and percentage for electricity, diesel, and LPG gas consumption in the "C" building

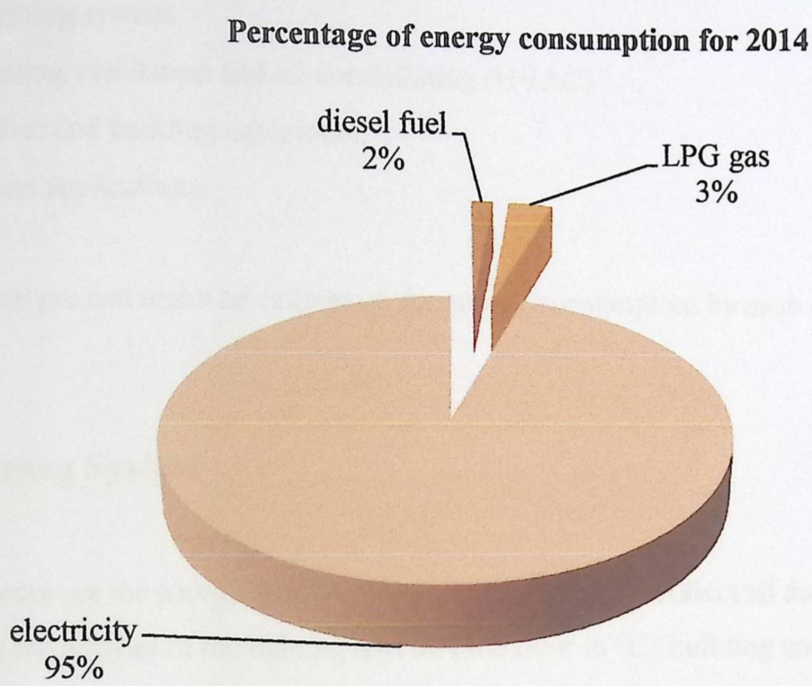


Figure 3.5: Percentage of total energy consumption in "C" building

From the figure3.5, and table 3.5, we note that the electricity is the highest energy consumption in "C" building, so in our project we design a smart system to reduce this consumption and to be able to design this system, we need to study and analyze the consuming electrical system (electrical distribution) very well.

3.3 Electricity Distribution at "C" Building

From the above analysis we note that the electricity consumption is very high and very cost, so we want to study and analyze the electricity distribution system to be able to design a smart system to reduce this consumption without effect on the function of the electricity distribution system in the building.

After we study the nature of electrical loads in "C" building that consume electrical energy we divided into three kind of load:

- Lighting system.
- Heating ventilation and air conditioning (HVAC)
- Office and building equipment.
- Other applications.

Then, we analyze and make an estimation for energy consumption by each one of these kinds.

3.3.1 Lighting System

Lighting energy are the energy used to power electric lights, we collect all the data of the lighting by counting the number of the lighting unit on each floor in "C" building and knowing the rated power of each unit then we determine the average time that this unit remain in working condition (on mode) and after this we calculate the total energy that the lighting which consumed.

Lighting is one of most important opportunity to save energy, it aims to decrease the consumption by using many methods mainly using a designed smart system control of switch on/off lighting automatically when the light must be on and when must be off (this system mentioned at the next chapter) and replacing the lamps by less consumed power one and lamps have higher efficacy than other type.

The table 3.6, describe the energy consumption by the lighting system just for three floors from "C" building (ground floor , first floor, and second floor) the energy consumption by the lighting system for all building are shown in details at Appendix (C) at (lighting system).

Table 3.6: Energy Consumption by the Lighting System

Floor	Place	Lamps type	Lamps N	n	N*n	Rated power	Total Rated Power(W)	(h/day)	Operation Time (h/year)	Energy Consumption (kWh/year)
Ground Floor	Library	FL	2	4	8	18	144	8	1,584	228
		FL	75	2	150	36	5400	8	1,584	8,554
		CFL	5	1	5	23	115	8	1,584	182
		CFL	3	1	3	11	33	8	1,584	52
	nstruction materials	FL	61	2	122	36	4392	8	1,584	6,957
	Corridor	FL	2	2	4	36	144	8	1,584	228
	Laboratory soil	FL	16	2	32	36	1152	8	1,584	1,825
	depository	FL	29	2	58	36	2088	8	1,584	3,307
		CFL	9	1	9	23	207	8	1,584	328
		CFL	5	2	10	11	110	8	1,584	174
First Floor	Corridor 1	CFL	35	2	70	23	1610	8	1,584	2,550
		CFL	3	1	3	23	69	8	1,584	109
	مدرج الشهيد بلال عمرو	CFL	76	1	76	18	1368	8	1,584	2,167
		Spot	74	1	74	3	222	8	1,584	352
	bathroom 1	CFL	7	1	7	23	161	8	1,584	255
		CFL	5	2	10	11	110	8	1,584	174
	storage room	CFL	1	1	1	23	23	8	1,584	36
	bathroom 2	CFL	7	1	7	23	161	8	1,584	255
		CFL	5	2	10	11	110	8	1,584	174
	Corridor 2	CFL	58	1	58	23	1334	8	1,584	2,113
	مختبر المساحه المتقدمه	FL	24	2	48	36	1728	8	1,584	2,737
	Corridor 3	FL	20	4	80	18	1440	8	1,584	2,281
	Finance Section	FL	19	2	38	36	1368	8	1,584	2,167
		FL	7	4	28	18	504	8	1,584	798
	Reception	FL	1	4	4	18	72	8	1,584	114
	Registration office	FL	12	2	24	36	864	8	1,584	1,369
		FL	9	2	18	36	648	8	1,584	1,026
	Kitchens	CFL	2	1	2	23	46	8	1,584	73
	Security Room	FL	1	2	2	36	72	8	1,584	114
Second Floor	Corridor 1	CLF	69	1	69	23	1587	8	1,584	2,514
	عماده شؤون الطلبه	FL	18	2	36	36	1296	8	1,584	2,053
		CFL	3	1	3	23	69	8	1,584	109
	Class Room C102	FL	14	2	28	36	1008	8	1,584	1,597
	Class Room C104	FL	4	2	8	36	288	8	1,584	456
	Teachers Office C103	FL	8	2	16	36	576	8	1,584	912
	Corridor 2	FL	16	4	64	18	1152	8	1,584	1,825
	Kitchens	FL	1	2	2	36	72	8	1,584	114
		CFL	1	1	1	23	23	8	1,584	36
	bathroom 1	CFL	9	1	9	23	207	8	1,584	328
	bathroom 2	CFL	9	1	9	23	207	8	1,584	328
	Teachers Office C101	FL	8	2	16	36	576	8	1,584	912
	Computer Center	FL	7	2	14	36	504	8	1,584	798
	Drawing Hall	FL	12	2	24	36	864	8	1,584	1,369
	GIS lab	FL	17	2	34	36	1224	8	1,584	1,939
	Aerial photography lab	FL	15	2	30	36	1080	8	1,584	1,711
	Office	FL	2	2	4	36	144	8	1,584	228
		CFL	1	1	1	23	23	8	1,584	36
	bathroom 3	CFL	2	1	2	23	46	8	1,584	73

Where:

FL: florescent lamp

CFL: Compaq florescent lamp

Spot: spot lamp

N: number of lighting units

n: number of lamps in the unit

We determine the energy consumption of lighting and it is 121849 (KWh).

3.3.2 HVAC System

There is two system for air conditioning that use in the "C" building:

- Split unit system
- Central group air conditioning system.

The split unit system is using in each floor in the building and each unit have an a rated power, we collect the number of these unit and the rated power for each one and at this step we use the data sheet for each unit to know its rated power, then we calculate the total energy consumption by this system.

The other system is central group air conditioning system used in the fourth floor in the "C" building specially in the office of the director and we calculate the total energy consumption by this system too.

Table 3.7: Energy Consumption by HVAC System

Heating ventilation and air conditioning (HVAC)					
Equipment	No.	Rated Power (kW)	(h/day)	Operation time	Consumption (kWh/year)
Split unite (Small capacity)	16	4.8	3	594	45619.2
Split unite (medium capacity)	9	9.05	2	396	32254.2
HVAC system	2	16	4	792	25344
					103217.4

The energy consumption by the split unit and HVAC system is 103217.4 (KWh).

3.3.3 Office and Building Equipment

In the "C" building there is many of office equipment's and labs equipment uses, like a computers and its LCD screen, multifunction printers, and copiers we collect all data for these equipment's by collect the number of these equipment and the rated power for each one and then calculate the energy consumption according to its the operation time.

The below table descript the consumption by office and lab equipment.

Table 3.8: Energy Consumption by Office and Building Equipment

Office and building equipment					
Equipment	No.	Rated Power (kW)	(h/day)	Operation time	Consumption (kWh/year)
computers	110	0.25	5	990	27225
Multifunction printers	22	1.201	2	396	10463.112
Copiers	2	0.0096	2	396	7.6032
ppu web servers	15	0.42	24	4752	29937.6
boilers	6	2	2	396	4752
elevator	1	4	6	1188	4752
Fax	14	0.00622	8	1584	137.93472
data show	10	0.33	3	594	1960.2
					79235.44992

Energy consumption by office and building equipment is 79235.5 (KWh).

3.4 Total Electricity Consumption

At this section we summarize the total electrical energy consumption by all loading at C-building:

- Lighting load.
- Heating ventilation and air conditioning (HVAC) load.

- Office and building equipment load.
- Other applications.

For each one of these load we design an smart system for saving the wasted energy through it that mentioned in chapter four with details, and in the below we describe the energy consumption for each one of these loads and its percentage from total load for "C" building.

.

Table 3.9: Total Electricity Consumption by all Loads in "C" Building

Total electricity consumption		
system	Consumption (kWh/year)	%
lighting system	121849	39%
Heating ventilation and air conditioning (HVAC)	103217.5	33%
Office and building equipment	79235.5	26%
Other application	4582.2	2%
	308884.2	100%

The figure 3.6, describe the percentage of each load in the building from total electrical load

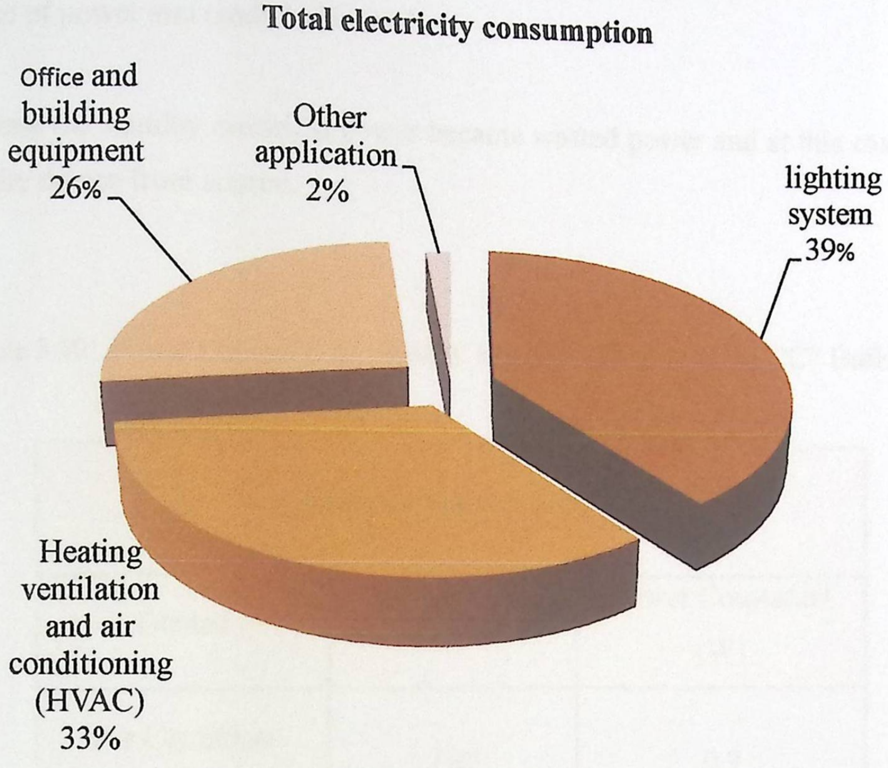


Figure 3. 6: Percentage of Total Electricity Consumption in "C" Building

For each one of these load we design a smart system for saving the wasted energy through it.

3.5 Energy Consumption at Standby Mode

As we know the devices consumed electrical power at standby mode called standby power, standby power is electrical power that a device consumes when not in present use, but plugged in to a source of power and ready to be used.

For a long time the standby electrical power became wasted power and at this case we need to disconnect the device from source.

Table 3.10: Power Consumed at Standby Mode for Device in the "C" Building

Power at Standby Mode		
Device	Mode	Power Consumed (W)
Air Condition	Off	0.9
Mobile Phone Charge	On(charged)	2.24
	On(charging)	3.8
	Power Supply Only	0.28
Hub (USB)	Off	1.44
Modem(DSL)	Off	1.373
Printer	Off	1.7

Scanner	Off	2.5
Data Show	Off by Remote	6.9
	Off by Switch	6.6
LCD	Off	1.3
	Sleep	1.6
Fax	Off	5.31
Computer Box	Off	3.9
	Sleep	21.4

3.6 System Balance

As we know the balance play an major role in wasted energy and energy loss in the device, if the electrical system is unbalanced there is an a voltage drop happened causing increasing in the current and more loss appears in the device and there is another effect in the device by decreasing the life usage of device, so in this section we want to examine for the electrical system in “C” building to know if it is balance or not and if the system is unbalanced there is an a solution must be done to reduce the losses in energy.

The testing include two profiles:

1. Voltage profile.
2. Current profile.

We can say the system is balance just if the two profiles are balance.

Voltage profile:

The testing of voltage profile done in the period between (Monday-9/11/2015 and Sunday - 15/11/2015) to know if the system is balanced or not as shown in the table 3.11.

Table 3.11: Voltage Profile Testing for Each Phase

day	V on phase 1	V on phase 2	V on phase 3
Saturday -14/11/2015	236.4	236.6	236
Sunday -15/11/2015	236.7	236.7	236.6
Monday-9/11/2015	234.29	235.28	234.4
Tuesday - 10/11/2015	234.4	235.1	234.3
Wednesday - 11/11/2015	234.7	235.2	234.3
Thursday -12/11/2015	235.5	235.7	235.1
Friday -13/11/2015	236.6	236.7	236.7

From the table 3.11, we can say that the voltage value in the three phase almost the same so the voltage profile is balance.

Current profile:

The testing of current profile done in the period between (Monday-9/11/2015 and Sunday - 15/11/2015) to know if the system is balanced or not as shown in the table 3.12.

Table 3.12: Current Profile Testing for Each Phase

day	I on phase 1	I on phase 2	I on phase 3
Saturday -14/11/2015	37	26	32
Sunday -15/11/2015	80	60	93
Monday-9/11/2015	82	56	64
Tuesday - 10/11/2015	74	49	59
Wednesday - 11/11/2015	47	55	50
Thursday -12/11/2015	62	50	51
Friday -13/11/2015	33	20	22

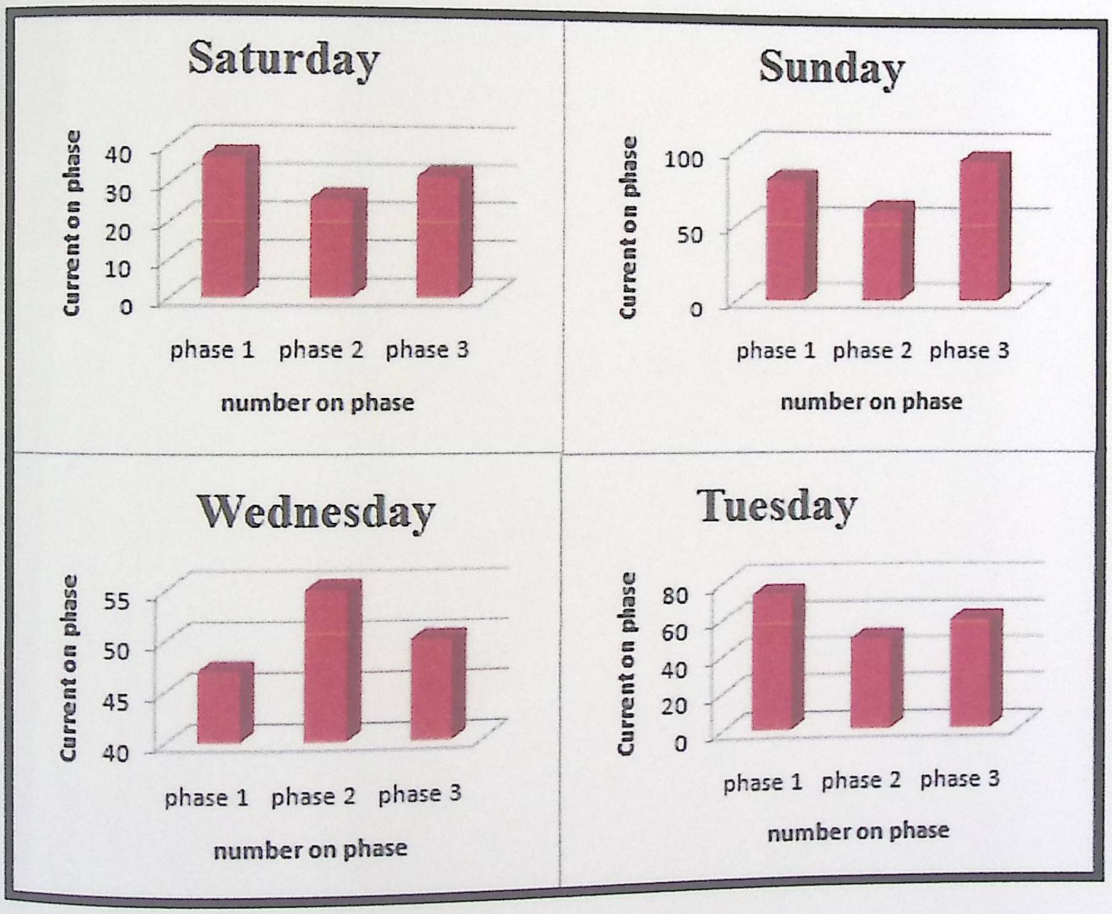


Figure 3.7: Current Profile Testing at Four Days

Hint: testing for all days are shown in the Appendix (D).

From the table and figure above we can note that the current profile is not balanced.

The system in the "C" building is unbalance and to solve this problem we need to redistribute the load in the building between three phases equally and this is difficult to do practically and if we doing any single phase load connect on the system it make the system unbalance.

4

Chapter four: System Design

4.1 Introduction

In this chapter we are going to design the audit system using smart system, this chapter consist of three parts, briefly the first part deal with light system, the second part deal with HVAC system, the third part deal with other application like laptop, cell phone, etc.,

In this project we want to apply the smart system in C-building in Palestine Polytechnic University, the aim of applying this system is conservation of energy from losses, without compromising the comfort of people.

We are going to control of all applications in C- building, this applications consist of Light, HVAC, and office and building equipment system, this system can be control either mobile phone or by automatic system, or by the both ways.

To access the correct design in this project we are going to divide the project into two sections, the first section deal with light and HVAC systems, the second section deal with other application,

4.2 General Block Diagram of the First Section of Design

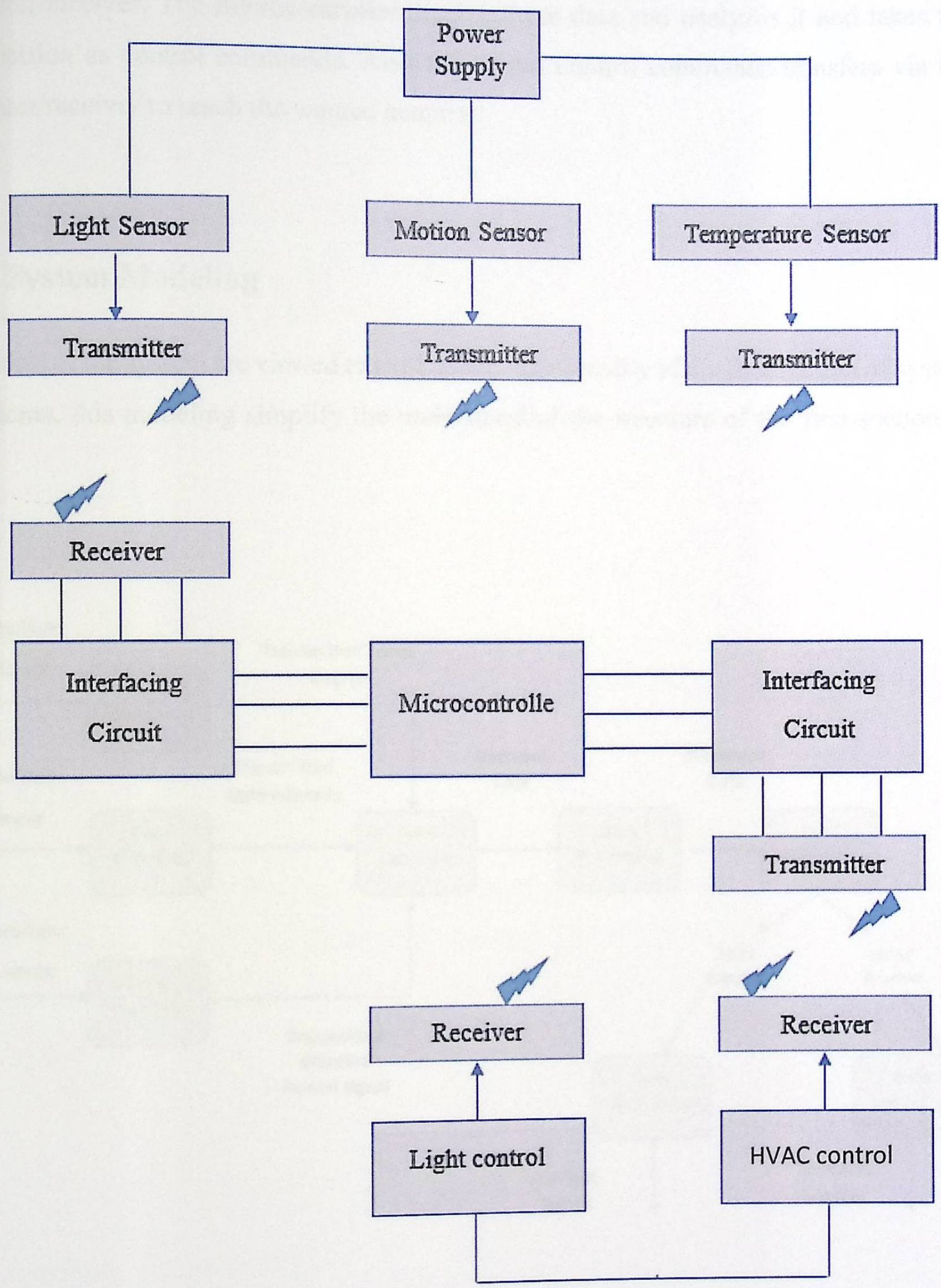


Figure 4.1: General Block Diagram for the first section

As shown in Figure 4.1, the general block diagram of the system, the sensors are put in the room independently to measure different parameters (temperature degree, light intensity, and motion detection). These measured values are sent to the microcontroller through the transmitter/receiver. The microcontroller receive these data and analyzes it and takes the right decision as control commands. Also the output control commands transfers via the transmitter/receiver to reach the wanted actuator.

4.2.1 System Modeling

The models of the system are viewed to explain the functionality of the first section of system components, this modeling simplify the understood of the structure of the first section of system.

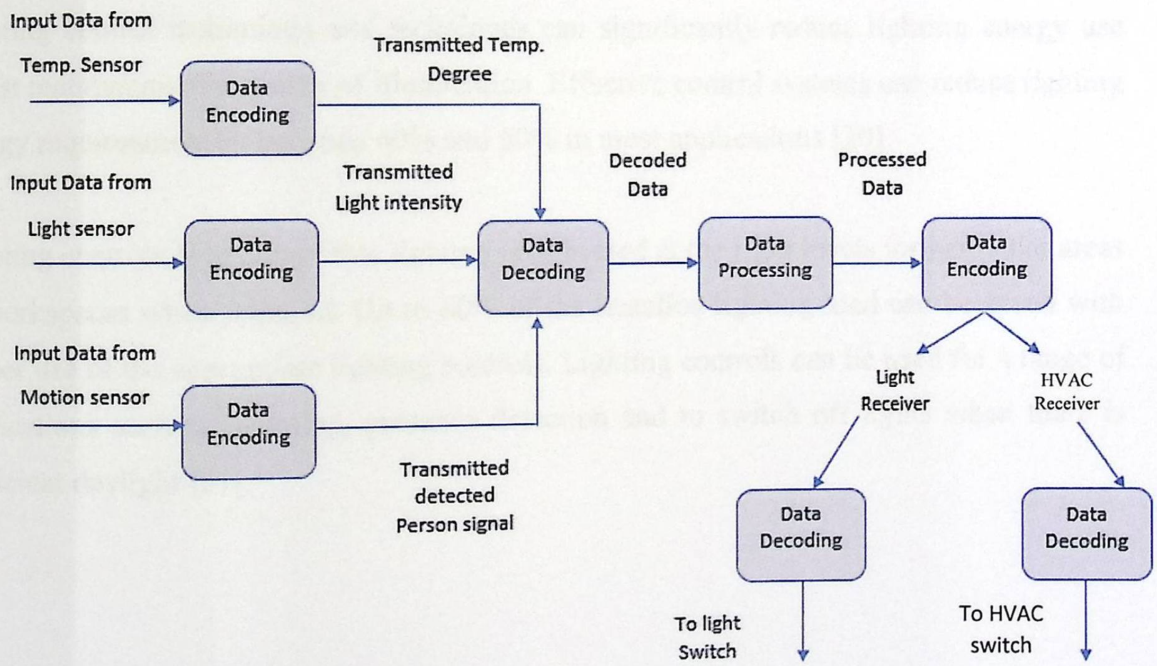


Figure 4.2: Data flow model

Figure 4.2, shows the data flow model of the system. It shows how the sequence of data start with enter the data from sensors that gather data about the surrounded environment, these data is encoded through the interfacing circuit in order to transmit it to the microcontroller, the sent data is carried out using RF-wireless technique, when the microcontroller gets this decoded data from the receiver converts it from analog to digital data in order to determine the address of the source transmitter.

After that the micro-controlling unit analyzes this data, and takes the appropriate decision, this decision is transmitted via the transmitter attached to the micro-controlling unit. Finally the transmitter sends the data to the address generated from the microcontroller to the receiver that is attached to the actuator in order to do the desired action, such as turn on light, turn on air conditioner.

4.2.2 Lighting Control

Lighting control technology and techniques can significantly reduce lighting energy use whilst maintaining the quality of illumination. Effective control systems can reduce lighting energy requirements by between 40% and 60% in most applications [30].

Lighting controls help ensure that lighting is delivered at the right levels for particular areas or workspaces when required. Up to 60% of the installed lighting load can be saved with proper use of the appropriate lighting controls. Lighting controls can be used for a range of applications such as dimming, presence detection and to switch off lights when there is sufficient daylight [31].

Lighting Control Technology

The main strategies for lighting control include: local switching and dimming, presence detection, daylight linked and time operated. The following diagram shows effective strategies for lighting control.

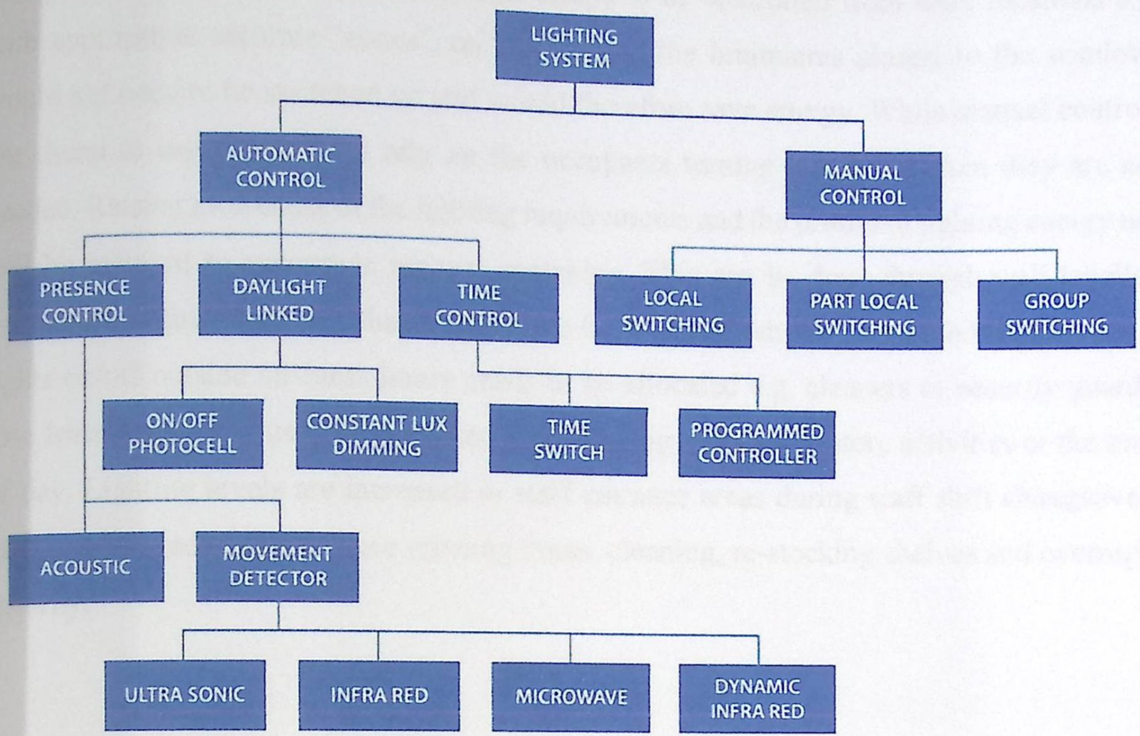


Figure 4.3: Effective strategies for lighting Control.

Each zone where lighting controls are to be used should be evaluated for the best strategy of control. Manual control includes the way the switches are linked to individual and groups of luminaires. Controllers can also be automated, and these can react to presence detection, daylight availability or time of day. Multiple zone controllers use a communications protocol known as a 'BUS' system to link each component together. The main control strategies are outlined below.

Manual Control

These are either permanently wired (such as the standard wall switch), or ceiling mounted pull switches, and can be used for switching or dimming. Part switching and group switching allows a certain number of luminaires or lamps to be controlled from local locations e.g. with appropriate separate 'zones', on bright days the luminaires closest to the windows would not need to be switched on and would therefore save energy. While manual controls are cheap to install they still rely on the occupants turning lights off when they are not needed. Raising awareness of the lighting requirements and the profile of lighting energy use will be required to encourage manual switching. This can be done through well labelled switches and guidelines on what lights are to be used and when. Responsibility for turning lights on/off outside business hours needs to be allocated e.g. cleaners or security guards. One Irish retail chain uses different levels of lighting matched to store activities or the time of day. Lighting levels are increased in staff entrance areas during staff shift changeovers and levels are adjusted for store opening times, cleaning, re-stocking shelves and overnight security.

Automatic Controls

This can be used to:

- Automatically switch lights on and off as people enter and leave an area or room.
- Manually switch lights on upon entry and automatically switch lights off when people leave an area or room.

Passive infra-red (PIR) units are low cost traditional presence detectors which can also have daylight sensor facilities.

Some types of PIR sensors can be set to keep the lights off when there is sufficient natural light and detect presence, automatically switching the lights on or off when a person enters or exits a space. Adjustable sensitivity is possible for both presence detecting and daylight sensing.

The mounting position of automatic presence detectors (on the wall or ceiling) will be determined by the size and shape of the area:

- For small areas, infra-red detectors mounted on the wall, are likely to provide sufficient detection and the detector should be able to be 'seen' from all positions in an area.
- For larger areas, ultra-sonic or microwave detectors, are more sensitive to movement and therefore more suitable for areas where small movements are made. The direction of the detector head needs to be considered as a sonic beam will detect movement through glass i.e. outside the office.

Daylight Linked Control

Daylight controls/photocells linked to switch or dimming luminaires respond to daylight levels. The luminaires in a large workspace could be split into three lighting control zones. One zone along windows, a second zone in the middle of the room and a third zone at the back of the room. The luminaires in each zone can then adjust lighting levels depending on the natural light entering the space.

Time Control

These are used to switch lights off when they are not required, such as at lunchtime or at the end of the day and in any situation with a regular period of occupation (always provide manual override to allow users to switch lights on if necessary).

Block Diagram

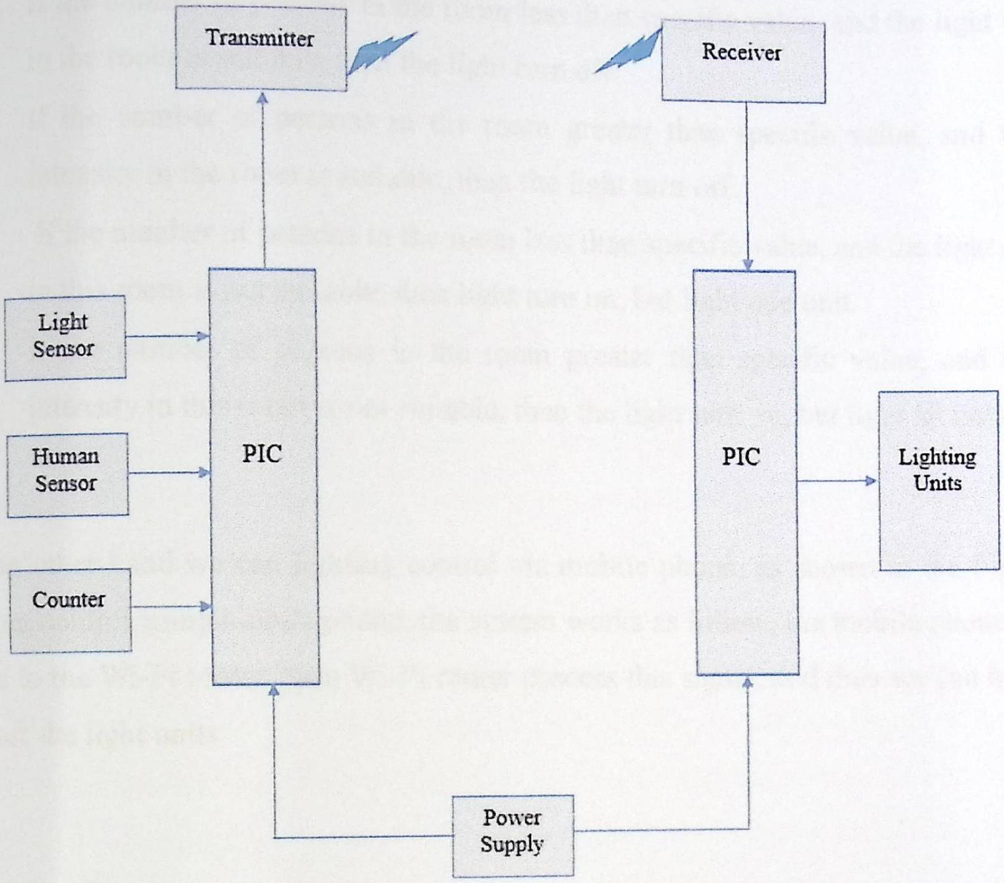


Figure 4.4: Block Diagram for Lighting Control System

As shown in Figure 4.4, the block diagram for lighting system, in this system the sensors put in the room to detect lighting intensity, and presence human , and the counter put in the beginning of the room to count the number of persons who are enter to the room, this system works as the follow, count which measure the number of persons entering in any room, this person count will be incremented if somebody enter inside the room, and at that time the light unit turn on, but to save energy, the system will work according to the following conditions.

- If nobody in the room the light turn off.
- If they are persons in the room and the light intensity in the room is suitable, then the light turn off.
- If the number of persons in the room less than specific value, and the light intensity in the room is suitable, then the light turn off.
- If the number of persons in the room greater than specific value, and the light intensity in the room is suitable, then the light turn off.
- If the number of persons in the room less than specific value, and the light intensity in this room is not suitable, then light turn on, but light one unit.
- If the number of persons in the room greater than specific value, and the light intensity in this room is not suitable, then the light turn on, but light all units.

On the other hand we can lighting control via mobile phone, as shown in the Figure 4.5, lighting control using mobile phone, the system works as follow, the mobile phone sent the signal to the Wi-Fi router, then Wi-Fi router process this signal, and then we can turn on or turn off the light units.

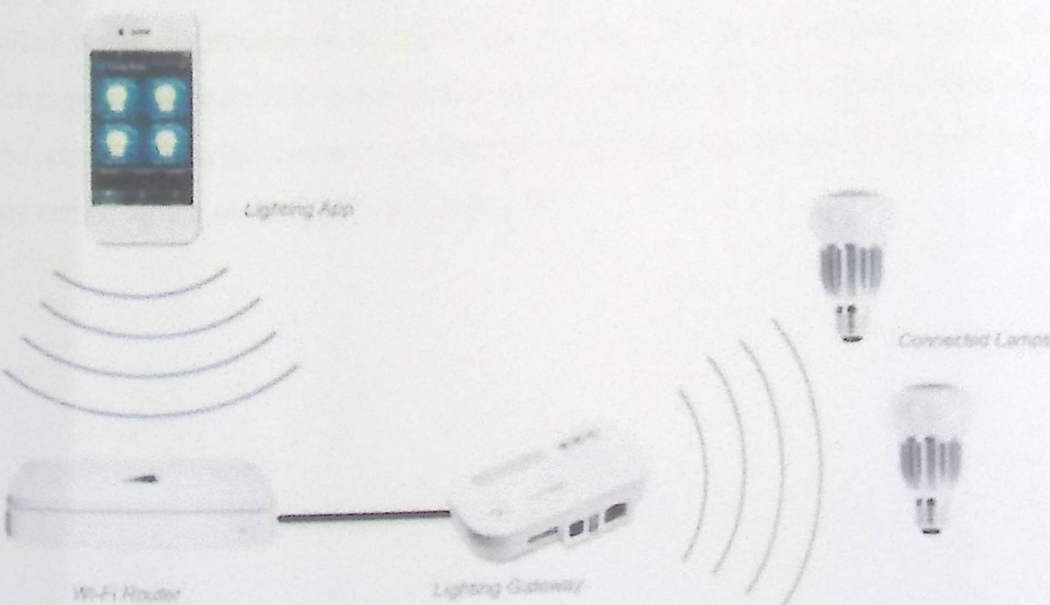


Figure 4.5: Lighting Control Using Mobile Phone

4.2.3 HVAC Control System

For a higher quality and comfortable modern lifestyle, people rely on air conditioners (ACs) much more than before, in both developed and developing countries, ACs increase the occupancy ratio of building areas, this also leads to a rapid growth in the energy consumption be ACs, according the static data [32], HVAC almost consumed half of the energy in building and 20% of the overall national energy consumption, therefore it is important to decrease the energy consumption of ACs in residential and commercial building [33].

Before going into the design, the following is a brief explanation about:

HVAC systems are classified as either self-contained unit packages or as central systems. Unit package describes a single unit that converts a primary energy source (electricity or gas) and provides final heating and cooling to the space to be conditioned. Examples of self-contained unit packages are rooftop HVAC systems, air conditioning units for rooms, and air-to-air heat pumps. With central systems, the primary conversion from fuel such as gas or electricity takes place in a central location, with some form of thermal energy distributed throughout the building or facility. Central systems are a combination of central supply subsystem and multiple end use subsystems. There are many variations of combined central supply and end use zone systems. The most frequently used combination is central hot and chilled water distributed to multiple fan systems. The fan systems use water-to-air heat exchangers called coils to provide hot and/or cold air for the controlled spaces. End-use subsystems can be fan systems or terminal units. If the end use subsystems are fan systems, they can be single or multiple zone type [34].

Block Diagram

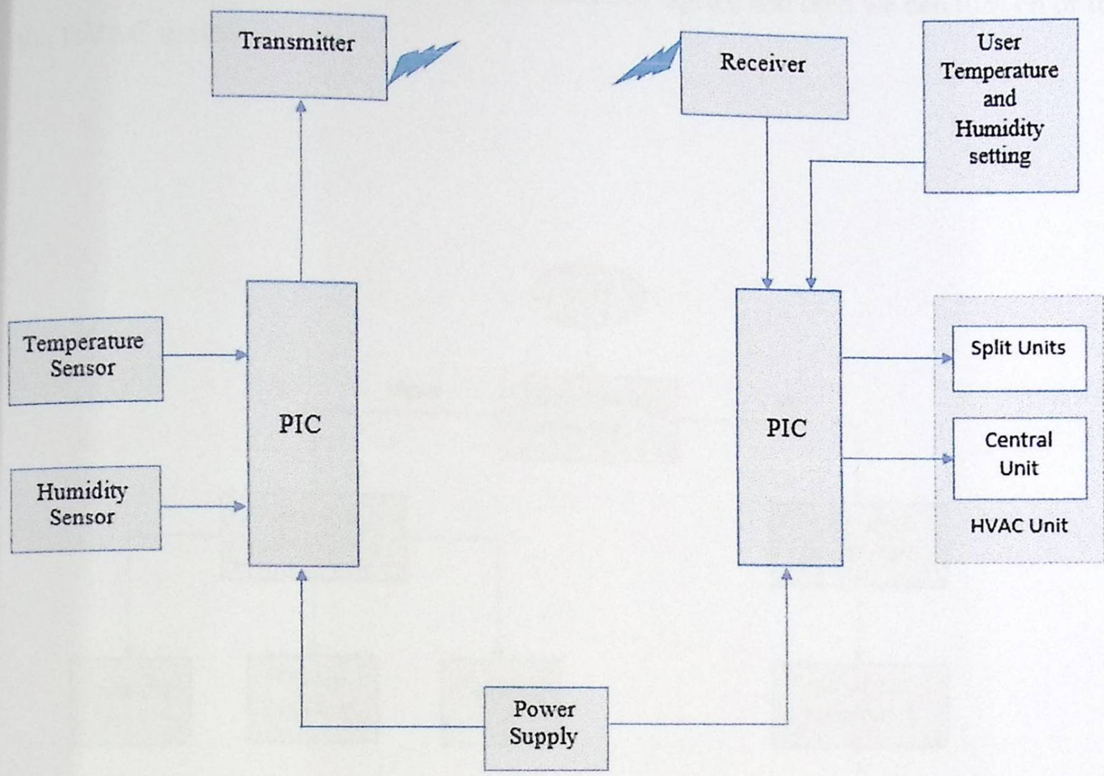


Figure 4.6: Block Diagram for HVAC System

As shown in Figure 4.6, the block diagram for HVAC system, in this system sensors put in the room to detect the temperature and humidity, these values are taken as inputs by the climate control system and it electronically controls the temperature and humidity and maintains them at user-specified values, These sensors continuously read the temperature and humidity values of the area and feed it to the microcontroller. These readings are then compared by the setting value defined by the occupants, based on the comparison result, it is controlled by the HVAC system either turned off or turned on.

On the other hand we can control of the HVAC system via mobile phone, HVAC control system using mobile phone, the system works as follow, and the mobile phone sent the signal to the Wi-Fi router, then Wi-Fi router process this signal, and then we can turn on or turn off the HVAC units.

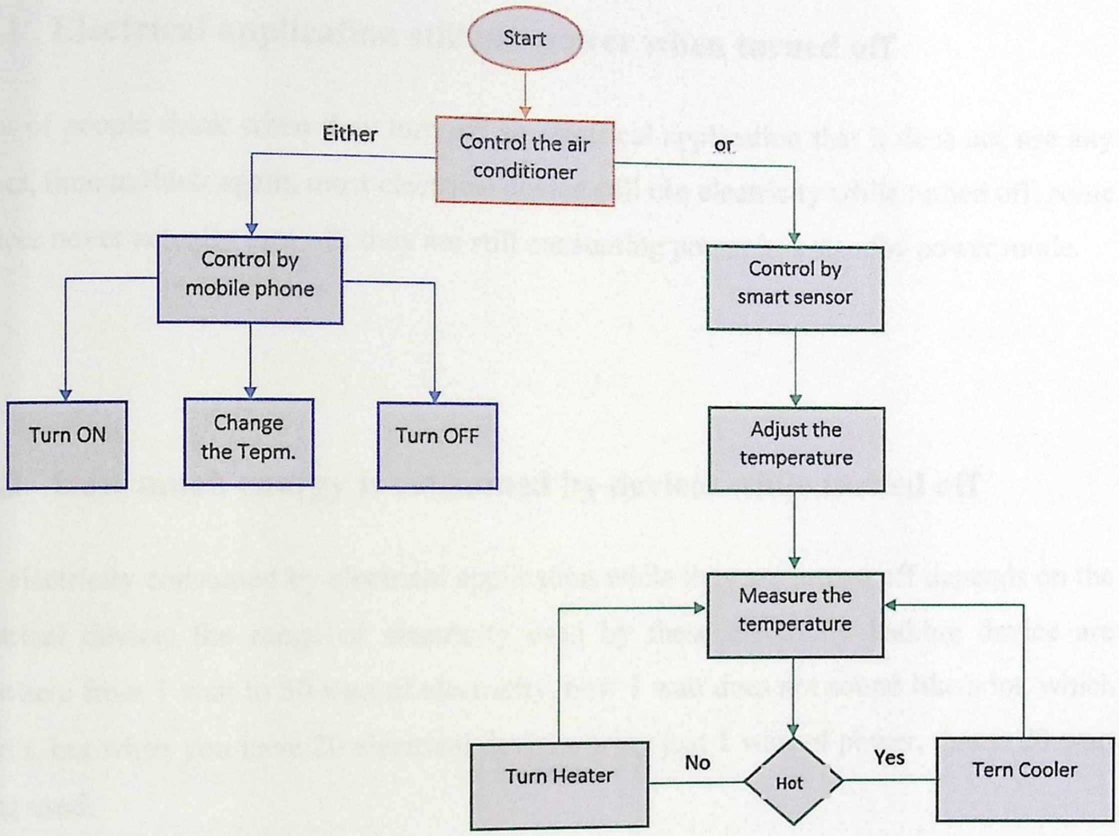


Figure 4.7: HVAC System Control Flowchart

4.3 Separate Automatic for Electrical Application

In the previse section we discussed the smart lighting control, and smart air conditioner control, in this subsection we discuss the other application like laptop, cellphone, LCD, etc., but before deal with design we want to illustrate some important points.

4.3.1 Electrical application still use power when turned off

A lot of people think when they turn off an electrical application that it does not use any power, time to think again, most electrical device still use electricity while turned off, some devices never actually turn off, they are still consuming power in a standby power mode.

4.3.2 How much energy is consumed by devices while turned off

The electricity consumed by electrical application while they are turned off depends on the electrical device, the range of electricity used by these electricity leaking device are anywhere from 1 watt to 50 watt of electricity, now 1 watt does not sound like a lot, which it isn't, but when you have 20 electrical devices using just 1 watt of power, that is 20 watt being used.

A single cellphone charger will consume 1 watt while plugged into the wall, even without a phone plugged into it! The same cellphone charger will also consume 4.5 watts of electricity with a cellphone plugged into it that is already fully charged! The same cellphone charger will consume 8 watts of power while charging a cellphone.

A stand-alone DVR set top box will consume 48.5 watts of power while turned off. A digital cable DVR set top box will consume 43.5 watts of electricity while turned off, while a digital cable box without DVR will consume 33 watts of electricity. A satellite set top box with or without DVR will consume 33.5 watts of power while turned off.

Almost everyone has a TV in their home, so how much electricity do TVs consume while turned off? Rear projection TV will consume 48.5 watts of electricity while it is turned off! A standard CRT TV will consume 13 watts while turned off.

So for this reason we are going to design smart system to Separate Automatic for Electrical Application, in the next section we illustrate the design principle for these separate automatic.

4.3.3 Design Principle

As shown in Figure 4.8, the block diagram for automatic interruption process, the system works as follow, when load dis-connected to the supply, the sensor give change in the current, and then the value is converted to the voltage, then adjust the voltage value using amplifier gain, even fit with the voltage allowed enter the electronic programmed piece. It is then compared to the value entered with the programmed value, if the entered value is less than the programmed value, then be sent command to the transistor, then sent to the relay to be automatic interruption process.

When it is re-connect the load, the sensor works and gives change in current, then it is transferred to the voltage, then enter value to transistor then to triac, and therefore electricity is connected to Transformer again.

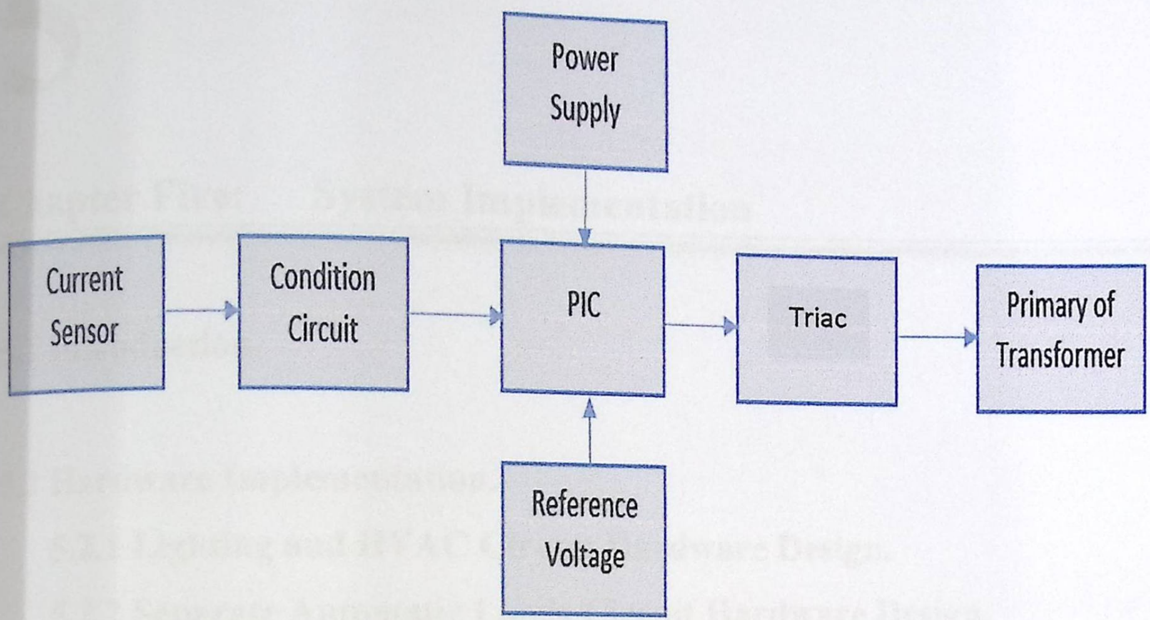


Figure 4.8: The Block Diagram for Automatic Interruption Process

5

Chapter Five: System Implementation

5.1 Introduction.

5.2 Hardware Implementation.

5.2.1 Lighting and HVAC Circuit Hardware Design.

5.2.2 Separate Automatic Loads Circuit Hardware Design.

5.2.3 Android Application Circuit Hardware Design.

5.3 Software Implementation.

5.3.1 Transmitter Side Software Design.

5.3.2 Receiver Side Software Design.

5.3.3 Separate Automatic Loads Software Design.

5.3.4 Android Application Software Design.

5.1 Introduction

In chapter 4, we discussed the conceptual design of the system in details including the idea, the main system parts, system modeling, and the algorithms that will be applied to achieve the project objectives.

In this chapter we will dig more deeply in implementation side of the project. Section 5.2 will focus on the electrical considerations in the design including the main diagram, electrical calculations, and will discuss other possible variation of the design beside the advantages and disadvantages of each one. Section 5.3 will focus on the software implementation, and will discuss the various codes that have achieved the goals of the project.

5.2 Hardware Implementation

In this section we will discuss the detailed electrical circuit, as mentioned in section 4.1, the system consists of three parts: Lighting system, HVAC system, other application system, As well as for the mobile application relating to the first part and the second.

5.2.1 Lighting and HVAC circuit Hardware Design

As a results of similarities on control between Lighting circuit and HVAC circuit, in this section we will collection two control circuits in one control circuit, Lighting and HVAC control circuit consist of two parts, transmitter circuit and receiver circuit. Figure 5.1 shows circuit diagram of the transmitter circuit. This circuit consist of three main components:

- Different Sensors (work as input to the system).
- PIC atmega328.
- XBee module.

In the following paragraph we discuss the main function of each components.

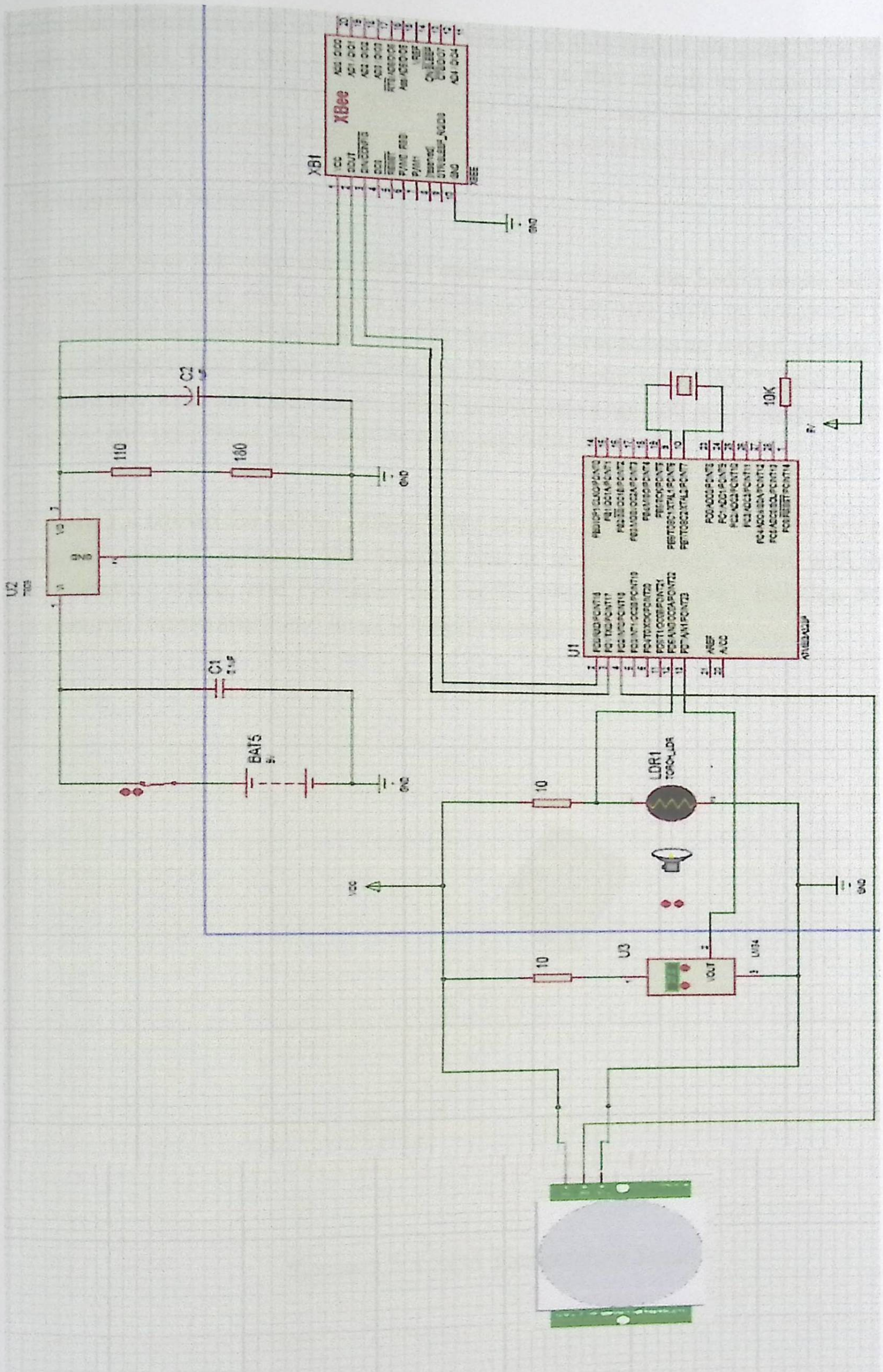


Figure 5.1: Circuit Diagram for Transmitter Circuit.

The transmitter circuit consist of many components, in this circuit we used three sensors (Temperature, Light, PIR), this sensors use as input to this circuit to measure different parameter like, temperature of the room, light intensity, and detect the human exist, following is a brief explanation about how this sensors is working in the circuit.

- **Temperature Sensor.**

In this project we used the LM35 Temperature sensor, the LM35 is an integrated circuit sensor that can be used to measure temperature with an electrical output proportional to the temperature in (C°) the LM35 sensor has an output voltage that is proportional to the Celsius temperature, the scale factor is (0.1V/C°) and it does not require any external calibration, LM35 is that draws only 60 micro amperes from its supply and possesses a low self-heating capability [35].

Figure 5.2 shows the LM35 Temperature sensor, LM35 is three terminal device, Pin number one for ground, Pin number two is analog voltage output with respect temperature value, and Pin three for 5-volt voltage supply [36]. Relation between measured temperature and analog output voltage is:

10 C° = 10 m volt

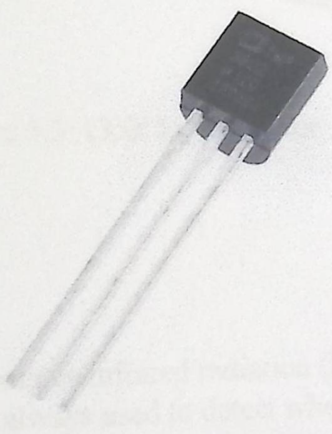


Figure 5.2: LM35 Temperature Sensor

Hence for every one degree increase in temperature there will be an increment of 10m volt in output voltage of LM35 sensor. PIC atmega328 is used to measure analog voltage value, PIC atmega328 built in Analog Digital Converter (ADC) is used to measure analog voltage, after reading ADC value, using voltage and temperature relationship voltage is converted back into temperature. A conversion factor is used to convert voltage back into temperature. All these conversion has been done through programming.

- **Light Sensor**

Light sensor is used to sense amount of light. There are many light sensors available in market but Light dependent resistor (LDR) is used as a light sensor. Figure 5.3 shows the LDR Light Sensor. Because it is cheap in price, easily available in market and can be easily interfaced with microcontroller to sense intensity of light. LDR have property to change its resistance according to intensity of light. If light is high, LDR will have low resistance and if light is low, LDR will have high resistance. So microcontroller can easily read this resistance in the form of voltage and which can be back converted into proportional value of light by using a formula available in datasheet [37].

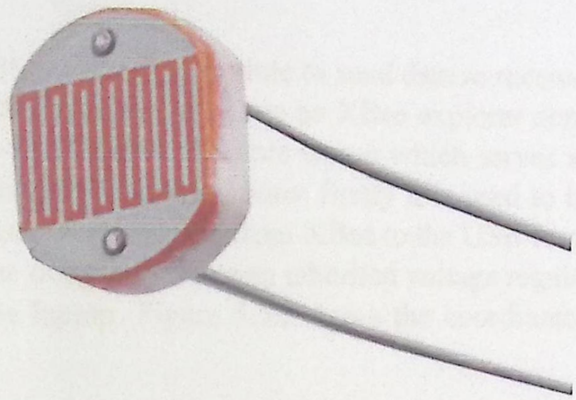


Figure 5.3: LDR Light Sensor

- **Human Sensor**

In this project we used the passive infrared radiation (PIR) sensor, PIR sensor allow you to sense motion, almost always used to detect whether a human has moved in or out the sensor range. They are small, inexpensive, low-power, easy to use and don't wear out.

PIR sensor consists of three Pins, the Pin number one for ground, Pin number two for output signal, Pin number three for voltage supply (5V), figure 5.4 shows the PIR sensor.

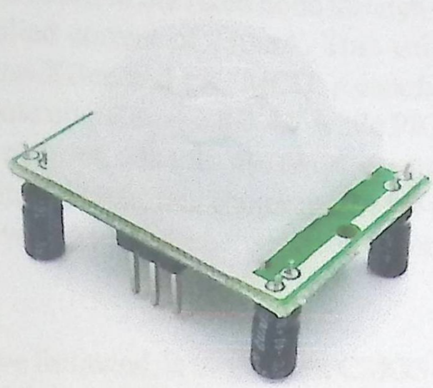
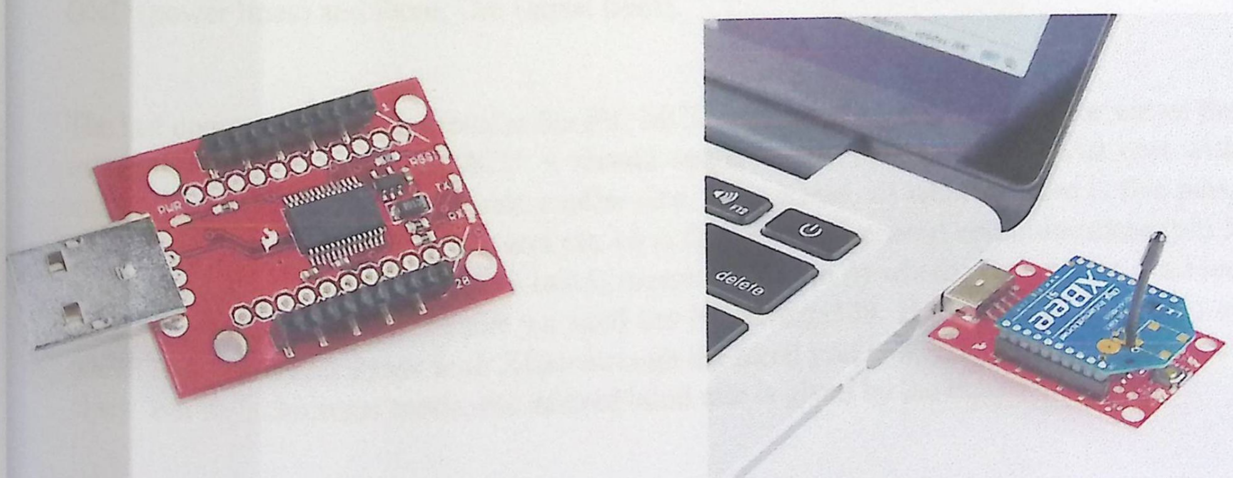


Figure 5.4: PIR Sensor

The other component we used the XBee module to send data to receiver circuit, in this part the XBee treated as transmitter module, we use an XBee explorer dongle (shown in figure 5.5a) to connect the XBee to the administrators laptop which serves as its microcontroller unit (MCU). The dongle has two main functions: firstly it is used to interface the XBee to the laptop by converting serial data coming from XBee to the USB format to be readable by the computer. Secondly, the dongle contains an inherited voltage regulator at 3.3V to power the XBee module from the laptop. Figure 5.5b shows the coordinator nodes components connected together.



(a) XBee explorer dongle.

(b) XBee, PC and the dongle all together.

Figure 5.5: Coordinator node.

On the other hand, the power is fed to the fixed node through an AC-DC power adaptor with 7.5V and a maximum supplied current of 250mA. This voltage is passed through voltage regulation stage to power the XBee and PIC MCU. According to their datasheets (refer to appendix B) the XBee module operates at 2.8-3.4V while PIC is known to work at 5V. From this point we have had two choices: either to use two separate regulators to power XBee and PIC on the their suitable voltage levels, this choice means we will need a voltage level-shifter circuit (usually a transistor with a resistor) between serial port of XBee and serial port of the PIC.

The second choice, which we followed, is to choose a CMOS-type PIC MCU. The advantage of using a CMOS MCU is that they operate at low voltage (from 2.2-5.5V) which is very suitable in our case. Note that this solution does not only reduce the cost of the node by using a minimum components but also keep the board size more compact. The above circuit (figure 5.1) shows the circuit diagram of the transmitter circuit, the TS317 variable regulator is derived by two resistor of 110 and 180 ohm to provide the desired 3.3V output voltage according to the following equation:

$$Vout = 1.25V * (1 + R2/R1) + Iadj * R2 \qquad (5.1)$$

The presence of the two capacitors is optional to keep stable at the input and filter out the ripples at the output. As a general rule, when external capacitors are used with any I.C. regulator it is sometime necessary to add protection diodes to prevent the capacitors from discharging through low current points into the regulator. The protection diode is recommended for output voltage in excess of 25V or high capacitance value. However, since we are dealing will low rating power we ignore this diode.

The XBee module, it is 20 pin transceiver with only four pins are of our interest which, Vcc, GND (power lines) and Dout, Din (serial lines).

The last component in this circuit is the PIC MCU. From our previous discussion we set the requirements for the needed MCU: it should operate at 3.3V, and have a serial port with minimum number of pins to ensure smaller size. As in XBee, all what we need is five pins, two for power lines (pin 1 is Vcc and pin 14 is GND), two for serial communication (pin 5 is Rx and pin 6 is Tx), and the last one is master clear (pin 4) which we maintain disabled (i.e. at level high). In this circuit we used the PICatmega328. However, the baud rate at which PIC communications with XBee through the serial port is directly affected by chosen clock. For asynchronous mode, the desired baud rate is given by the equation:

$$BaudRate = \frac{Fosc}{64(BRG+1)} \qquad (5.2)$$

Where BRG register store 8-bit number that controls the baud rate of the PIC. And the oscillator frequency is four time the operation clock frequency. The default baud rate for serial communication is 9600. Let say we went to find the actual baud rate, then solver for BRG value

$$BRG = \left(\frac{\left(\frac{Fosc}{BaudRate}\right)}{64}\right) - 1 \tag{5.3}$$

$$BRG = \left(\frac{\left(\frac{16000000}{9600}\right)}{64}\right) - 1 = 25$$

Now calculate the actual baud rate using equation 5.2, the result is 9615 with giving by

$$Error = \frac{(Calc.BaudRate - DesiredBaudRate)}{DesiredBaudRate} = 0.16\% \tag{5.4}$$

This small drift in timing did not cause much problems if we make sure that our transmitted packets through serial ports are short. A 0.16% error means that every 640 bits (i.e. 9600/15) there is one additional bit (i.e. one error occur every 80 byte). However, our packets do not exceed 50 bytes at any circumstances so we are safe.

Briefly the transmitter circuit work as follow, PIC take different data from sensors, then process this data, and finally transfer this data to the XBee module, then XBee module prepare this data and send it to another XBee module (receiver circuit).

Figure 5:6 shows the circuit diagram of receiver circuit, this circuit consist of three main components:

- XBee module.
- PIC atmega328.
- Output Circuit (Lighting & HVAC).

In the following paragraph we discuss the main function of each components.

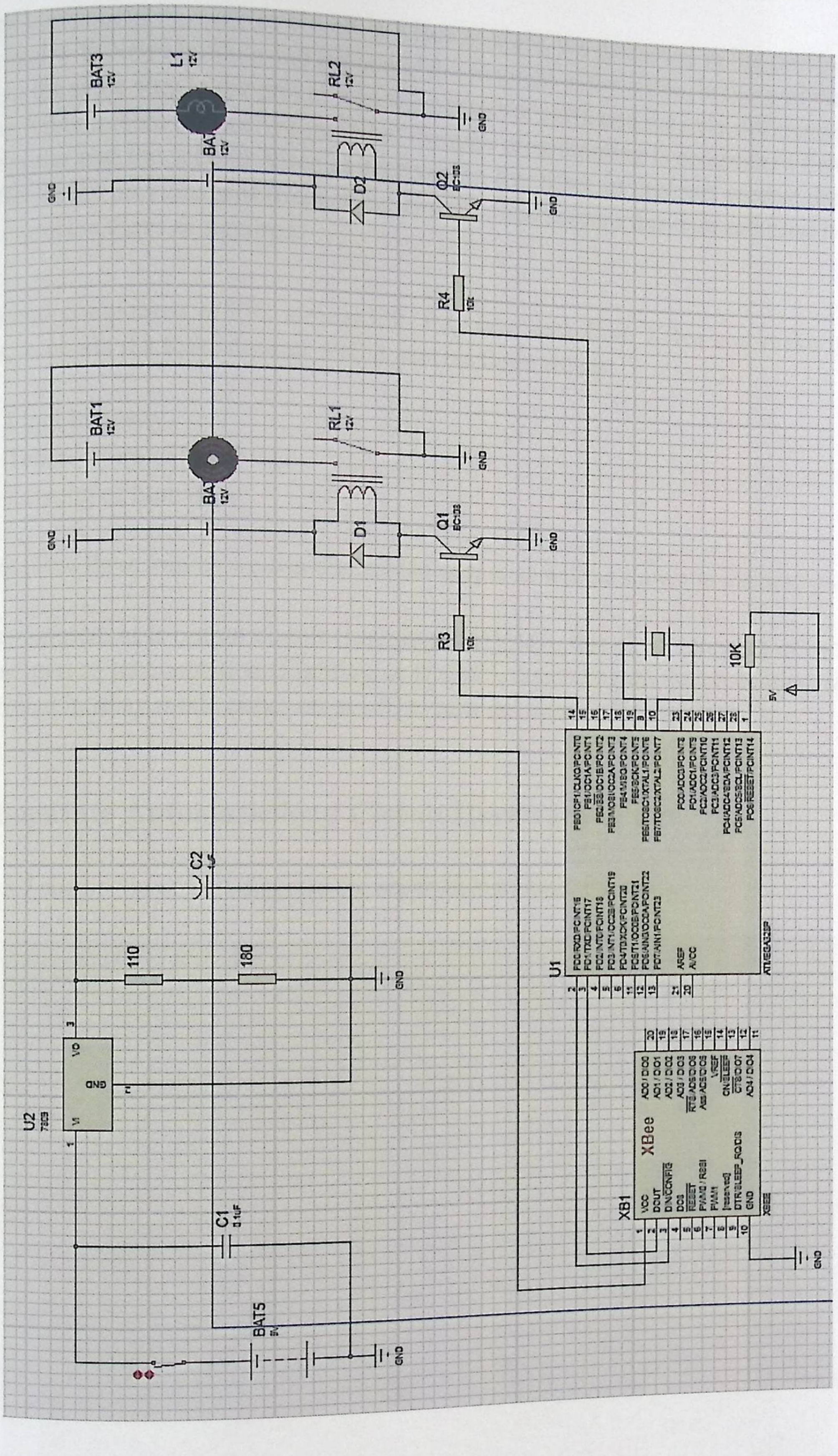


Figure 5.6: Circuit Diagram for Receiver Circuit.

The first component in receiver circuit is XBee module, we discussed in the previous part how to deal with XBee module and explained the function of the XBee, in this part the XBee treated in the same way in the previous part (transmitter part), and the only difference in this part the XBee treated as receiver module. Through programming is determined first XBee as transmitter and the second XBee as receiver, so the XBee in this part receive data from first XBee in the previous part (transmitter circuit), then prepare this data and send it to PIC MCU to process them as required.

The second component is PIC atmega328, PIC take data from XBee and make it some process, to obtain the tasks desired. PIC it process three values:

- Light intensity.
- Temperature value.
- Existing of human.

Through these three values we can control the output as will be shown in the next phase.

The last component is output circuit (Lighting & HVAC), this circuit consists of two parts, relay and part to be controlled (Lighting or HVAC), depending on the processing values it is controlled in relay mode either on or off, to turn on or turn off the output.

5.2.2 Separate Automatic load Circuit Hardware Design

Figure 5.7 shows the circuit diagram for separate automatic for loads.

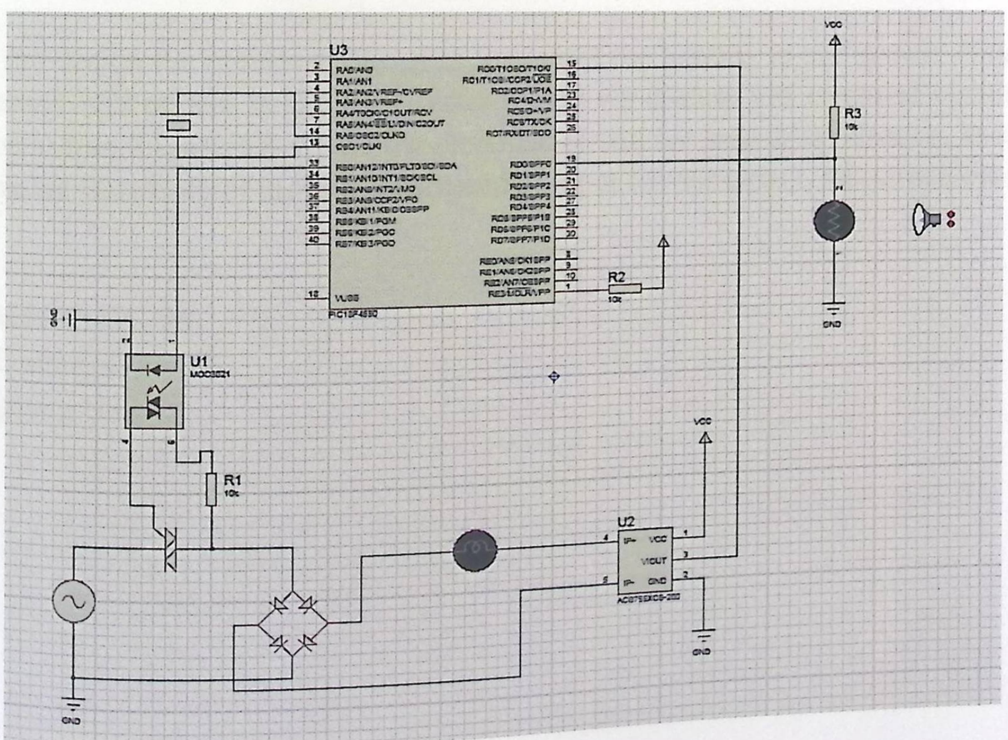


Figure 5.7: Circuit Diagram for Separate Automatic Loads

This circuit consists of three main parts:

- Current sensor.
- PIC atmega328.
- Triac.

Dis-connect load from network depending on the current sensor, and re-connect load to the network depending on the LDR sensor.

Separate automatic circuit work as the following steps:

- When load is connected to the supply the current sensor have a value, this value is the current that load withdrawn from the network, and we will be depending on this value in the separation automatic.
- When load dis-connected from supply then the current withdrawn from the network is small, this value is determine by measuring current when load is dis-connected.
- The value of this current go to the PIC MCU then PIC MCU make processer and send signal to the triac to separate load from supply.
- When re-connect load to the network, then the LDR sensor value become very small.
- This value go to the PIC MCU, then PIC MCU send signal to the triac to re-connect load.

5.2.3 Android Application Hardware Design

We made and design the mobile application to control the lighting in our system, detail of this application will appear in the next section, hear we discuss just electrical circuit for android application. Figure 5.8 shows the electrical circuit for android application, as show in the figure the Bluetooth of mobile considered as input for this circuit, this circuit consists of:

- Bluetooth HC-06.
- PIC atmega328.
- Lighting Units.

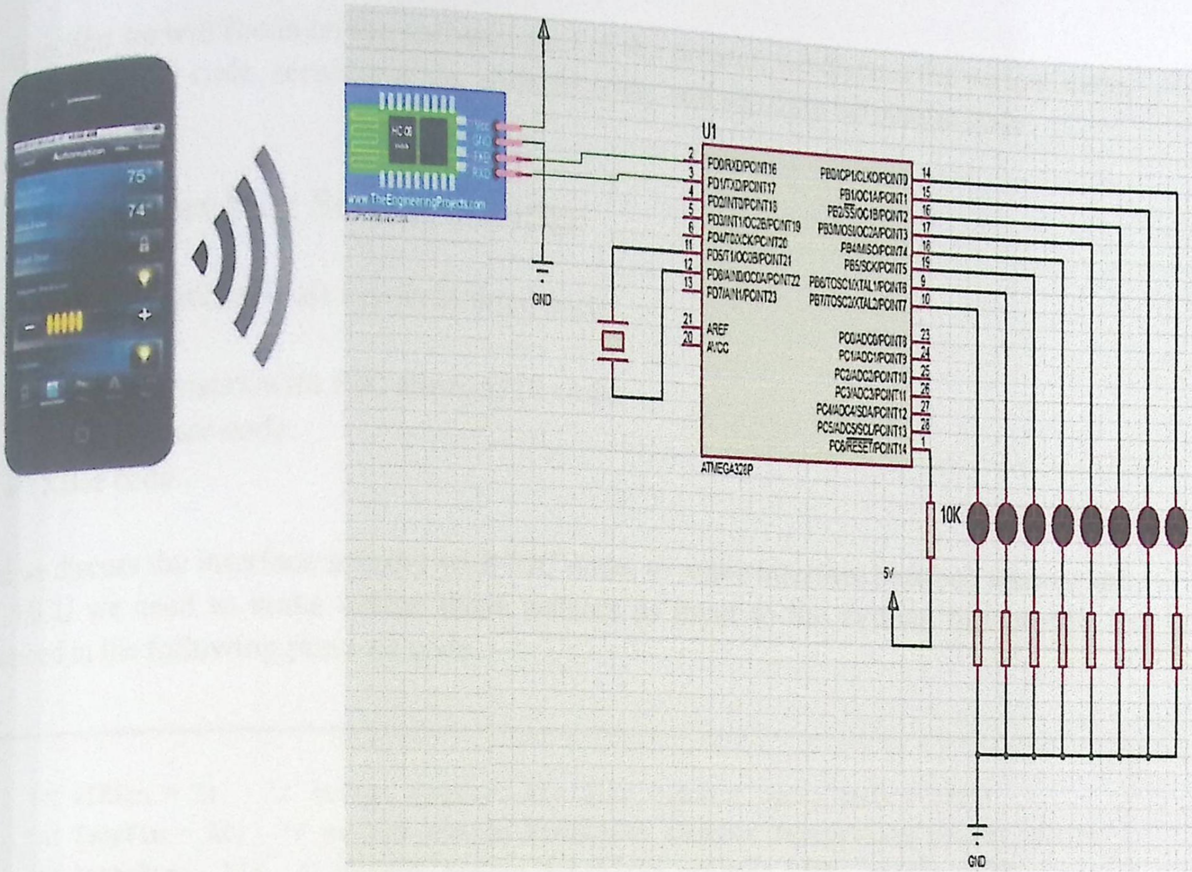


Figure 5.8: Circuit Diagram for Android Application

This circuit works as the following steps:

- The mobile send the number of lighting unit to be activated, through the Bluetooth of mobile.
- Bluetooth HC-06, mounted with PIC atmega328, received the number of lighting unit to be activated, and send this number to PIC.
- PIC atmega328 check out this number, and therefore do a lighting unit required.

5.3 Software Implementation

In this section we will focus on the software part of the project, we discuss the various code, such as, transmitter code, receiver code, android code, and separate automatic code.

5.3.1 Transmitter Side Software Design

In the transmitter circuit, code involves three parts:

- Interface sensors with PIC atmega328 code.
- PIC processor code.
- XBee code.

First we discuss the interface sensors with PIC code, to make interface between sensors and PIC MCU we need to make define these sensors as input to the system, this process is described in the following piece of code:

```
int PIRPin = 2;    // select digital Pin(2)to connect human sensor (PIR)
int TempPin = A0;  // select analog Pin(A0)to connect Temperature sensor (LM35)
int LightPin = A1;  // select analog Pin(A1)to connect Light sensor (LDR)

int PIR;    // to store PIR value
int Temp;    // to store Temp. value
int LDR;      // to store Light value
int i = 0;


void setup() {

Serial.begin(9600);

pinMode(2,INPUT);  // define Pin(2) as input to the system
pinMode(A0,INPUT);  // define Pin(A0) as input to the system
pinMode(A1,INPUT);   // define Pin(A1) as input to the system

}
```

As we explained previously, this code shows how make interface between sensors and PIC MCU, through the code it is clear that PIR sensor connect with digital Pin (2) in PIC MCU, and Temperature sensor connect with analog Pin (A0) in PIC MCU, and the LDR sensor connect with analog Pin (A1) in PIC MCU, then we defined these sensors as input to the system.

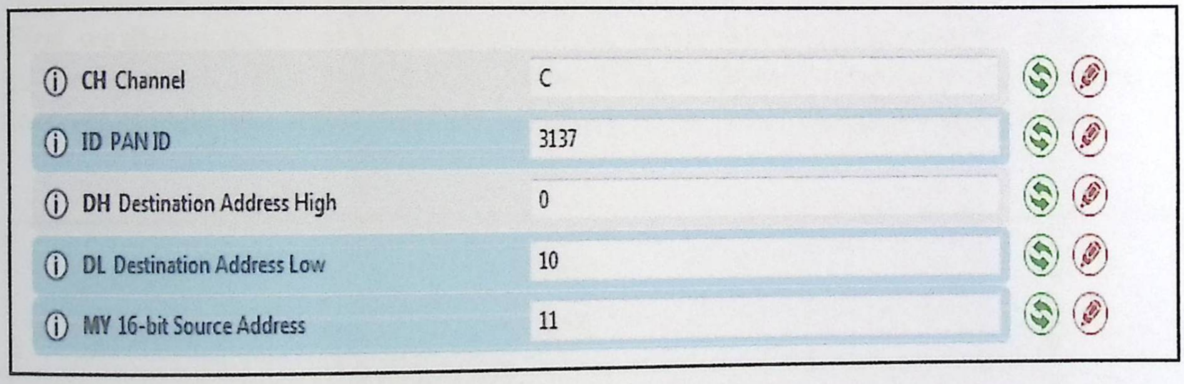
Second, we discuss the PIC MCU processor code, in this part PIC read the values of the sensors and make some process to give us values we can deal with it, this process is described in the following piece of code:

```
void loop() {

    PIR = digitalRead(2);   // read PIR sensor value
    Temp = analogRead(A0);   // read Temp sensor value
    LDR = analogRead(A1);   // read LDR sensor value

    Voltage = Temp * (5000 / 1024); // convert reading to millivolts
    Temperature = (Voltage - 500) / 10; // convert millivolts to temperature
```

The last part, XBee code, to programming XBee module we used the X-CTU program, through this program we can configuration the XBee, and define XBee as transmitter module, to define XBee as transmitter module we set the following parameter in the X-CTU program as the follow:



After configuration XBee on the X-CTU, now we make the interface between XBee and PIC atmega328, this process is described in the following piece of code:

```
#include <SoftwareSerial.h>

int PIR;
int Temp;
int LDR;

int array[3];   // define array to store three sensors values

void setup() {

  Serial.begin(9600);

}

```

```
void loop() {

    int array[] = {PIR,Temp,LDR};

    Serial.write(array[3]);
    delay(1000);

}

```

5.3.2 Receiver Side Software Design

In the receiver circuit, code involves two parts:

- XBee with PIC processor code.
- Interface Output circuit with PIC code.

The above code addresses same the previous code addresses in the transmitter circuit, but the code content varies depending on the function of each component.

First, we discuss the XBee with PIC processor code, in this part we also use X-CTU program to configuration XBee, but hear we define XBee as receiver module, to define XBee as receiver module we set the following parameter in the X-CTU program as the follow:

CH Channel	C
ID PAN ID	3137
DH Destination Address High	0
DL Destination Address Low	11
MY 16-bit Source Address	10

After configuration XBee on the X-CTU, now we make the interface between XBee and PIC atmega328, this process is described in the following piece of code:

```
#include <SoftwareSerial.h>

int PIR;
int Temp;
int LDR;

int array[3];  // define array to store three sensors values

void setup() {

  Serial.begin(9600);

}

void loop() {

  if(Serial.available()){

     array[3] =Serial.read();

     PIR = received[0];
      Serial.println("PIR =  ");
      Serial.print(PIR);
      delay(1000);

     Temp = received[1];
      Serial.println("Temperature = ");
      Serial.print(Temp);
      delay(1000);

     LDR = received[2];
      Serial.println("Light= ");
      Serial.print(LDR);
      delay(1000);

  }
}

```

The above code works as the follow, the XBee receive values from the first XBee, then the PIC MCU read these values and store them in one dimensional array.

Second, interface output circuit with PIC code, output in the system involves two parts:

- Lighting.
- HVAC.

Through the sensors values we controlled the output, for example we want to control of light in the classroom and passage in C building, control in classroom depending on two parameters, first parameter light intensity in the classroom, second parameter if human exist in classroom, it was measured light intensity in classroom in C building, and we found light intensity inserted between two values [500 to 1000] lux in the summer season, and in the winter season light intensity inserted between [0 to 500] lux. Lighting control in passage depending on the numbers of human are exist in this passage.

On the other hand, when we want control in the HVAC system we need to two parameters, human exist, and temperature in the room. The following code shows how do you control in lighting and HVAC.

```
void loop() {

 if(PIR != 0){

    if(Temp <= 20){

        digitalWrite(13,HIGH);
        digitalWrite(12,HIGH);
    }

    if(Temp > 20){

        digitalWrite(13,HIGH);
        digitalWrite(12,LOW);
    }

    if(20 < LDR < 500){

        digitalWrite(4,HIGH);
        digitalWrite(5,HIGH);
        digitalWrite(6,HIGH);
        digitalWrite(7;HIGH);
    }

    if(500 < LDR < 800){

        digitalWrite(4,HIGH);
        digitalWrite(5,HIGH);
    }

    if(LDR > 900){

        digitalWrite(4,HIGH);
    }


  }
}
```

The above code work as the following steps:

- If human exist in the room then system is work, existing human is condition for turn on lighting and HVAC.
- If human exist and temperature less than 20 C° then HVAC work as heater, if temperature greater than 20 C° then HVAC work as fan.
- If light intensity inserted between [20 to 500] lux, then all lamps are turn on.
- If light intensity inserted between [500 to 800] lux, then just two lamps are turn on.
- If light intensity greater than 800 lux, then jest one lamps is turn on.

5.3.3 Separate Automatic loads Software Design

In this section we will discuss the separate automatic loads code, this code depending on the measurements values for loads either connect to the supply or dis- connect from supply, this process is described in the following piece of code:

```
void loop() {

  current = analogRead(A0);
  LDR = analogRead(A1);

  average = average + (.0264 * current -5); //for the 5A mode,

  if(average > 2){

    digitalWrite(2,HIGH);
  }

  if(average < 1.5){

    digitalWrite(2,LOW);
  }

  if(LDR < 100){

    digitalWrite(2,HIGH);
  }

}
```

5.3.4 Android Application Software Design

In this section we will discuss the code for android application, we will design the interface for android application and to design this interfaces we used the android studio program.

Figure 5.9 show the welcome interface android application.

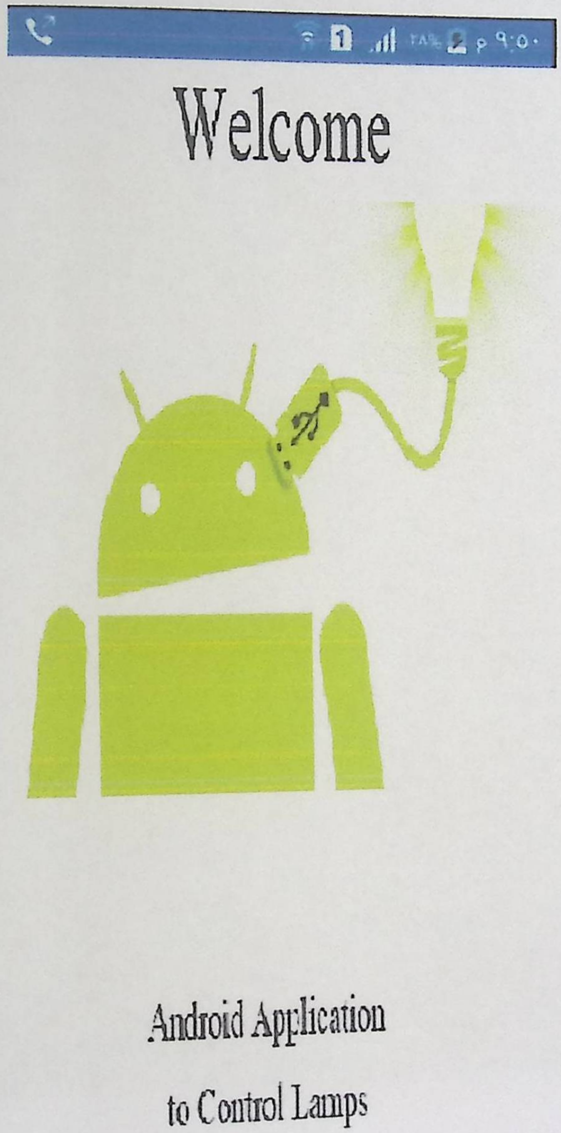


Figure 5.9: Welcome Interface android Application

Figure 5.10 show the interface android application, this interface consists of switch to connect mobile Bluetooth with HC-06 Bluetooth, and eight switches to turn on or turn off lamps, and additional two switches to either turn on all lamps or turn off all lamps.

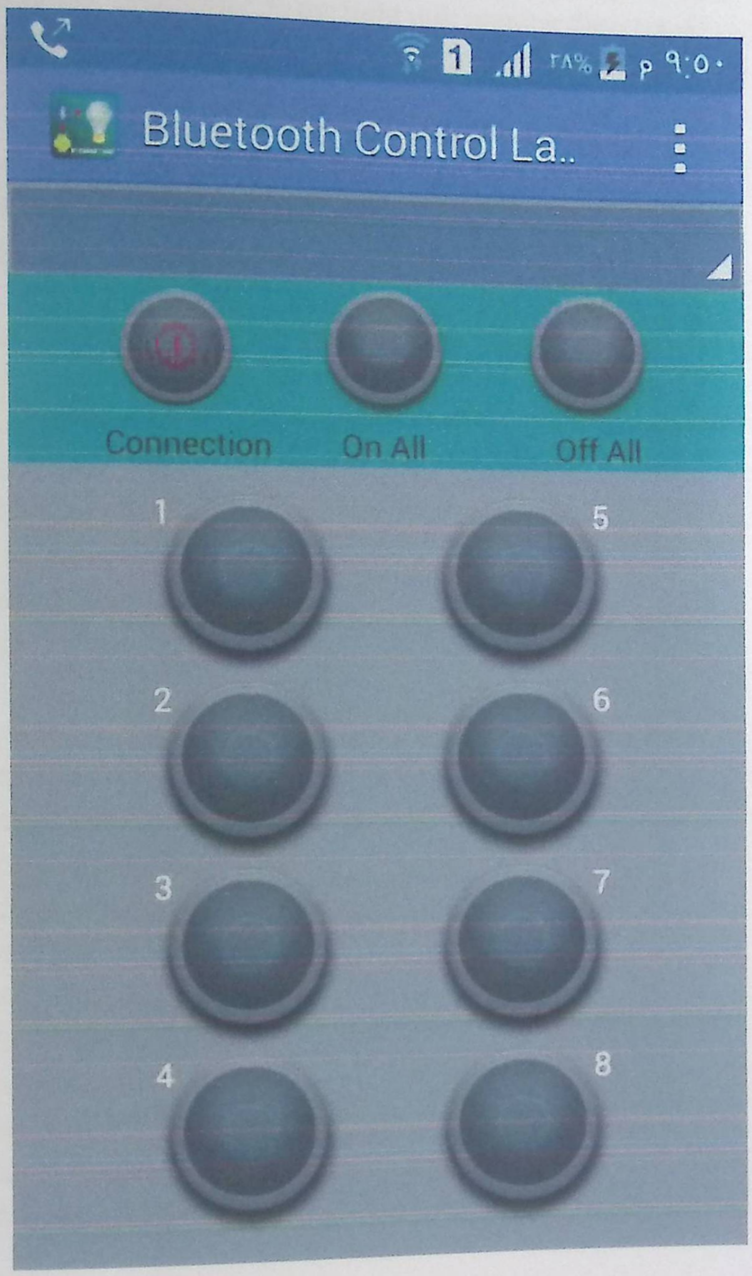


Figure 5.10: Interface Android Application

After we shown the interface for mobile application now we discuss the code for android electrical circuit that shown in the section 5.2.3, in this code firstly we interface Bluetooth (HC-06) with PIC MCU, to make interface between Bluetooth (HC-06) and PIC MCU we will used the same method that used when make interface between XBee with PIC MCU, then make this circuit able to receiver data from mobile, and finally we will able to control of lamps either on or off, depending on the light unit number that transfer from mobile to the Bluetooth (HC-06) this process is described in the following piece of code:

```
#include <SoftwareSerial.h>
SoftwareSerial mySerial(10, 11);

#define Lamp1 2
#define Lamp2 3
#define Lamp3 4
#define Lamp4 5
#define Lamp5 6
#define Lamp6 7
#define Lamp7 8
#define Lamp8 9

char val;
void setup() {
pinMode(Lamp1,OUTPUT);
pinMode(Lamp2,OUTPUT);
pinMode(Lamp3,OUTPUT);
pinMode(Lamp4,OUTPUT);
pinMode(Lamp5,OUTPUT);
pinMode(Lamp6,OUTPUT);
pinMode(Lamp7,OUTPUT);
pinMode(Lamp8,OUTPUT);
mySerial.begin(9600);
Serial.begin(9600);
}
```

```
void loop() {
//cek data serial from bluetooth android App
if( mySerial.available()  ) {
val = mySerial.read();
Serial.println(val);
}
//Lamp is on
if( val == '1' ) {
digitalWrite(Lamp1,HIGH); }
else if( val == '2' ) {
digitalWrite(Lamp2,HIGH); }
else if( val == '3' ) {
digitalWrite(Lamp3,HIGH); }
else if( val == '4' ) {
digitalWrite(Lamp4,HIGH); }
else if( val == '5' ) {
digitalWrite(Lamp5,HIGH);}
else if( val == '6' ) {
digitalWrite(Lamp6,HIGH);}
else if( val == '7' ) {
digitalWrite(Lamp7,HIGH);}
else if( val == '8' ) {
digitalWrite(Lamp8,HIGH);}
else if( val == '9' ) {
digitalWrite(Lamp1,HIGH);
digitalWrite(Lamp2,HIGH);
digitalWrite(Lamp3,HIGH);
digitalWrite(Lamp4,HIGH);
digitalWrite(Lamp5,HIGH);
digitalWrite(Lamp6,HIGH);
digitalWrite(Lamp7,HIGH);
digitalWrite(Lamp8,HIGH);
}
```

```
//Lamp is off
else if( val == 'A' ) {
digitalWrite(Lamp1,LOW); }
else if( val == 'B' ) {
digitalWrite(Lamp2,LOW); }
else if( val == 'C' ) {
digitalWrite(Lamp3,LOW); }
else if( val == 'D' ) {
digitalWrite(Lamp4,LOW); }
else if( val == 'E' ) {
digitalWrite(Lamp5,LOW);}
else if( val == 'F' ) {
digitalWrite(Lamp6,LOW);}
else if( val == 'G' ) {
digitalWrite(Lamp7,LOW);}
else if( val == 'H' ) {
digitalWrite(Lamp8,LOW);}
else if( val == 'I' ) {
digitalWrite(Lamp1,LOW);
digitalWrite(Lamp2,LOW);
digitalWrite(Lamp3,LOW);
digitalWrite(Lamp4,LOW);
digitalWrite(Lamp5,LOW);
digitalWrite(Lamp6,LOW);
digitalWrite(Lamp7,LOW);
digitalWrite(Lamp8,LOW);
}
}
```

6

Chapter Six: Testing and System's Performance.

6.1 Introduction

6.2 Test the Lighting and HVAC Circuit

6.3 Test the Separate Automatic Circuit

6.4 Test the Android Application

6.1 Introduction

In chapter five, we explain the idea behind the project, and discussed the conceptual design as well as the implementation of both hardware and software parts. This chapter is dedicated to the test performance of the system. The performance will be tested through three parts: the first is to test the Lighting and HVAC circuit that was designed for our system. The second is to test the separate automatic loads circuit. The final part is to test the android application that was designed for mobile.

6.2 Test the Lighting and HVAC Circuit

Lighting and HVAC circuit consists of two parts: transmitter part, and receiver part, initially we will doing transmitter part test, as the previous explanation for transmitter circuit in this section we will doing the test for interface sensors with PIC MCU, and we will doing test for XBee module to shows how this module transfer data to another XBee module (receiver part).

First, we show the test for interfacing sensors with PIC MCU, in chapter five we explain how this sensors connected to the PIC MCU, now we will test this connection, in this test we shows the sensors values in serial monitor, after that we shows how this values used to operate our system. Figure 6. 1 shows sensors value in serial monitor.

After interface sensors with PIC MCU and display its values, then this data become ready to send by XBee module (transmitter side) to another Xbee module (receiver side). Figure 6.2 shows how Xbee module (transmitter side) it works.

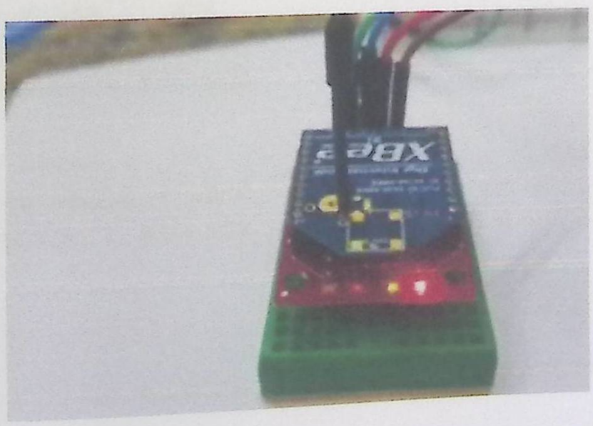


Figure 6.2: Xbee as transmitter module

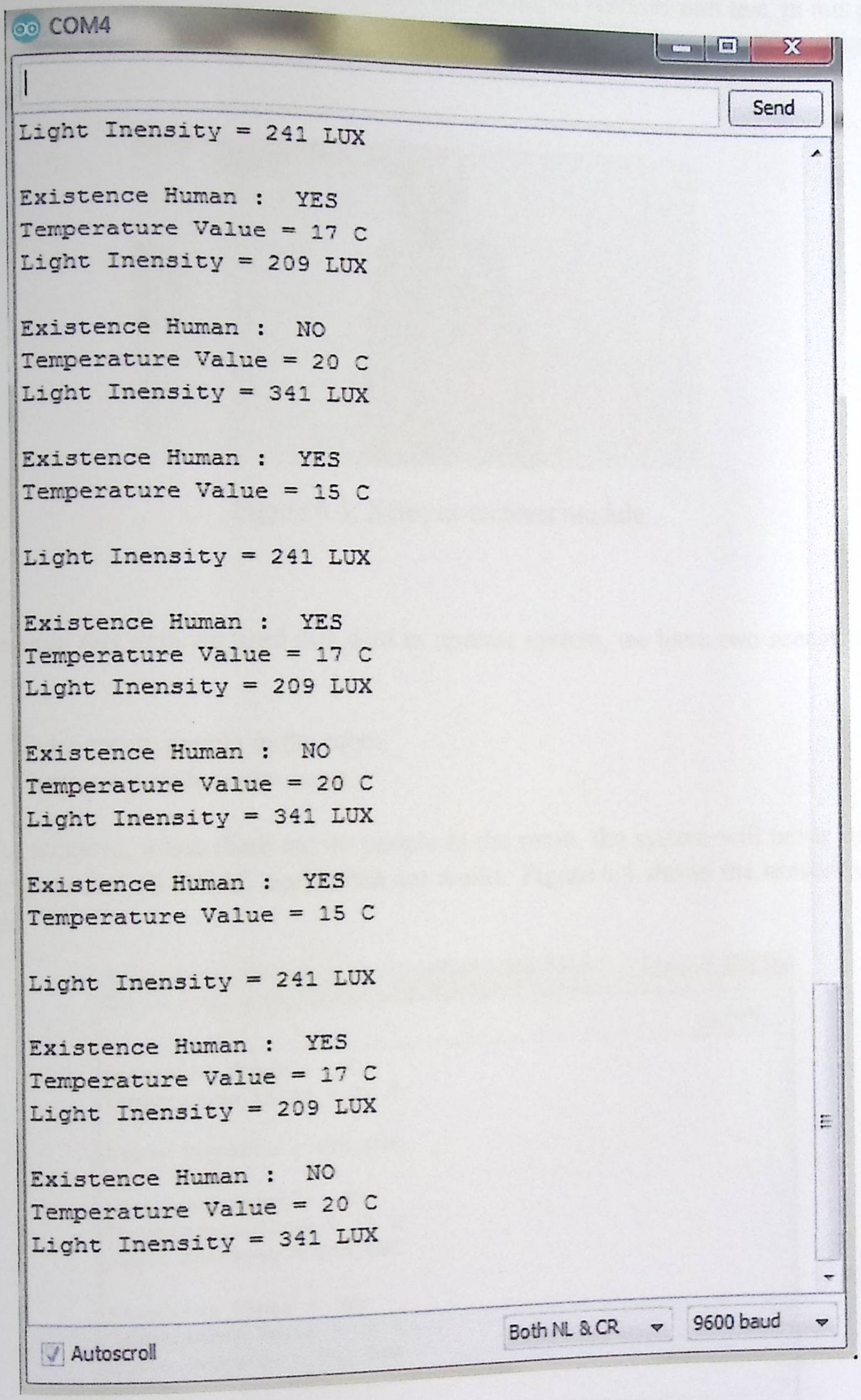


Figure 6.1: Sensors values in serial monitor

After we do the transmitter part test, now we will doing the receiver part test, in this part the XBee module (receiver side) receives data, then use this data to operate system. Figure 6.3 shows the how XBee module (receiver side) it works.

Figure 6.3: XBee as receiver module

After receive this data we used this data to operate system, we have two scenarios in our system:

- There are no people in the room.
- There are people in the room.

The first scenario, when there are no people in the room, the system will never works, all lighting units and all HVAC units does not works. Figure 6.4 shows the sensors values at this case.

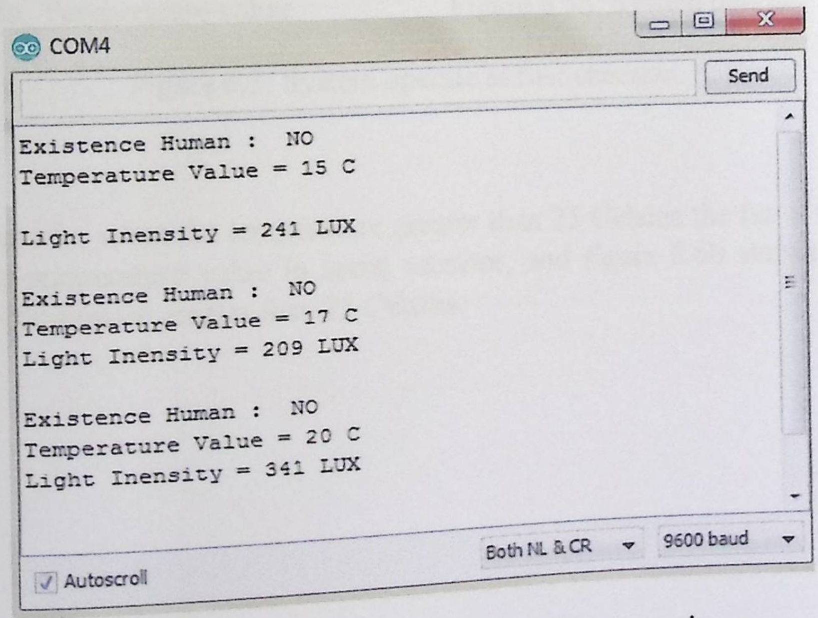


Figure 6.4: Sensors values in the first scenario

The second scenario, when there are people in the room the system begin works, in this case we have five scenarios, in the all scenarios peoples present in the room:

- When temperature value less than the 25 Celsius.
- When temperature value greater than the 25 Celsius.
- When light intensity inserted between [500 to 700] lux.
- When light intensity less than 500 lux.
- When light intensity greater than the 700 lux.

To make test for this scenarios we used simple LED, to simulate the HVAC system we used two LED, green LED and red LED, when green and red LED's are on this mean that the heater in HVAC it works, when only green LED is on that mean the fan on HVAC it works, to simulate light units also we used a simple LED's.

The first scenario, when the temperature value less than 25 Celsius the heater it works, figure 6.5a shows the temperature sensor value, and figure 6.5b shows how system operate when temperature value less than 25 Celsius.

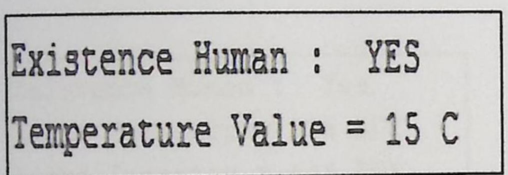


Figure 6.5a: Temperature value

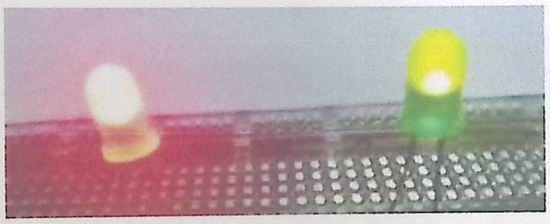
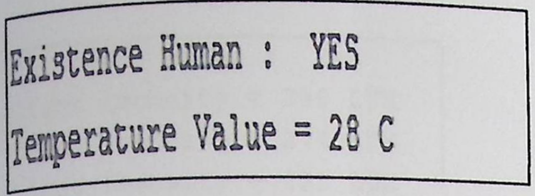


Figure 6.5b: System operate

Figure 6.5: System operate at first scenario

The second scenario, when the temperature greater than 25 Celsius the fan it works, figure 6.6a shows the temperature value in serial monitor, and figure 6.6b shows how system operate when temperature greater than 25 Celsius.



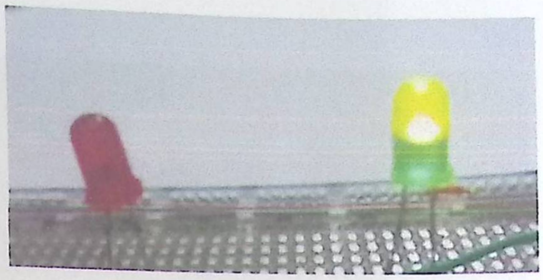


Figure 6.6a: Temperature value

Figure 6.6b: System operate

Figure 6.6: System operate at second scenario

The third scenario, when light intensity inserted between [500 to 700] lux that mean light intensity in the room is good, so the only two lighting units are works, figure 6.7a shows light sensor value, and figure 6.7b shows how system operate when light intensity inserted between [500 to 700] lux.

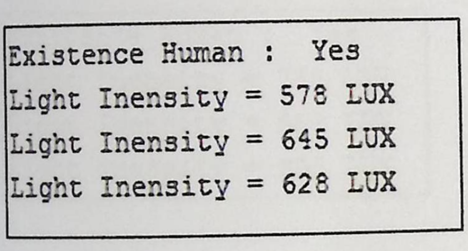


Figure 6.7a: light sensor value

Figure 6.7b: System operate

Figure 6.7: System operate at third scenario

The fourth scenario, when light intensity is 500 lux that mean the light intensity in the room is not enough and we will turn all light units in this case, figure 6.8a shows the light sensor value, and figure 6.8b shows how system operate when light intensity less than 500 lux.

```
Existence Human :  Yes
Light Inensity = 399 LUX
Light Inensity = 274 LUX
Light Inensity = 135 LUX
```

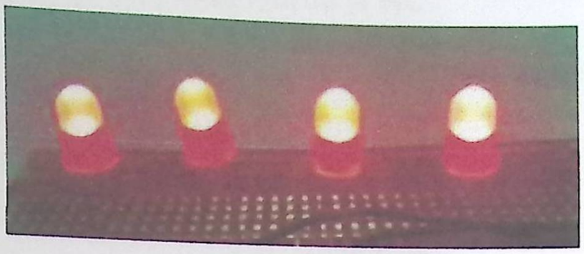


Figure 6.8a: Light sensor value

Figure 6.8b: System operate

Figure 6.8: System operate at fourth scenario

The last scenario, when light intensity greater than 700 lux that mean the light intensity in the room is excellent and we will turn only one lighting unit, figure 6.9a shows the light sensor value, and figure 6.9b shows how system operate when light intensity greater than 700 lux.

```
Existence Human :  Yes
Light Inensity = 785 LUX
Light Inensity = 886 LUX
Light Inensity = 905 LUX
```

Figure 6.9a: Light sensor value

Figure 6.9b: System operate

Figure 6.9: System operate at last scenario

Hint: in the C-building have a large windows, because it the light intensity is very excellent in the classroom, and on the most of time we do not need to turn any lighting unit, but when light intensity is excellent we turn one lighting unit because we are located in classroom which it must operate at least one lighting unit.

6.3 Test the Separate Automatic Load Circuit

Separate automatic load circuit use to separate other application in our system, like laptop, printer, cell phone, and others, to test this circuit we need to simulate this other application to but in our module, we use the lamps, this lamps when turn on or off withdrawn current, this current is very close to the other application current when turn on or off.

When this lamp turn on withdrawn current, this current shows in the serial monitor in figure 6.10.

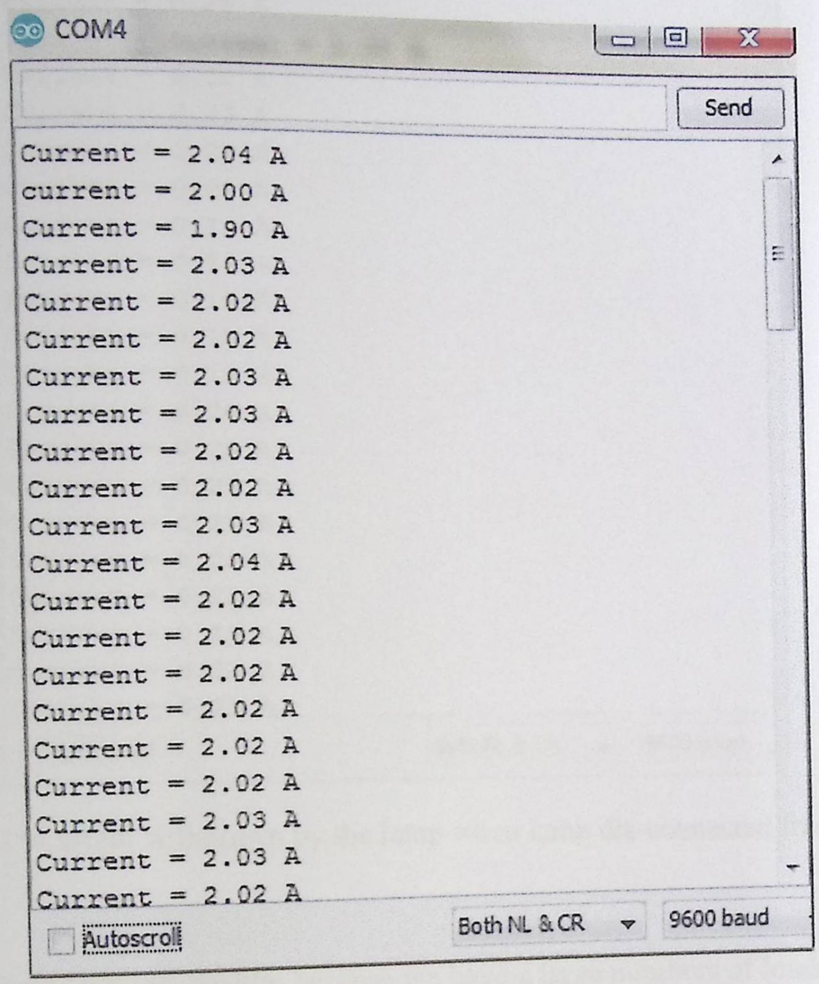


Figure 6.10: Current withdrawn by the lamp when lamp connected to the network

When load disconnected, theoretically the current must be zero, but practically the current will never be zero, after disconnected the load the current values shows in figure 6.11, this current represents a lost energy, especially when we have a large numbers of this loads.

An increasing number and variety of consumer devices incorporate standby features. Often a device is in standby mode when the consumer thinks it is completely powered-down, placing the power switch in the OFF position does not guarantee that a device consumes no power. The only way an everyday consumer can be sure a device is not drawing power is to unplug it from the utility outlet.

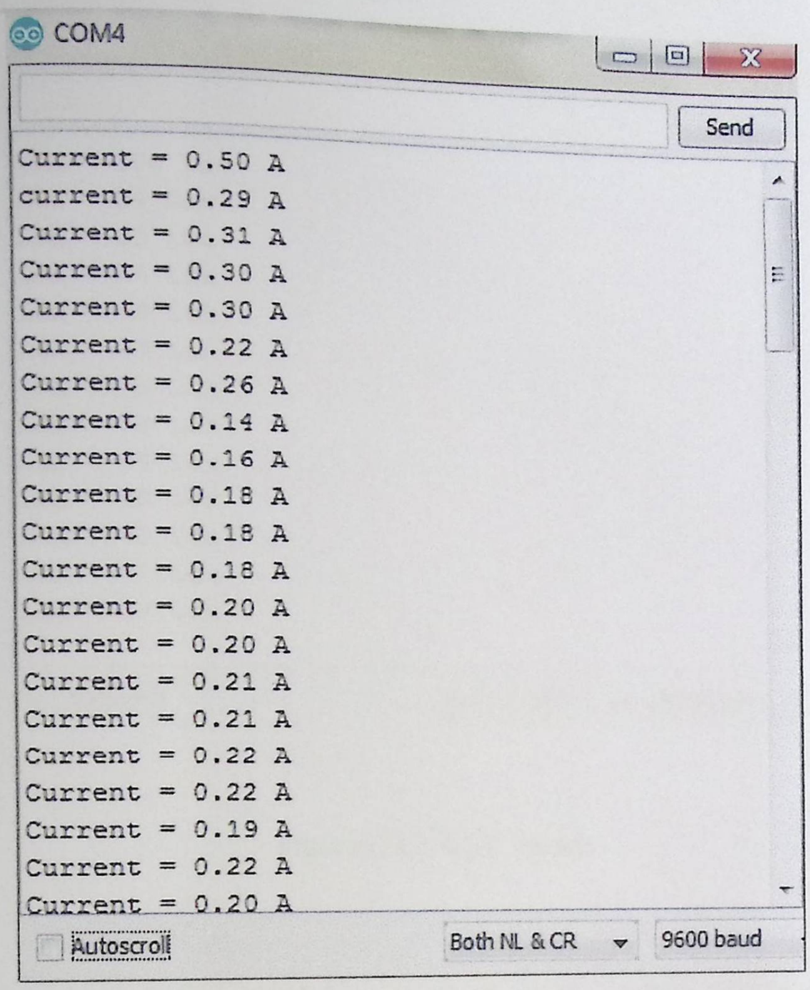


Figure 6.11: Current withdrawn by the lamp when lamp dis-connected from network

But this solution is not reasonable, because we have a large numbers of loads, for example C-building has a 90 computer device, it is unreasonable to do my unplug power outlets for each of these devices.

We will depend on triac when load dis-connected from the power outlets, and when load re-connected to the power outlets, when re-connect the load we depend in the LDR sensor, when person re-connect the load the LDR value decrease to small value, figure 6.12 shows how this value changes.

When LDR value become very small, then the PIC MCU send signal to the triac gate to firing the triac then the triac re-connected the load again.

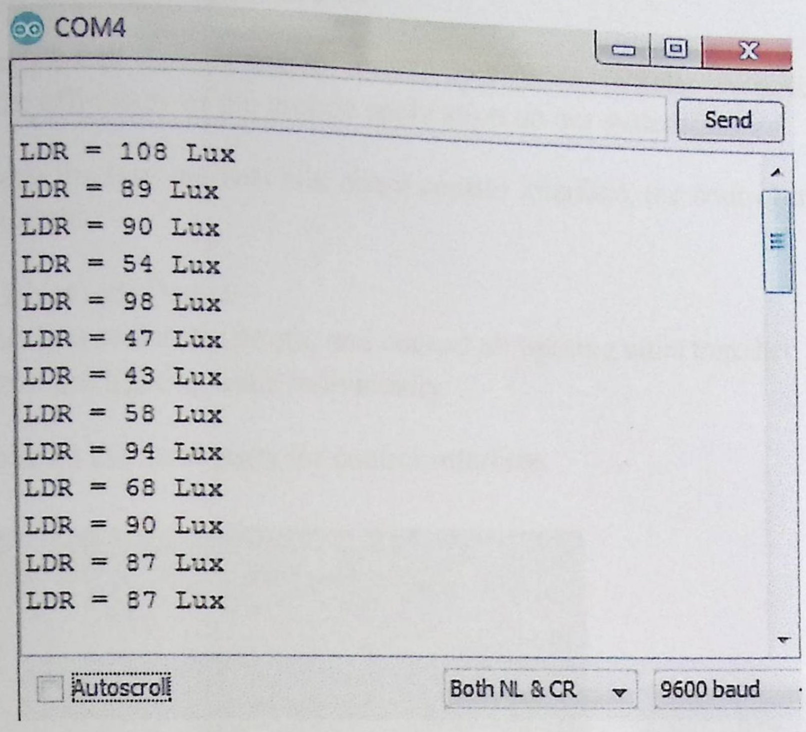


Figure 6.12: LDR values

We simulate re-connected case and figure 6.13 shows the voltage of triac when the triac is firing, after the triac is firing the load is re-connected again.

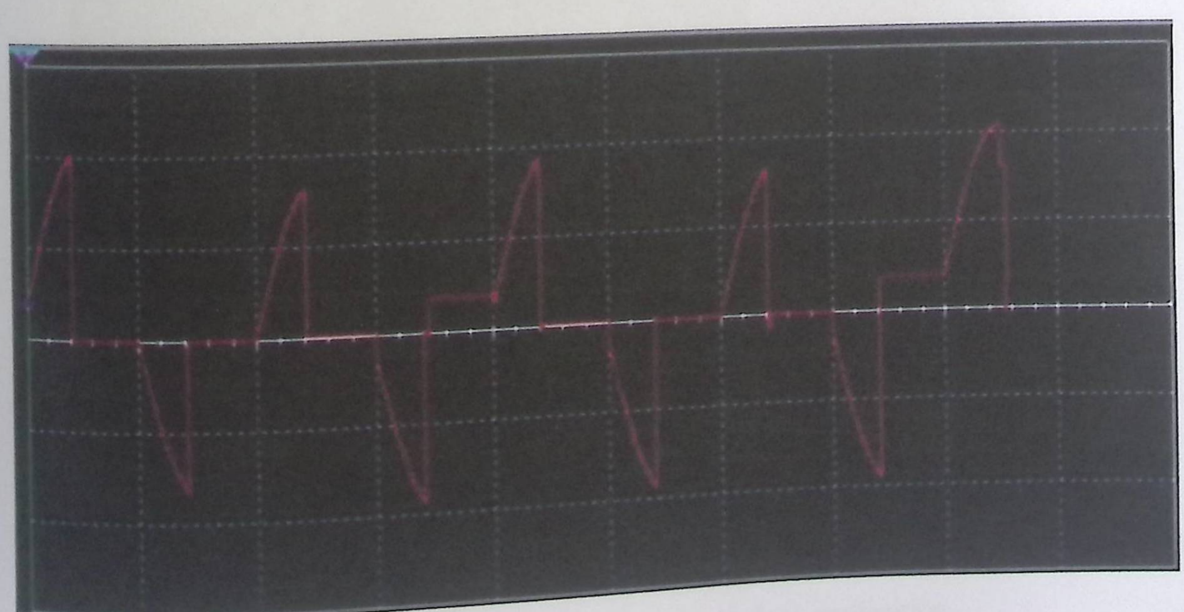


Figure 6.13: voltage of triac when triac is firing

6.4 Test the Android Application

In this section we will doing a test for mobile application, initially we make test on simple LED to test the efficiency of the mobile application on our system.

Before us doing the test, we will talk about control interface, the control interface consists of three main parts:

- Find Bluetooth Device.
- Connection to the Bluetooth, and control all lighting units together.
- Control the lighting units individually.

Figure 6.14 shows the three parts for control interface.

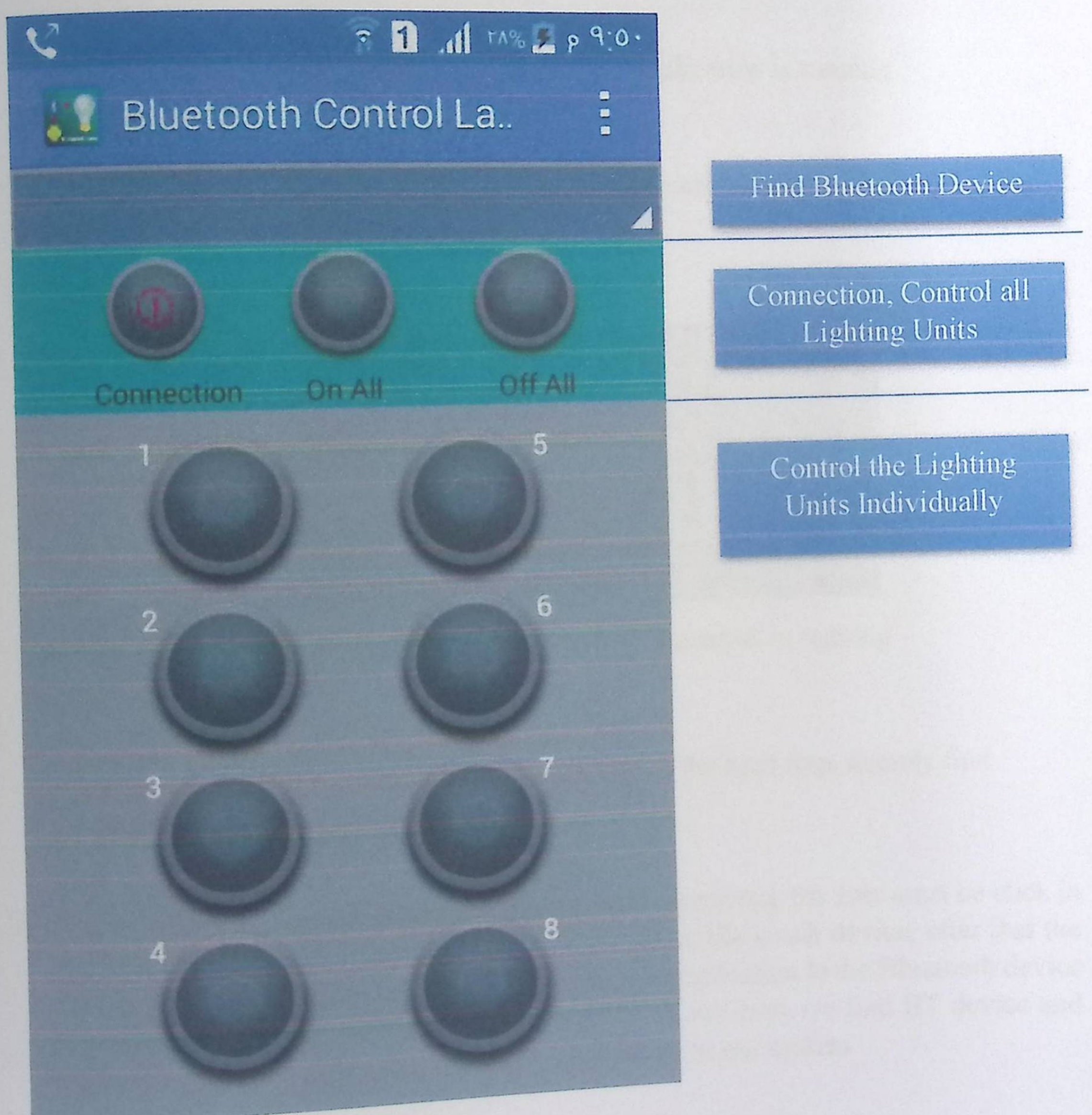


Figure 6.14: Control interface for mobile application

The following steps explain how mobile application was tested:

1) The first step, when running the application the message in figure 6.15 it will appear.

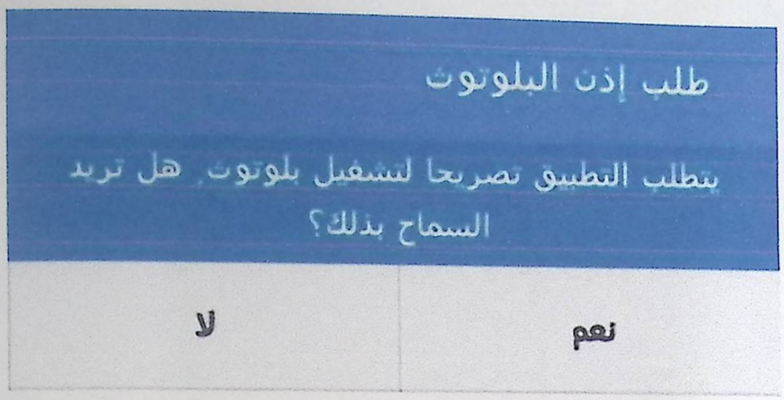


Figure 6.15: Message that appear when application is running

The user must choose the first option (Yes), when user choose the first option the message in figure 6.16 it will appear.

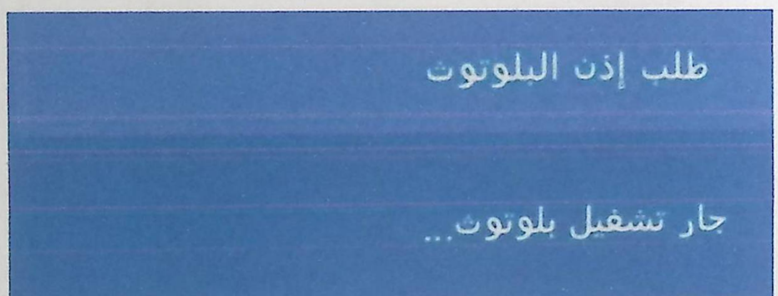


Figure 6.16: Message that appear when Bluetooth is running

After running the Bluetooth mobile, the user go to the next step, namely find the Bluetooth devices was connected.

2) The second step, find the Bluetooth devices that connected, the user must be click in the (Find BT Device) icon, then choose the correct Bluetooth device, after that the user must click in bottom (connection) to connect application to the Bluetooth device that connected to the our system. Figure 6.17a shows how we find BT device and figure 6.17b shows how connected this application to our system

Figure 6.17a: Find Bluetooth device

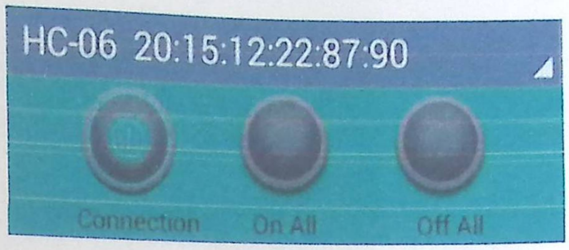


Figure 6.17b: Connect BT device

Figure 6.17: Find and connect BT device

4) The third step, the user chose if he want to control all lighting unit together, or he want to control lighting unit individually. If user want to turn on all light units then he must click on bottom (On All), show figure 6.18a and figure 6.18b. If user want to turn off all light units he must click on bottom (Off All), show figure 6.19a and figure 6.19b.

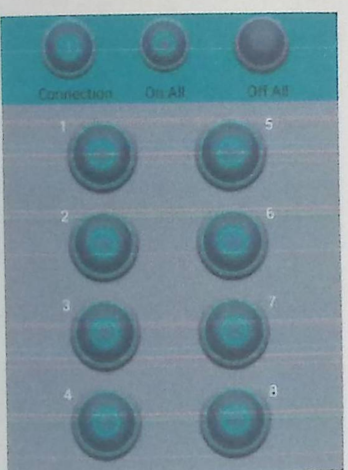


Figure 6.18a: Bottom on all is active

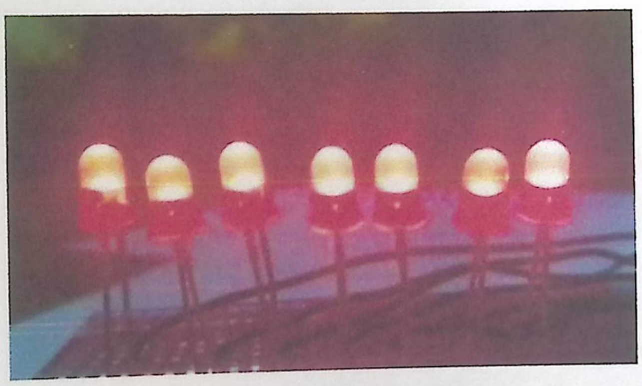
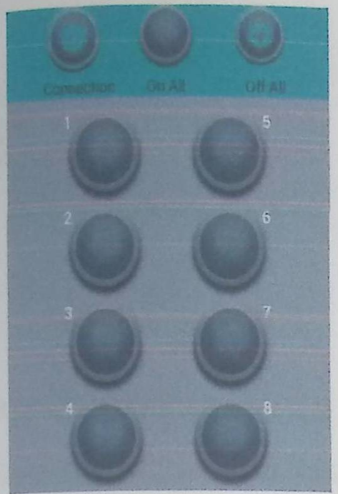


Figure 6.18b: System operate

Figure 6.18: System operate when bottom on all is active



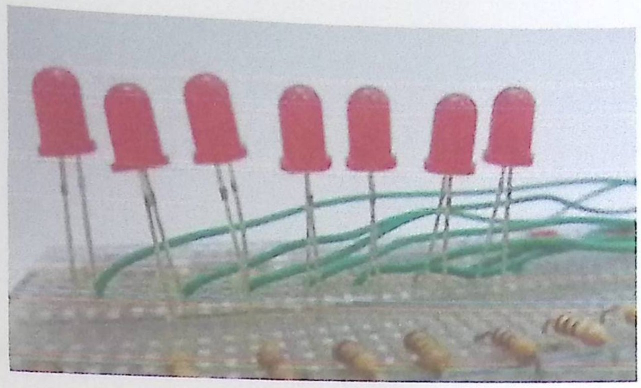
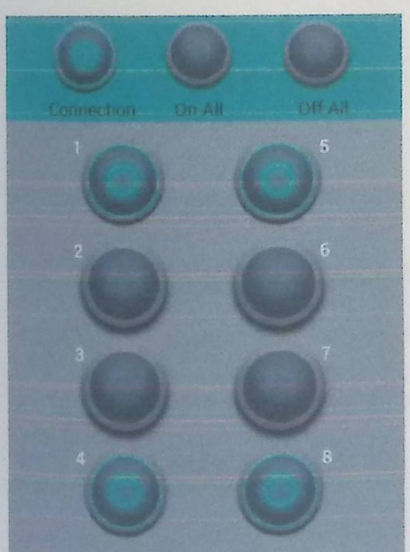


Figure 6.19a: Bottom off all is active

Figure 6.19b: System operate

Figure 6.19: system operate when bottom off all is active

5) The fourth step, the user chose control light units individually, through the selection the lighting unite number, that user to be controlled either on or off, figure 6.20a and figure 6.20b shows how user control light units individually



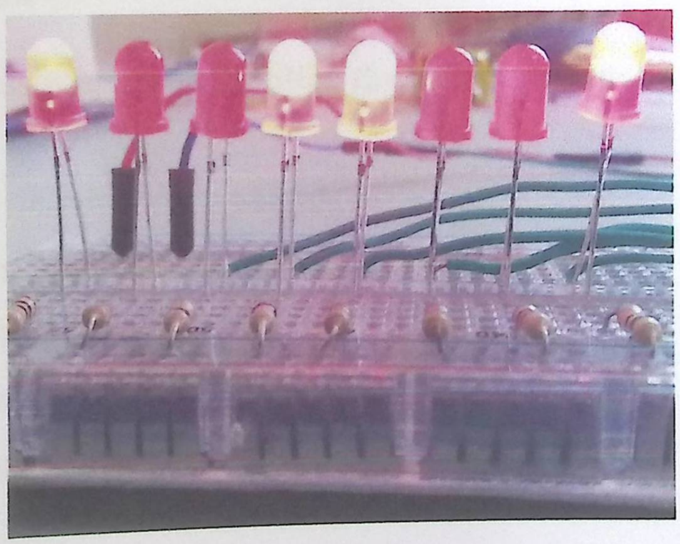


Figure 6.20a: Lamp number that have been selected to be active

Figure 6.20b: System operate

Figure 6.20: System operate when user selection lighting units numbers

7

Chapter Seven: Energy Consumption after Apply Smart System

7.1 Introduction

7.2 The Consuming System after we Apply the Smart System

7.2.1 Lighting System

7.2.2 Heating ventilation and air conditioning (HVAC) system

7.2.3 Office and Building Equipment

7.3 Total Electrical Energy Consumption after Applied the Smart System

7.4 Power Factor Correction and its influence on Grid

7.4.1 Design a Power System in Matlab/Simulink

7.4.2 Capacitor Bank Calculations

7.4.3 Power Factor Correction Smartly

7.4.4 Benefits from Correction the Power Factor

7.1 Introduction

In this chapter we study the load in C- building after we apply the smart system that will be designed in our project, and calculate the amount of power that the system is saving in each consuming system in the building, after this we calculate the total power consumption that the system is saved (new load in C- building). Then we mention the calculation for correction of power factor in the C- building and study the effect of this correction on the grid.

7.2 The Consuming System after we Apply the Smart System

From the previous chapters we know that the smart system that will be designed is to reduce and saving the energy consumption in each consuming system in the building without effect on the function of the electricity distribution in these systems.

In this section we make an estimation for the electrical energy that the smart system is saving in each consuming system in the building.

As we know the consuming system in C- building is:

- Lighting System.
- HVAC System.
- Office and building equipment system.
- Other application.

7.2.1 Lighting System

We calculate the total energy that the lighting system in building "C" is consumed in chapter three and its (121849 kwh/year).

In the lighting system there is two scenarios we will doing to reducing and saving the electrical power, this scenarios are:

1. Replacing the CFL lighting unit with LED lighting unit.

   At this step we want to replacing the CFL lighting unit that using in C- building with LED unit that consumed less power and achieve the same function, we must note that this replacement dose not effect on the function of the lighting.

   After we study the LED unit we chose the Philips LED unit and make a comparison between the CFL unit that used in the building and LED unit that we want to replacing with it, table 7.1 shows this comparison.

Table 7.1: Comparison between CFL unit and LED unit

Lighting Type	CFL Lighting Unit	LED Lighting unit
Rated Power	23 watt, 18 watt, 11 watt	8 watt
Average Life Span	8000 hrs.	25000 hrs.
Presence of Mercury	There is mercury use	No mercury use
Heat Releasing	More heat releasing	Less heat releasing

From the above table we note that the LED unit is better than CFL unit and consumed less energy and doing the same function.

There is three type of CFL unit that suing in C-building:

- CFL consumed 23 watt.
- CFL consumed 18 watt.
- CFL consumed 11 watt.

We replacing all these type with LED unit that consumed only 8 watt, and at the end of this scenario we can saving (15187 kwh/year).

2. Applying the smart system that will be designed on lighting system.

   After we replaced the lighting unit as in the previous scenario we apply the smart system that we designed on all lighting unit in the building and make an estimation for the amount of energy that will saved.

   At the end and after we make our estimation we can say we saved (47397 kwh/year) at lighting system, and the new consumption for lighting system after apply the system is (74333 kwh/year).

7.2.2 Heating ventilation and air conditioning (HVAC) system

As we know there is tow system for air conditioning that use in the C-building:

- Split units.
- Central group air condition units.

The previous calculation showed that the HVAC system consumed (103217 kwh/year) but after we apply our smart system that we designed in the project we estimate that the HVAC system consumed (79313 kwh/year).

Table 7.2: Energy consumption by HVAC system after smart system applied

Heating Ventilation and air Conditioning (HVAC)					
System	NO	Relater Power (KW)	(h/day)	Operation time	Consumption (KWh/years)
Split unit (Small capacity)	16	4.8	2.5	495	38016
Split unit (medium capacity)	9	9.05	1.5	297	24190.65
Central unit	2	16	2.7	534.7	17102.2
					79313.85

At the end and after we make our estimation we can say we saved (23904 kwh/year) at HVAC system.

7.2.3 Office and Building Equipment

From previous we note that the office and building equipment system is consumed (79235 kwh/year) before we apply our smart system. At this consuming system our smart system saved the energy consumed by cutting off the power from the device in the period that the device is consumed power without using it usefully.

We estimate the time that the smart system cutting off the power that we don't using it useful and estimate the new energy that the office and building equipment system is consumed after we apply our system and its (62490 kwh/year). Table 6.3 shows the energy consumption by the office building equipment after smart system applied.

At the end and after we make our estimation we can say we saved (16744.7 kwh/year) at office and building equipment system.

Table 7.3: Energy consumption by office and building equipment after smart system applied

Office and Building Equipment's					
Equipment's	NO	Relater Power (KW)	(h/day)	Operation time	Consumption (KWh/years)
Computers	110	0.25	3	594	16335
Multifunction Printers	22	1.201	1.5	297	7847.334
Copiers	2	0.0096	1.5	297	5.7024
PPU web servers	15	0.42	2.4	4752	29937.6
Boilers	6	2	1	198	2376
Elevators	1	4	5	990	3960
Fax	14	0.00622	4	790	68.96736
Data show	16	0.33	3	594	1960.2
					62490.80376

7.3 Total Electrical Energy Consumption after Applied the Smart System

At this section we summarize the total electrical energy consumption by all the consuming system in C- building after we apply the smart system that we designed in the project.

In table 7.4 we mention the consumption for each consuming system in C- building before and after apply our smart system and calculation the amount of energy that we saved in each consuming system.

Table 7.4 Total electricity consumption by all loads in C- building before and after apply the smart system.

Total electricity consumption before and after apply the smart system			
Consuming system	Consumption before apply the system (KWh/year)	Consumption after apply the system (KWh/year)	Saved energy (KWh/year)
Lighting System	121849	74333	47516
HVAC system	103217.4	79313	23904.4
Office and building	78235.5	62490.8	16744.7
Other application	4582.2	3500	1082.2

In figure 7.1 we show the consumption for each consuming system in the C- building before and after we apply the smart system that we designed in our project.

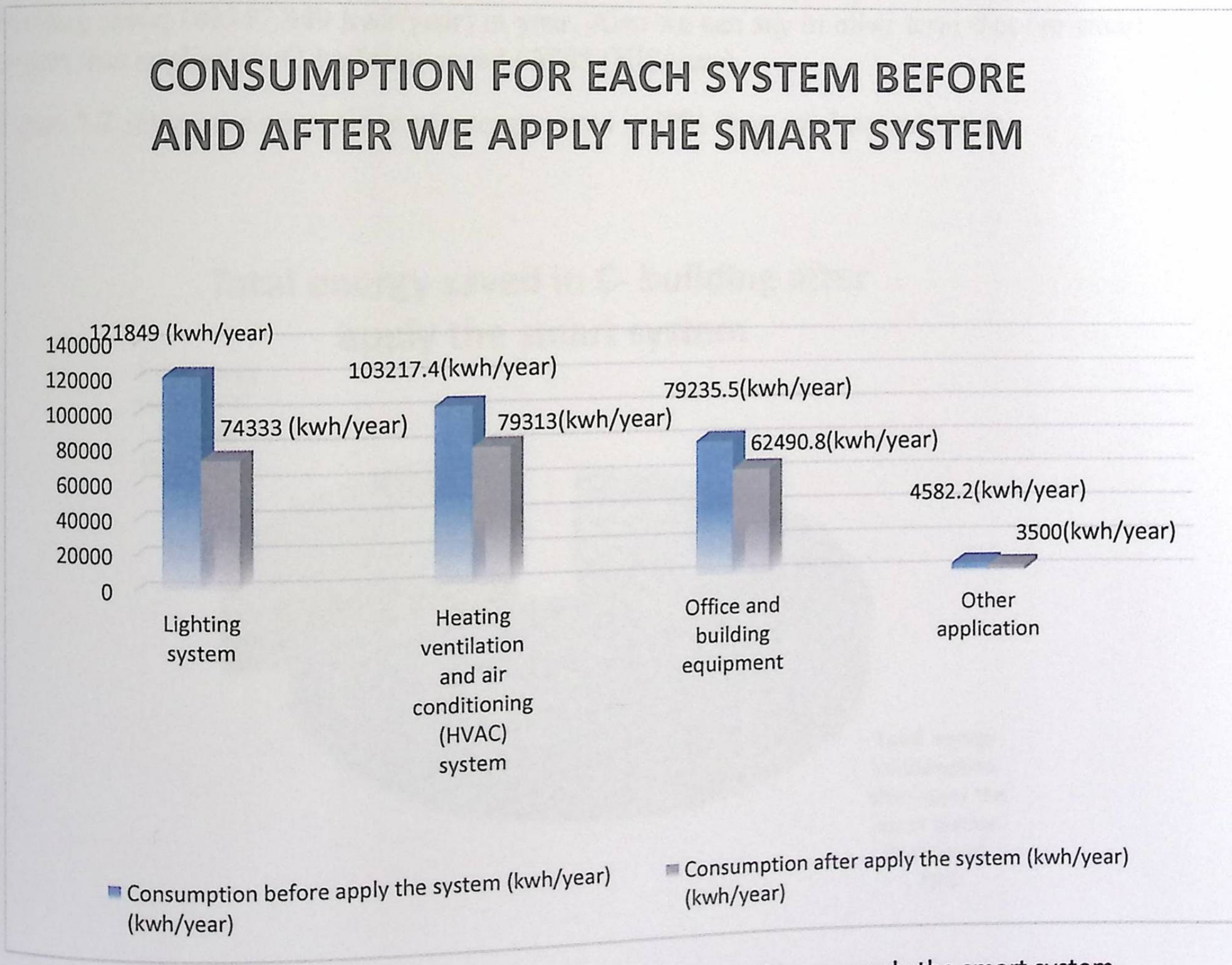


Figure 7.1: Consumption for each system before and after we apply the smart system

After this we want to know the total energy saved by the smart system in all the C-building with its all loads, the table 7.5 describe the old total consumption of the building before apply the system and the new total consumption and then we calculate the total energy saved in all C-building.

Table 7.7: Total energy saved in C- building after apply the smart system

Total energy saved in C-building after apply the smart system		
Total energy consumption before apply the smart system (kwh/year)	Total energy consumption after apply the smart system (kwh/year)	Total energy saved in "C" building (kwh/year)
308884.261	219636.412	89247.849

After we doing all of these observation we say that our smart system that we applied on C-building saved (89247.849 kwh/year) in year. Also we can say in other term that our smart system that applied on C-building saved 63565 (NIS/year).

Figure 7.2 shows the percentage of energy saved is 29% from total consumption.

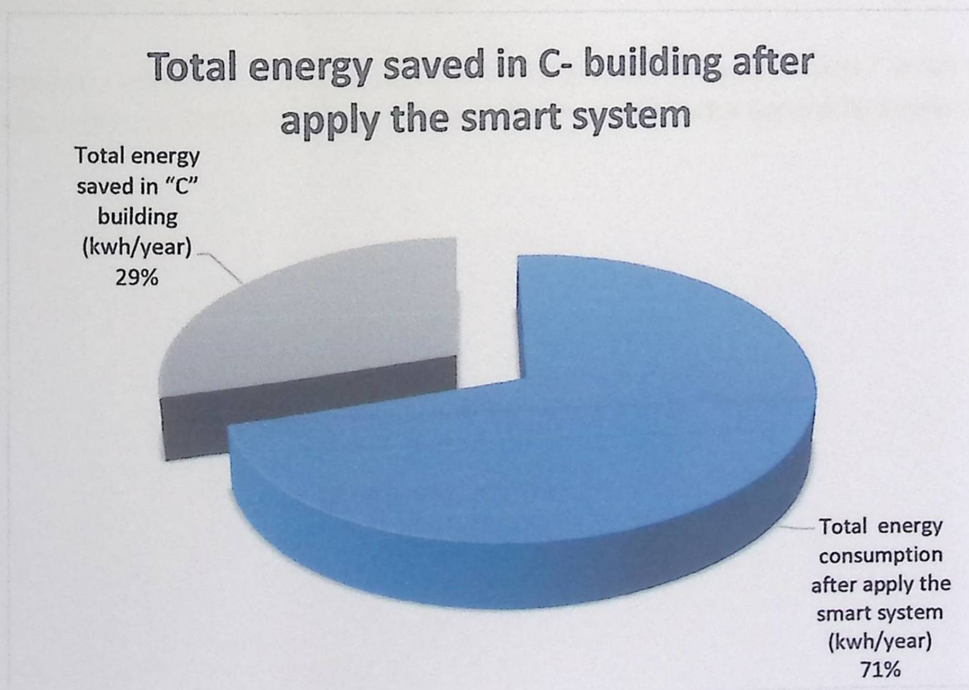


Figure 7.2: Total energy saved after apply the smart system

7.4 Power Factor Correction and its Influence on Grid

One of the important thing that we must thinking of it is the power factor (PF) in the C-building because the power factor simply is a measure of how efficiently we using the power in the building without wasted power in other word the power factor is the measure the load current that converted into a useful work output so, we need to correction the power factor in the building to reduce wasted energy.

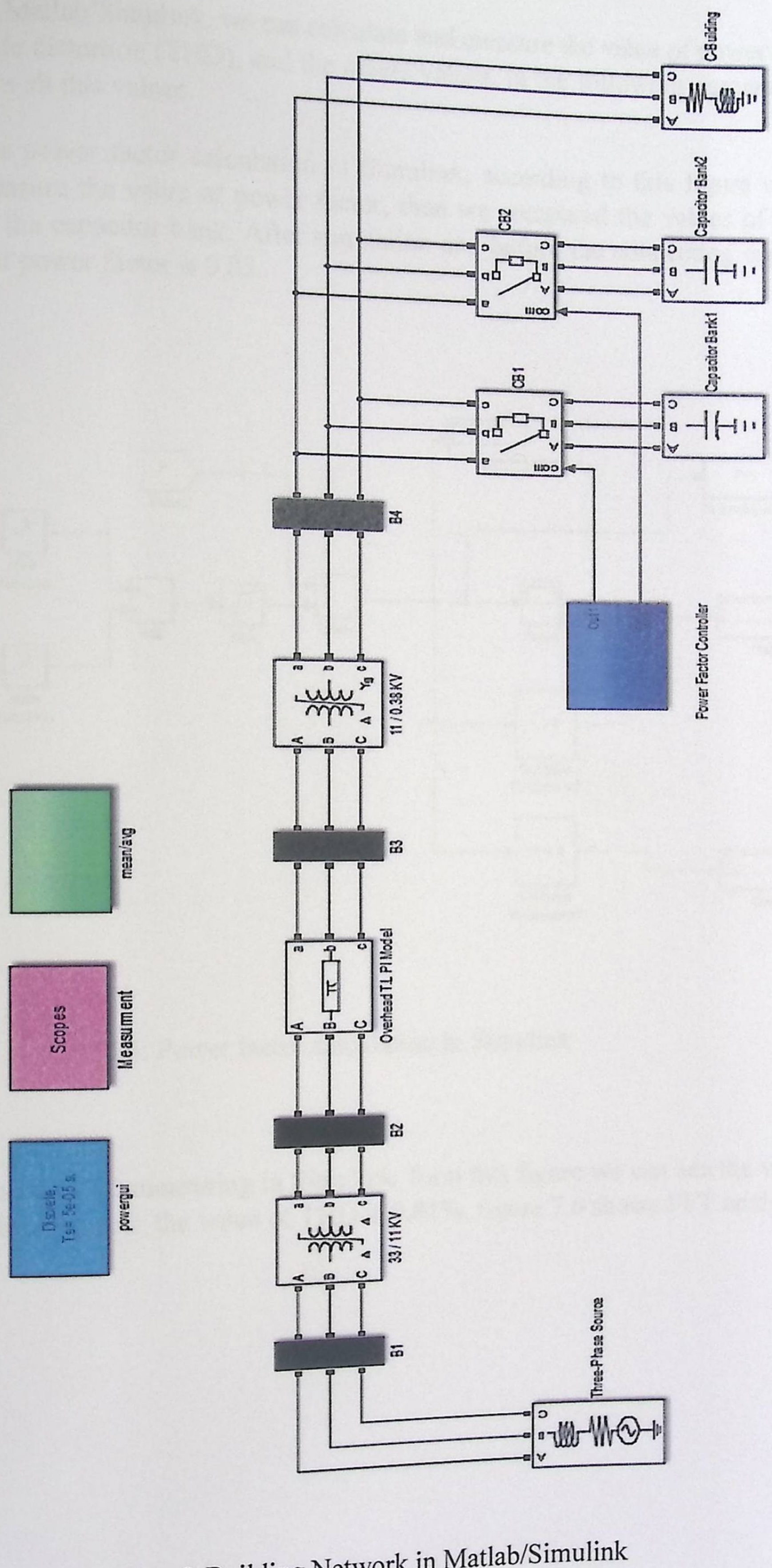
7.4.1 Design a Power System in Matlab/Simulink

After we know the important of power factor in reducing the wasted energy we need to maintain the value of this power factor in the building close to 0.95 and to do this we need to design a smart system that work to improve and correction the power factor automatically to this value.

Our smart system that we designed is correction the power factor through connect the capacitor bank with load to make the improvement. We designed a smart system to make a correction for the power factor, in this system we suppose the load and study the effect of improving the power factor in grid.

In our system and because we can't apply the system on the load in C- building practically and for more flexible we designed the network and we suppose load in the Matlab/Simulink as shown in figure 7.3, this network contain 3-phase source and transformers and overhead transmutation line and supposing load.

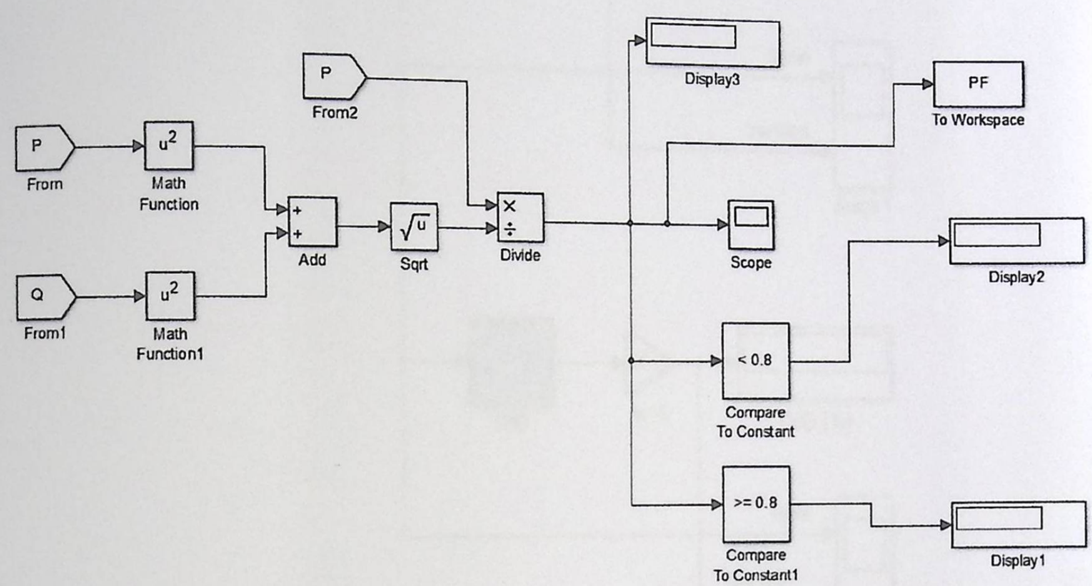
We suppose a load with real power (1000 kW) and reactive power (619.7 kvar) and make a calculation for the capacitor bank to improve the power factor according supposing load.



7.3: C-Building Network in Matlab/Simulink

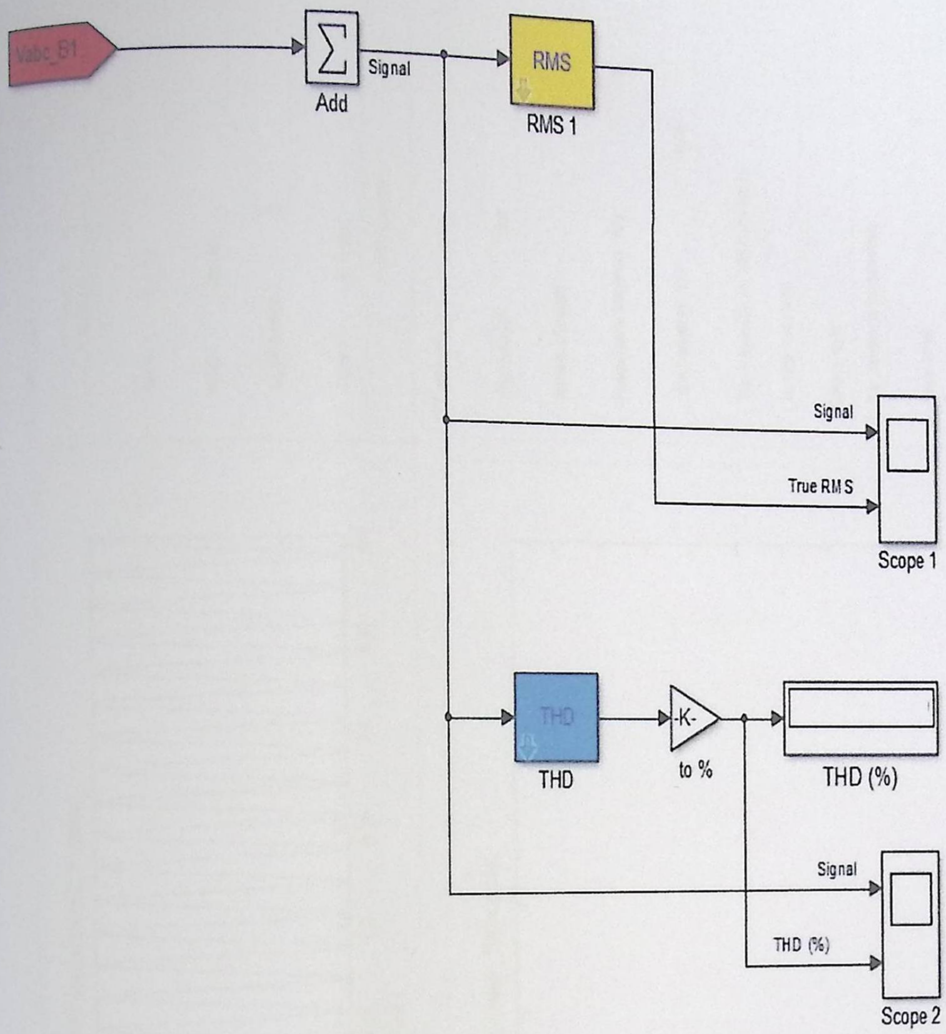
According to the Matlab/Simulink, we can calculate and measure the value of power factor, and total harmonic distortion (THD), and the others values, in the following paragraph we discuss and shows all this values.

Figure 7.4 shows power factor calculation in Simulink, according to this figure we can calculate and measure the value of power factor, then we compared the values of power factor to control the capacitor bank. After simulation and before the connecting capacitor bank, the value of power factor is 0.85.



7.4: Power factor calculation in Simulink

Figure 7.5 shows the THD measuring in Simulink, form this figure we can see the value of THD in C-building network, the value of THD is 0.81%, figure 7.6 shows FFT analysis for THD.



7.5: THD measuring in Simulink

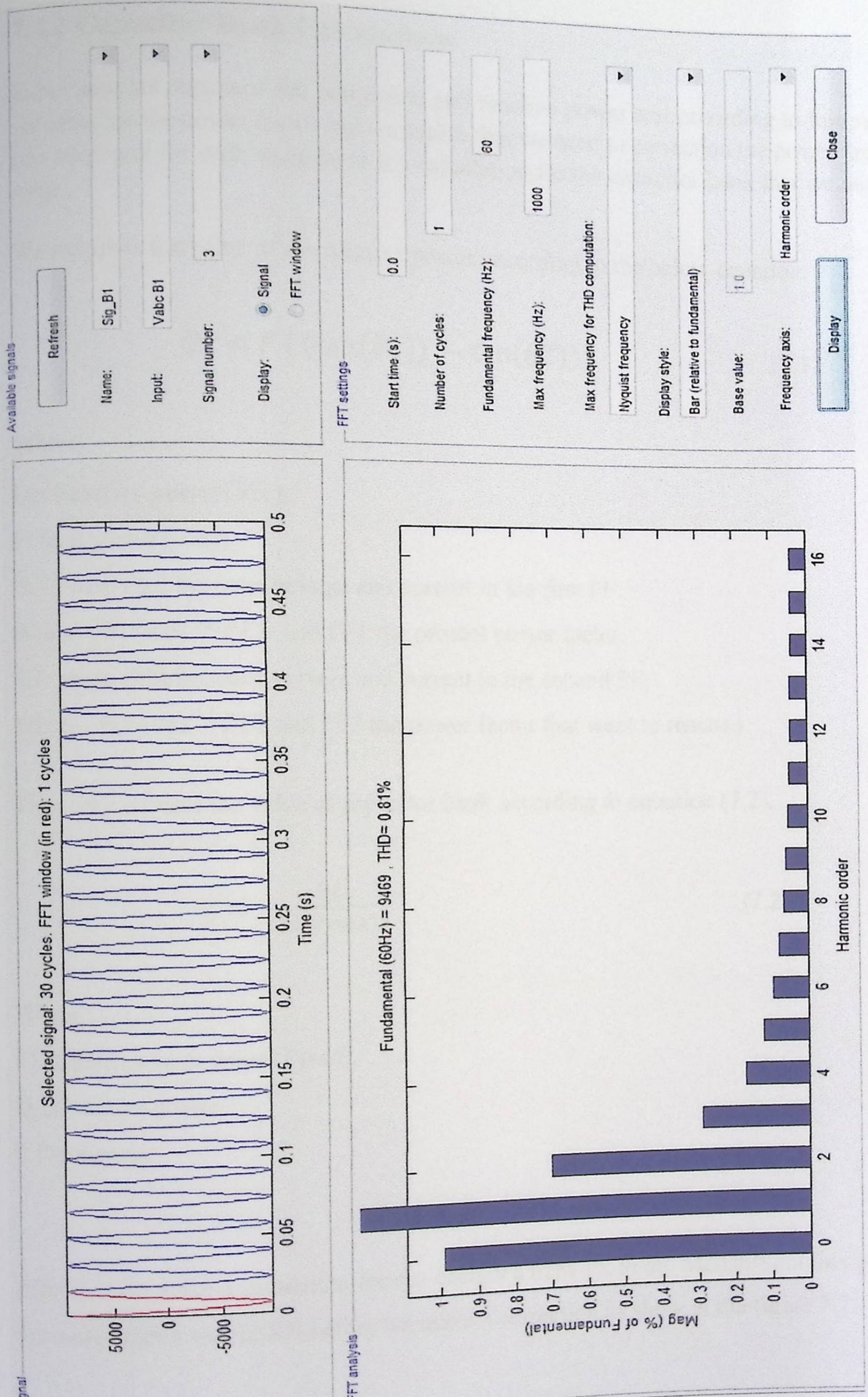


Figure 7.6: FFT analysis for THD

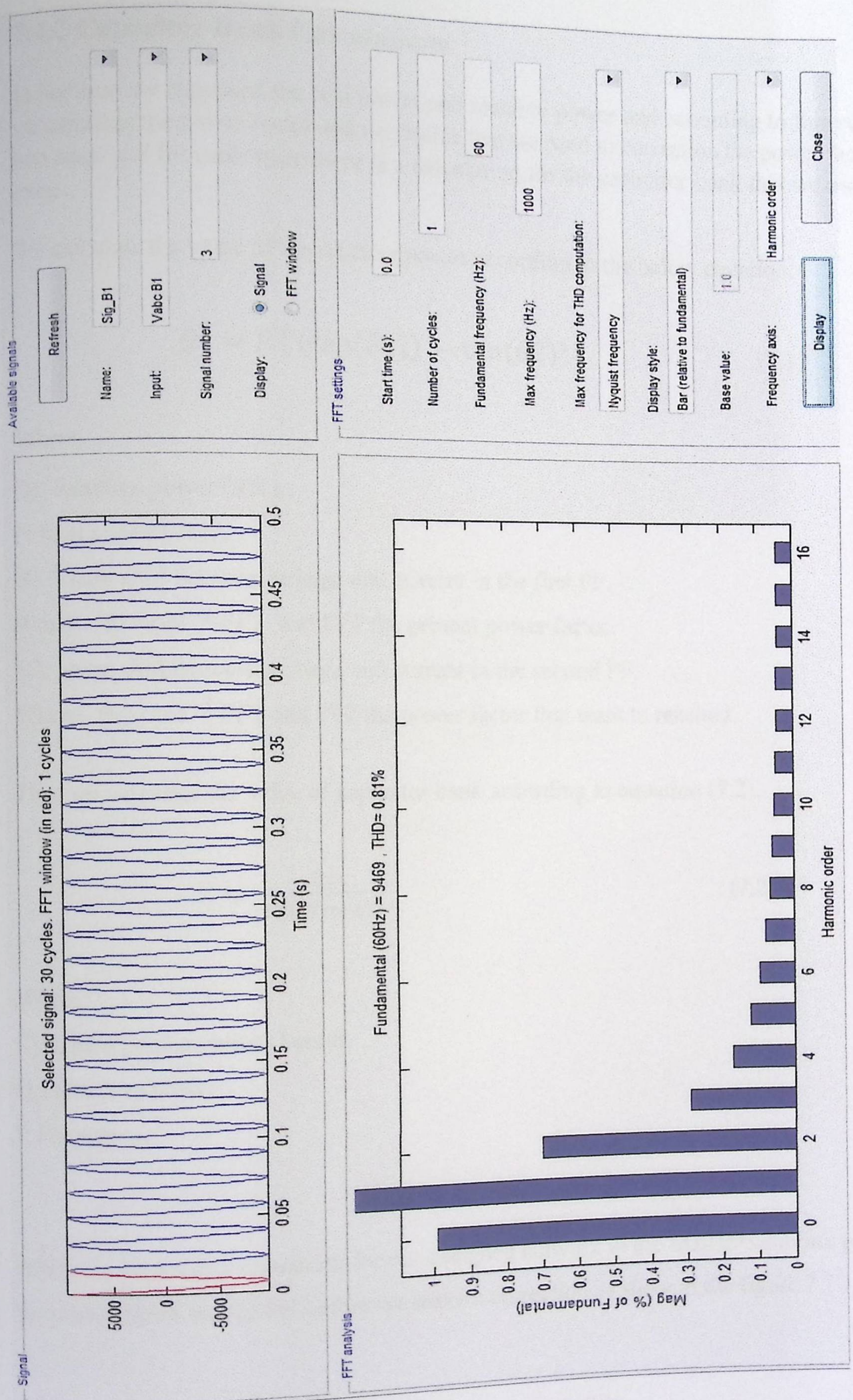


Figure 7.6: FFT analysis for THD

7.4.2 Capacitor Bank Calculations

In our case we supposed the real power and reactive power and according to this supposed we calculate the power factor and we decide that we need to correction the power factor into two stage and for each stage there is a calculation for the capacitor bank that we use in this stage.

We calculate the value of the reactive power according to the below equation:

$$Qc = P\,[\,(\tan(\theta 1)) \; - \tan(\theta 2))] \qquad (7.1)$$

Where:

Qc: Reactive power (Var).

P: Real power (watt).

Θ1: Phase shift between voltage and current in the first PF.

Where Θ1= $\cos^{-1} PF1$ and PF1 the present power factor.

Θ2: phase shift between voltage and current in the second PF.

Where Θ2= $\cos^{-1} PF2$ and PF2 the power factor that want to reached.

Then we calculate the value of capacitor bank according to equation (7.2).

$$C = \frac{Qc}{2\pi f * Vrms^2} \qquad (7.2)$$

Where:

C: Capacitor bank value (Farad).

Qc: Reactive power.

f: Frequency.

After this we make a simulation for our designed network in the Matlab/Simulink program, the power factor was (0.85) before we make a correction as show in the figure 7.7.

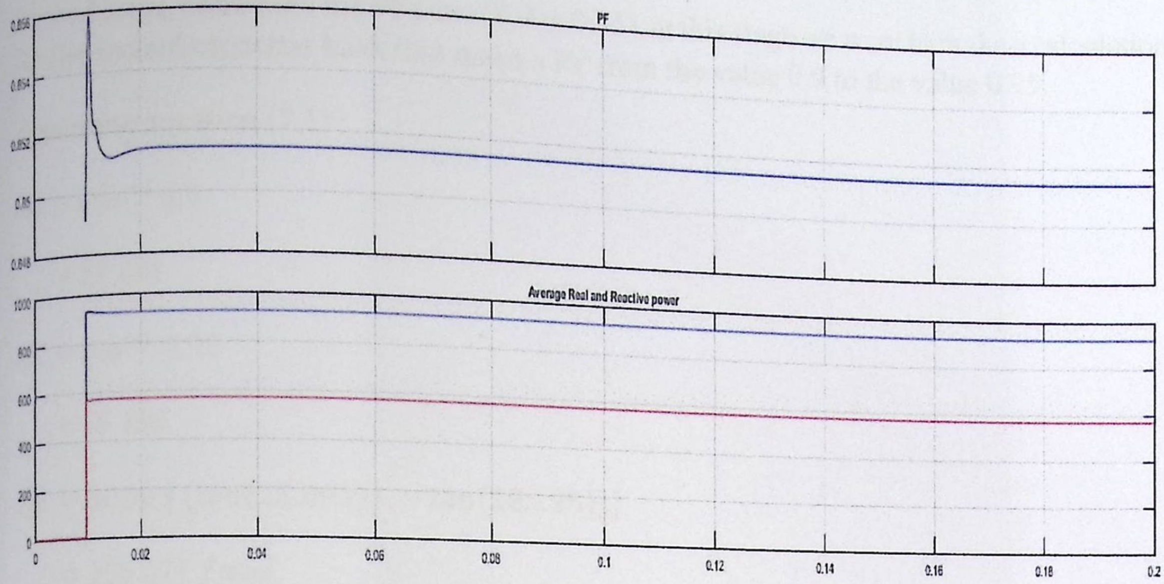


Figure 7.7: Power factor before we make a correction [PF=0.85]

In the second step we want to improve this power factor through connect capacitor bank with the load, we make a calculation for this capacitor in the following paragraph.

After that we make a correction for power factor, as we talked previously we corrected power factor through two stages.

To correction the power factor we have two stages:

- Correction the PF from (0.85 to 0.9).
- Correction the PF from (0.9 to 0.95).

First stage, correction the PF from (0.85 to 0.9), at this stage we want to make a calculation for the first capacitor bank that make a PF from the value 0.85 to the value 0.9.

According equation (7.1)

$\Theta 1 = \cos^{-1} 0.85$

$= 31.782$

$\Theta 2 = \cos^{-1} 0.9$

$= 25.891$

$Qc = 1000\ [\ (\tan(31.782)) \ - \tan(25.891))]$

$= 135.241$ Farad.

The value of first capacitor bank is 135.241 Farad.

Second stage, correction the PF from (0.9 to 0.95), at this stage we want to make a calculation for the second capacitor bank that make a PF from the value 0.9 to the value 0.95.

According equation (7.1)

$\Theta 1 = \cos^{-1} 0.9$

$= 25.891$

$\Theta 2 = \cos^{-1} 0.95$

$= 18.195$

$Qc = 1000\,[\,(\tan(25.891)) - \tan(18.195))]$

= 155.671 Farad.

The value of first capacitor bank is 155.671 Farad.

The first capacitor bank is (155.671 Farad) and the second one is (135.241 Farad).

After we calculate the value of the capacitor bank that we want to use in the correction, we shown below the power factor in each stage of correction with calculation capacitor.

When the system connect the first capacitor bank the power factor is improvement to become (0.9) as shown in the figure 7.8.

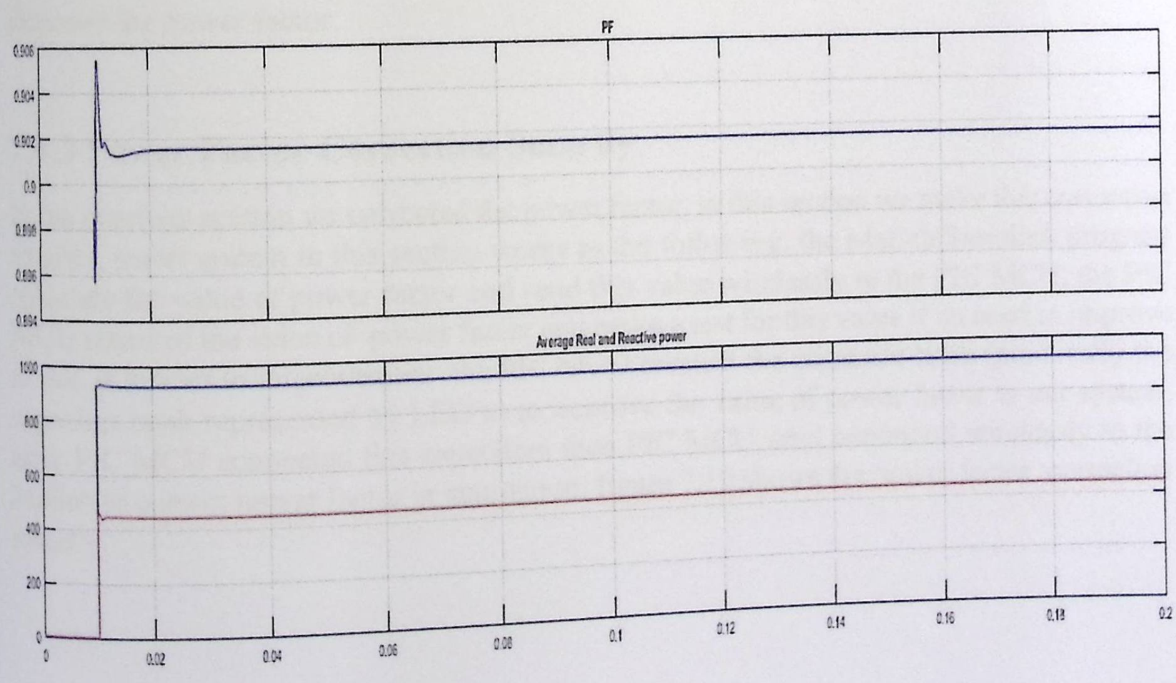


Figure 7.8: Power factor in the first stage of correction [PF=0.9]

And when the system needed to connect the second one the power factor became (0.95) as shown in the figure 7.9.

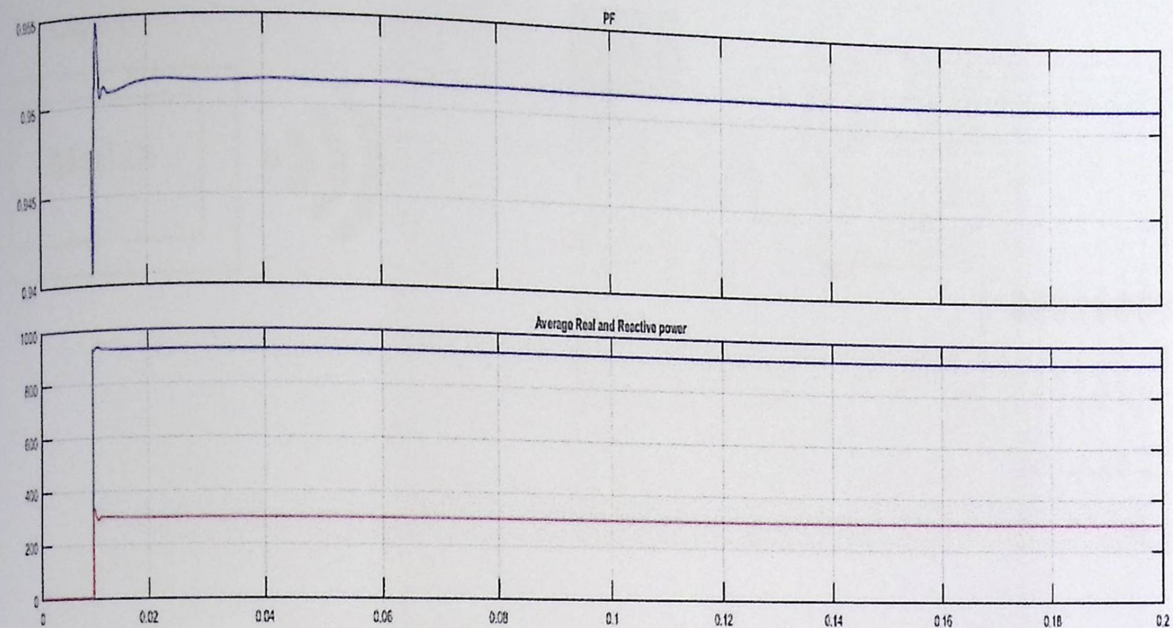


Figure 7.9: Power factor in the second stage of correction [PF=0.95]

In the next section we explain how the system connect the capacitor bank with load to improve the power factor.

7.4.3 Power Factor Correction Smartly

In the previous section we corrected the power factor, in this section we make this correction smartly, smart system in this section works as the following: the Matlab/Simulink program calculate the value of power factor and send this value wirelessly to the PIC MCU, the PIC MCU received the value of power factor and make a test for this value if its need to improve or not, if it need to improvement the PIC MCU connect the capacitor bank (practically the capacitor bank represented by LED's) to improve the value of power factor in our system, after PIC MCU connected this capacitors then PIC MCU send command wirelessly to the Matlab to correct power factor in simulation, figure 7.10 shows the power factor correction smartly.

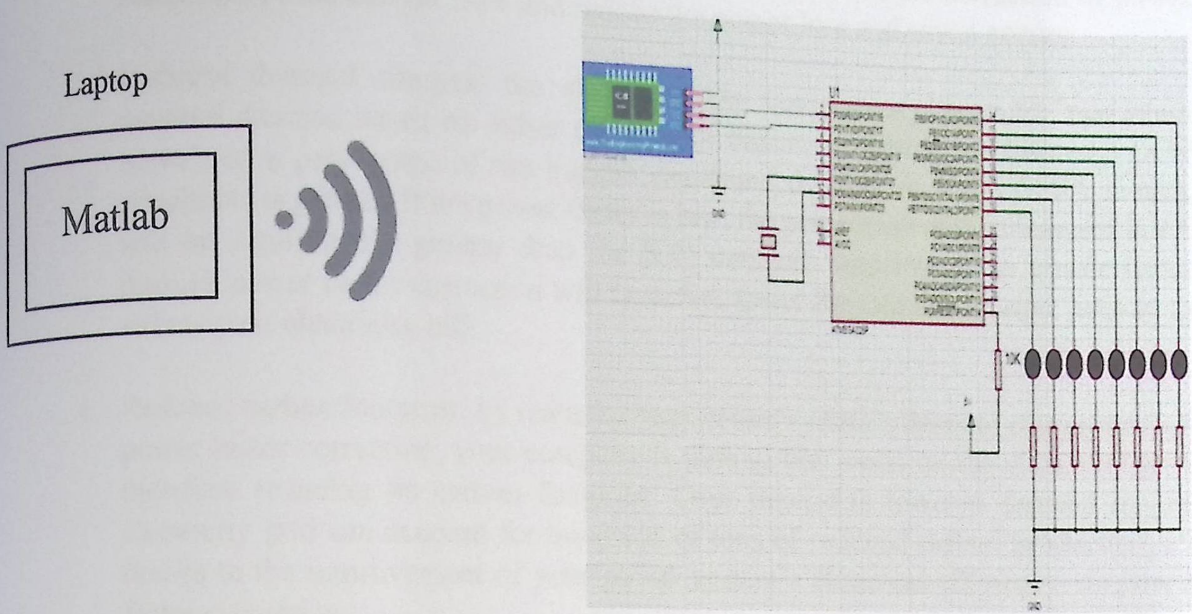


Figure 7.10: Power factor correction smartly circuit

7.4.4 Benefits from Correction the Power Factor

In our project we make a special system for correction and improvement the power factor (PF), why we doing this?

as we mention in the previous the power factor is simply the measuring of how efficiently we using the power, so in this section we want to explain the important of correction the power factor and calculate the amount of power that this correction is saved.

Hint: the calculation done on the supposed load.

First, we discuss the benefits of power factor correction, the benefits of improved power factor clarified through the following points:

1. Improved the voltage: a low power factor causes a high current flow to the load, and when the current flow is increase the voltage drop in the conductor increase too and this cause a drop in the voltage in the equipment so when we improve the power factor the voltage drop in the conductor is reduced so we improve the voltage at the equipment.

2. Reduced the power system losses and saved energy: the loss in the conductor in the system are proportional with current squared according to P loss = I2 * R so when

the current increase the loss in the conductor increase too, the correction of power factor reduce the current flow and reduce the power loss and saved energy.

3. Reduced demand charges: the electric utility companies charge for maximum metered demand based on either the highest registered demand in kilowatts (KW meter), or a percentage of the highest registered demand in KVA (KVA meter), whichever is greater. If the power factor is low, the percentage of the measured KVA will be significantly greater than the KW demand. Improving the power factor through power factor correction will therefore lower the demand charge, helping to reduce your electricity bill.

4. Reduced carbon footprint: by reducing your power system's demand charge through power factor correction, your company is putting less strain on the electricity grid, therefore reducing its carbon footprint. Over time, this lowered demand on the electricity grid can account for hundreds of tons of reduced carbon production, all thanks to the improvement of your power system's electrical efficiency via power factor correction.

5. At the end we can say saving money is the benefit form correction the power factor.

Now we want to calculate the amount of energy that we can saved from the correction, this calculation is doing on the supposed load (real power (1000 kW) and reactive power (619.7 kvar).

We can calculate the reduction factor according to equation (7.3)

$$\text{reduction factor} = 1 - \left(\frac{\text{original PF^2}}{\text{new PF^2}}\right) \tag{7.3}$$

In our supposed load the reduction is:

$$\text{reduction factor} = 1 - \left(\frac{0.85\text{^}2}{0.95\text{^}2}\right) = 0.199$$

Since the energy loss before the correction was 2% of the real power so the reduction is

1000 kW * 0.02 * 0.199 = 3.988 KW energy saved.

8

Chapter Eight: Conclusions and Future Works

8.1 Introduction

8.2 Main Challenges

8.3 Acquired Learning Outcomes

8.4 Conclusion

8.5 Future Works

8.1 Introductions

In this chapter we will talk about many important points, such as, the biggest challenges we faced during the implementation, and the proposed solution for each one. Then the conclusion will be stated, and the chapter will be ended up with the future works.

8.2 Main Challenges

Many problems, challenges, and issues have been raised during the work on the project. Many experiments, suggestions, ideas and researches have been carried out to deal with the different situations. Some of these challenges are:

1. The X-CTU software that is designed by Digi to interface its XBee transceivers. The problem is that X-CTU was unable to store any measured data or received packet, it can only shows the information on the screen. However, storing the information was essential in order to plug these data in our monitoring system for further processing. So to overcome this problem we store this data in file in internet.

2. We faced a big problem in Bluetooth device, HC-05 BT, used in our project does not connect to our laptop, so to overcome this problem we re-programmed the all BT deceives, this programmed was very difficult, because the BT device usually come already programmed from its manufacturing.

3. In this project we used many components such as, XBee, PIC MCU, and others each component has a special program to deal with it, and programming languages is not homogeneous for all programs, so we face a big problem when connect all this components with each other.

4. The current of PIC MCU is 40 mA, this current is very small, when make a test we used a simple LED, this LED withdrawn a very small current, for example when connect an eight LED to the PIC MCU this eight LED withdrawn less than a 40 mA, so the PIC MCU can cover this current, but in our module we used a lamps (230 volt), and this lamps withdrawn a big current when connect to the PIC MCU, so the PIC MCU does not cover this current, to overcome this problem we used the ULM2083 to maximize the current value.

5. Finally, the most important challenge was having to dedicated lab in the university for graduation project. It was very bad to spend most of our time working of the corridors, this was a sort of wasting time and killing the creativity. So we wish that the electric department will provide reopen the graduation project lab for next coming students.

8.3 Acquired Learning Outcomes

After accomplishing the project tasks, many abilities have been achieved as:

1. We have learnt Android programming language that is used to program the mobile phone application, and how to deal with android developer tools program, which we depend on it to build a mobile application to control the lamps in the room.

2. We have learnt the Arduino programming language that use to program XBee shield, and BT device, in order to send and receive our data.

3. We have developed our abilities in troubleshooting and problem solving.

8.4 Conclusions

After accomplishing the project task, we will summarize the most important results that we have obtained:

1. We have accomplished all the project task, which mentioned in the introduction of the graduation project.

2. We achieved efficient use of energy in the different consuming system in C-building and canceled and reduced the wasted energy in each system, in the lighting system we saved (47397 kwh/year) and in the HVAC system we saved (23904 kwh/year) and in the Office and building equipment we saved(16744.7 kwh/year).

3. In our project we make a power factor correction by connecting capacitor bank, so we achieve reducing in the power loss in the system and reducing the voltage drop on the equipment and all of this mean reducing in wasted energy.

4. In the economic aspect, in our project we achieve saving in money through many way at first saving in the wasted energy in the consuming system in the C-building mean saving in the cost of this energy and from other hand saving in the loss energy in the power system (loss through conductor in the grid) by power factor correction also mean saving in money also improved the voltage by correction the power factor saving the equipment damage from voltage drop so it save money too.

5. In the environmental aspect, one more important thing that our project achieve is save the environment and reducing the carbon footprint on our world and this done by reducing the consumption of energy so reducing the production of this energy from carbon and other fossil fuels so reducing the damage effect of this fossil fuels on the environment.

6. At the end we can say we achieved the main objective for our project, which is the audit energy for C-building, it was clear that when we have apply this project in C-building the proportion of consumption in the C-building will be reduced by 29%, and we save around 63565 (NIS/year).

7. We have make economic study for our project, through this economic study we see that, if we want to apply the project to the all C- building the initial cost will be 90,000 NIS, then payback period for our project will be around 1.5 years.

8.5 Future Works

There are several ideas that could be implemented on our system in the future to measure or improves its performance.

1. Development the smart system by adding the other controller parts, such as doors control, windows control.
2. The system can use a camera to control outside the room or to provide the person with additional information about the outdoor.
3. Adding some features to the system in order to be placed in any security system, such as alarm smart system against theft and fires.
4. Modifying the system to operate on the human voice.
5. Expansion the smart grid to include the repair faults in the network, and monitor the other parts in grid like fluctuation on voltage.
6. Production of smart controller unit and marketed in local markets.

Bibliography

[1] Asian Productivity Organization (APO), 2008. Working manual on auditing in industry. Available at: http://www.apo-tokyo.org/00e-books/Gp-13 WorkingManualEnergy.

[2] Bureau of Energy Efficiency-india (BEE), 2008. General Aspect of Energy Management and Energy Audit- Chapter 3. Energy management and audit. Available at: http://www.bee-india.nic.in/index.php.

[3] Thumab, A. 1998. Handbook of Energy Auditing. Fairmont Press, Lilburn, GA.

[4] Center for Renewable Energy sources (CRES), 2000. Energy Audit Guide-Part A: Methodologies and techniques. Available at: http://www.cres.gr/kape/pdf/downlod/guide a uk.pdf.

[5] Thuman, A. and Hoside, R. 1994. Energy Management Guide for Government

Buildings. Fairmont Press, Lilburn, GA.

[6] Energy management handbook, John Wiley and Sons-Wayne C. Turner.

[7] Guide to Energy Management, Cape Hart, Turner and Kennedy.

[8] Moss, K.J., 2006. Energy Management in Building. Taylor & Francis, New York, USA.

[9] Turner, W.C. and Doty, S., 2007. Energy Management Handbook (six edition). Fairmont Press, Inc. USA.

[10] M. Krarti. 2000. Energy Audit of Building system: An Engineering Approach. CRC Press, Bota Raton, Fl.

[11] Environmental Protection Agency (US EPA), 2008b, "Energy Guide-Opportunities for Improving Energy Efficiency in a Focus Industry".

[12] a. Gziker, M. Chindris, "Mitigation of the unbalance steady state to industrial consumers. Theory and Application", (in Romanian), MEDIAMIRA Publishing House, Cluj-Napoca 2003, Romania.

[13] Power Quality in European Electricity supply Networks, Union of the Electricity Industry-EURELECTRIC, 2002.

[14] C. Lazaroiu, N. Golovanov, Propagation of voltage unbalance in power system supplying AC traction loads, the 6th International Power System Conference, 03-04.11.2005, Timisoara, Romania, pp.317 – 322.

[15] R. Tirnovan, S. Darie, Faults and abnormal functioning regimes in electric network, MEDIAMIRA Publishing House, Cluj-Napoca 2004.

[16] I. Boldea, Transformers and electrical machines, Didactic and pedagogic Publishing House, Bucharest 1994, Romania pp. 60 – 61.

[17] M. J. Heathcote, the J & P Transformer Book, Twelfth edidtion, A Practical Techology of the Power Transformer, Reed Educational and Professional Publishinh Ltd 1998,p.844.

[18] "VEGA78 User Manual", Copyright HT, Italy, 30/03/2012.

[19] http://avrmicrocontrollers.com/.

[20] http://www.microchip.com/pic/.

[21] S. S. Riaz, The role of ZigBee technology in future data communication system, India, 2007.

[22] A. Lonza, RF management application using ZigBee network, Germany, 2010.

[23] S. C. Ergen, ZigBee/IEEE 802.15.4 Summary, 2004.

[24] J. Lee, Yu-Wei Su, C. Shen, A Comparative Study of Wireless Protocols: Bluetooth, UWB, ZigBee, and Wi-Fi, Taiwan, 2007.

[25] http://www.smartsensorsystem.com.

[26] H. Cabrera, B. Bagnall, J.Faircloth, S.Goldberg, M.D, P.Chen, C# for Java Programmers, Syngress Publishing, Inc., USA, 2002.

[27] B.Evjen, J. Glynn, C. Nagel, M. Skinner, K. Watson, C# 2008, Wily Publishing Inc., 2008.

[28] https://www.2ac9-downloads.phpnuke.org/en/c113199/proteus.

[29] S. Attaway, Matlab: A Practical Introduction to Programming and Problem Solving, 2009.

[30] Maniccia D, Rutledge B, Rea MS, Morrow W. 1999. Occupant control of manual lighting controls in private offices. Journal of the IES, 28(2):42-56.

[31] Rundquist, R. A., McDougall, T. G., and Benya, J. R. (1996). Lighting controls: Patterns for design. (TR 107230) Pleasant Hills, CA: Electric Power Research Institute.

[32] Pérez-Lombard, L.; Ortiz, J.; Pout, C. A review on buildings energy consumption information. *Energy Build.* **2008**, *40*, 394–398.

[33] Zhao, K.; Liu, X.; Zhang, T.; Jiang, Y. Performance of temperature and humidity independent control air-conditioning system in an office building. *Energy Build.* **2011**, *43*, 1895–1903.

[34] Samsung Smart Series of Split A/C's—Air Conditioner. Available online: http://www.samsung.com/ au/consumer/home-appliances/airconditioner/wall-mounted-air-conditioners/AQV30TWDNXSA-features (accessed on 10 May 2014).

[35] Environmental Protection Agency (US EPA), 2008b, "Energy Guide-Opportunities for Improving Energy Efficiency in a Focus Industry".

[36] S. C. Ergen, ZigBee/IEEE 802.15.4 Summary, 2004.

[37] Asian Productivity Organization (APO), 2008. Working manual on auditing in industry Available at: http://www.apo-tokyo.org/00e-books/Gp-13 WorkingManualEnergy.

Appendix – A
Costing Calculations

Costing Calculation

EMO requiring capital expenditure shall be evaluated to see if it is economically justifiable. The evaluation can be done using the following methods.

Simple Payback Period

The payback period is the number of years required to recover the capital invested.

This method is simple in calculation, which normally excludes the consideration of timing of cash flows, inflation rate, interest rate of capital cost, depreciation, opportunity cost, etc. Its accuracy however will usually be within reasonable range.

Payback Period = initial capital cost / (yearly benefit – yearly cost)

For better accuracy, the net maintenance cost, interest on capital cost, net depreciation, opportunity cost, etc. can be added to the yearly cost. Likewise, the net productivity increase resulted from the investment, if any, can be added to the yearly benefit.

Net Present Value (NPV)

The NPV takes into account more systematically the time of cash flows, cost of money including interest on the capital cost investment, life time of equipment/installation, etc., which can better reflect the effectiveness of the investment. This method gives a present value to future earnings, which are expected to be derived from an investment.

$$NPV = \sum_{t=0}^{n} NCF_t \times 1/(1+i)^t$$

where NCF = net cash flow at year end t
(positive for savings and negative for expenditure)

i = interest rate
n = years of economic life of equipment/installation

The NPV concept recognises that the longer the time the money is gained the less attractive the investment becomes, as returns for each year are progressively discounted with time.

Example:

The following example shows the payback period for replacing 400 nos. of electromagnetic ballasts with electronic ballasts, each serving a single T8 36W (1200mm) fluorescent tube. Each electronic ballast costs $120 to purchase and install. The operating hours are 10 per day, 6 days per week and electricity cost is $0.9 per kWh.

Rating of fluorescent tube at 50 Hz operation	36W
Lighting system power with electromagnetic ballast	48W
Lighting system power with HF electronic ballast	36W
Lighting power saved = 48W – 36W	12W
Energy saving per year per lighting = 10 hr/day x 6 days/week x 52 weeks x 0.012kW	37.44kWh
Energy saving per year for 400 lightings = 37.44kWh x 400	14,976kWh

Initial capital cost = $120 x 400 = $48,000

Yearly benefit or cost savings = 14,976 kWh x $0.9/kWh = $13,478

Yearly cost = 0
(assuming no additional maintenance cost and depreciation cost and no cost of interest on the initial capital cost)

Payback Period = ($48,000) / ($13,478 - 0) = 3.6 **years**

Internal Rate of Return (IRR)

The IRR is a measure of the return in percentage to be expected on a capital investment. This takes into account the similar aspects as for NPV, with

$$NPV = \sum_{t=0}^{n} NCF_t \times 1/(1 + IRR)^t = 0$$

The higher the IRR the more cost effective is the investment.

Many financial calculators and spreadsheet computer programmes can calculate both NPV and IRR quite readily.

Appendix – B
Datasheets

IGI

EMBEDDED RF
MODULES FOR OEMS

BEE® 802.15.4 RF MODULES

w-cost, easy-to-deploy modules provide critical d-point connectivity to devices and sensors

ee 802.15.4 RF modules provide OEMs with a common tprint shared by multiple platforms, including multipoint l ZigBee/Mesh topologies, and both 2.4 GHz and 900 MHz utions. OEMs deploying the XBee can substitute one XBee another, depending upon dynamic application needs, h minimal development, reduced risk and shorter time-to-arket.

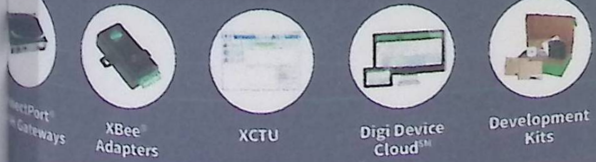
ee 802.15.4 RF modules are ideal for applications requiring latency and predictable communication timing. Providing ck, robust communication in point-to-point, peer-to-peer, l multipoint/star configurations, XBee 802.15.4 products enable robust end-point connectivity with ease. Whether deployed as a pure cable replacement for simple serial communication, or as part of a more complex hub-and-spoke network of sensors, XBee 802.15.4 RF modules maximize performance and ease of development.

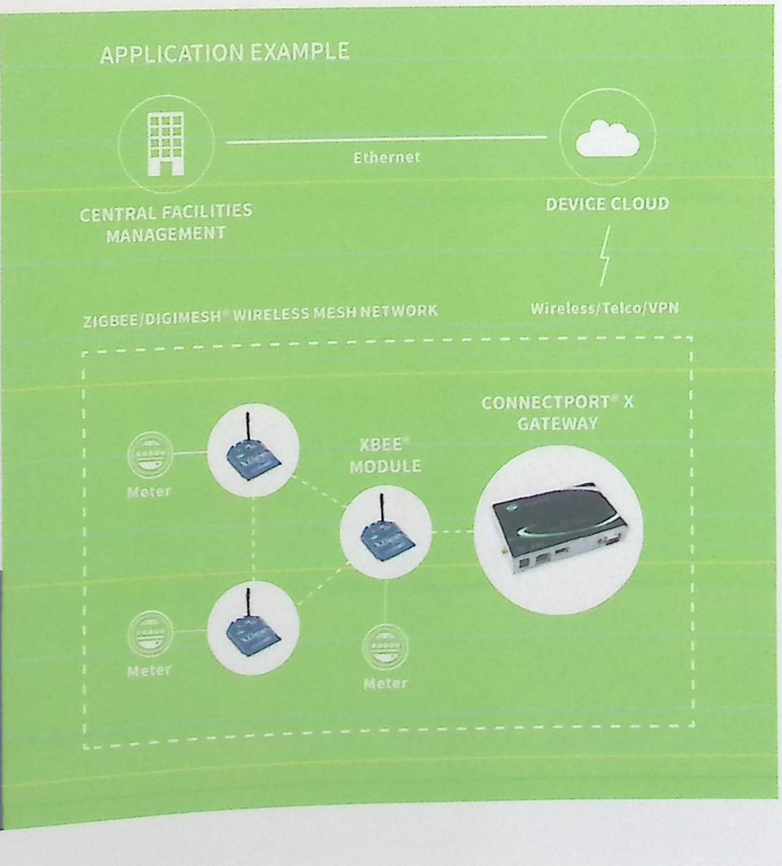
XBee 802.15.4 modules seamlessly interface with compatible gateways, device adapters and range extenders, providing developers with true beyond-the-horizon connectivity.

NEFITS

- Point-to-multipoint network topology
- 2.4 GHz for worldwide deployment
- 900 MHz for long-range deployment
- Fully interoperable with other other Digi networking products, including gateways, device adapters and range extenders
- Common XBee footprint for a variety of RF modules
- Low-power sleep modes
- Multiple antenna options
- Industrial temperature rating (-40° C to 85° C)

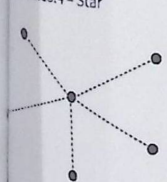
LATED PRODUCTS



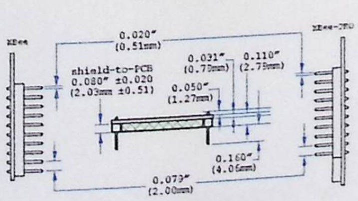


SPECIFICATIONS	XBee® 802.15.4	XBee-PRO® 802.15.4
RFORMANCE		
F DATA RATE	250 kbps	250 kbps
DOOR/URBAN RANGE	100 ft (30 m)	300 ft (100 m)
TDOOR/RF LINE-OF-SIGHT RANGE	300 ft (100 m)	1 mi (1.6 km)
ANSMIT POWER	1 mW (+0 dBm)	60 mW (+18 dBm)*
CEIVER SENSITIVITY (1% PER)	-92 dBm	-100 dBm
ATURES		
RIAL DATA INTERFACE	3.3V CMOS UART	
NFIGURATION METHOD	API or AT Commands, local or over-the-air	
EQUENCY BAND	2.4 GHz	
TERFERENCE IMMUNITY	DSSS (Direct Sequence Spread Spectrum)	
RIAL DATA RATE	1200 bps - 250 kbps	
C INPUTS	(6) 10-bit ADC inputs	
GITAL I/O	8	
TENNA OPTIONS	Chip, Wire Whip, U.FL, & RPSMA	
TWORKING & SECURITY		
CRYPTION	128-bit AES	
LIABLE PACKET DELIVERY	Retries/Acknowledgments	
S AND CHANNELS	PAN ID, 64-bit IEEE MAC, 16 Channels	
OWER REQUIREMENTS		
UPPLY VOLTAGE	2.8 - 3.4VDC	2.8 - 3.4VDC
RANSMIT CURRENT	45 mA @ 3.3VDC	215 mA @ 3.3VDC
ECEIVE CURRENT	50 mA @ 3.3VDC	55 mA @ 3.3VDC
OWER-DOWN CURRENT	<10 uA @ 25° C	
GULATORY APPROVALS		
C (USA)	OUR-XBEE	OUR-XBEEPRO
(CANADA)	4214A-XBEE	4214A-XBEEPRO
SI (EUROPE)	Yes	Yes - Max TX 10 mW
ICK AUSTRALIA	Yes	
LEC (JAPAN)	Yes	

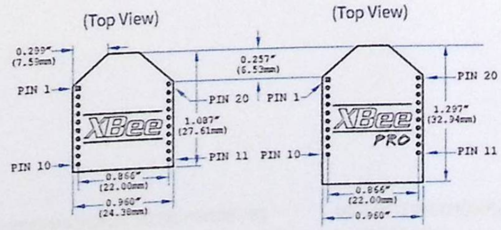
802.15.4 – Star



(Side Views)



(Top View) (Top View)



ART NUMBERS	DESCRIPTION
KB2-AT-WWC	Wireless Connectivity Kit w/ XBee 802.15.4
KB2-AT-WWG	XBee / Arduino Compatible Coding Platform
24-AWI-001	XBee 802.15.4 low-power module w/ wire antenna
24-API-001	XBee 802.15.4 low-power module w/ PCB antenna
24-AUI-001	XBee 802.15.4 low-power module w/ U.fl connector
24-ASI-001	XBee 802.15.4 low-power module w/ RPSMA connector
P24-AWI-001	XBee-PRO 802.15.4 extended-range module w/ wire antenna
P24-AWI-001J	XBee-PRO 802.15.4 extended-range module w/ wire antenna (International)
P24-AUI-001	XBee-PRO 802.15.4 extended-range module w/ U.fl connector
P24-AUI-001J	XBee-PRO 802.15.4 extended-range module w/ U.fl connector (International)
P24-ASI-001	XBee-PRO 802.15.4 extended-range module w/ RPSMA connector
P24-ASI-001J	XBee-PRO 802.15.4 extended-range module w/ RPSMA connector (International)
P24-API-001	XBee-PRO 802.15.4 extended-range module w/ PCB antenna
P24-API-001J	XBee-PRO 802.15.4 extended-range module w/ PCB antenna (International)

FOR MORE INFORMATION PLEASE VISIT WWW.DIGI.COM

GI SERVICE AND SUPPORT / You can purchase with confidence knowing that Digi always available to serve you with expert technical support and our industry ading warranty. For detailed information visit www.digi.com/support.

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C1/915

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ACS712

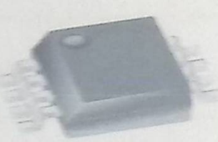
Fully Integrated, Hall Effect-Based Linear Current Sensor with 2.1 kVRMS Voltage Isolation and a Low-Resistance Current Conductor

Features and Benefits

- Low-noise analog signal path
- Device bandwidth is set via the new FILTER pin
- 5 μs output rise time in response to step input current
- 80 kHz bandwidth
- Total output error 1.5% at T_A= 25°C
- Small footprint, low-profile SOIC8 package
- 1.2 mΩ internal conductor resistance
- 2.1 kV_{RMS} minimum isolation voltage from pins 1-4 to pins 5-8
- 5.0 V, single supply operation
- 66 to 185 mV/A output sensitivity
- Output voltage proportional to AC or DC currents
- Factory-trimmed for accuracy
- Extremely stable output offset voltage
- Nearly zero magnetic hysteresis
- Ratiometric output from supply voltage

TÜV America
Certificate Number:
U8V 06 05 54214 010

Package: 8 Lead SOIC (suffix LC)



Approximate Scale 1:1

Description

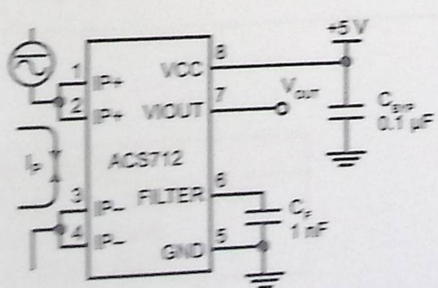
The Allegro® ACS712 provides economical and precise solutions for AC or DC current sensing in industrial, commercial, and communications systems. The device package allows for easy implementation by the customer. Typical applications include motor control, load detection and management, switched-mode power supplies, and overcurrent fault protection.

The device consists of a precise, low-offset, linear Hall sensor circuit with a copper conduction path located near the surface of the die. Applied current flowing through this copper conduction path generates a magnetic field which is sensed by the integrated Hall IC and converted into a proportional voltage. Device accuracy is optimized through the close proximity of the magnetic signal to the Hall transducer. A precise, proportional voltage is provided by the low-offset, chopper-stabilized BiCMOS Hall IC, which is programmed for accuracy after packaging.

The output of the device has a positive slope (>$V_{IOUT(Q)}$) when an increasing current flows through the primary copper conduction path (from pins 1 and 2, to pins 3 and 4), which is the path used for current sensing. The internal resistance of this conductive path is 1.2 mΩ typical, providing low power

Continued on the next page…

Typical Application



Application 1. The ACS712 outputs an analog signal, V_{OUT}, that varies linearly with the uni- or bi-directional AC or DC primary sensed current, I_P, within the range specified. C_F is recommended for noise management, with values that depend on the application.

scription (continued)

s. The thickness of the copper conductor allows survival of device at up to 5× overcurrent conditions. The terminals of conductive path are electrically isolated from the sensor leads ns 5 through 8). This allows the ACS712 current sensor to be d in applications requiring electrical isolation without the use opto-isolators or other costly isolation techniques.

The ACS712 is provided in a small, surface mount SOIC8 package. The leadframe is plated with 100% matte tin, which is compatible with standard lead (Pb) free printed circuit board assembly processes. Internally, the device is Pb-free, except for flip-chip high-temperature Pb-based solder balls, currently exempt from RoHS. The device is fully calibrated prior to shipment from the factory.

election Guide

Part Number	Packing*	T_A (°C)	Optimized Range, I_P (A)	Sensitivity, Sens (Typ) (mV/A)
CS712ELCTR-05B-T	Tape and reel, 3000 pieces/reel	–40 to 85	±5	185
CS712ELCTR-20A-T	Tape and reel, 3000 pieces/reel	–40 to 85	±20	100
CS712ELCTR-30A-T	Tape and reel, 3000 pieces/reel	–40 to 85	±30	66

Contact Allegro for additional packing options.

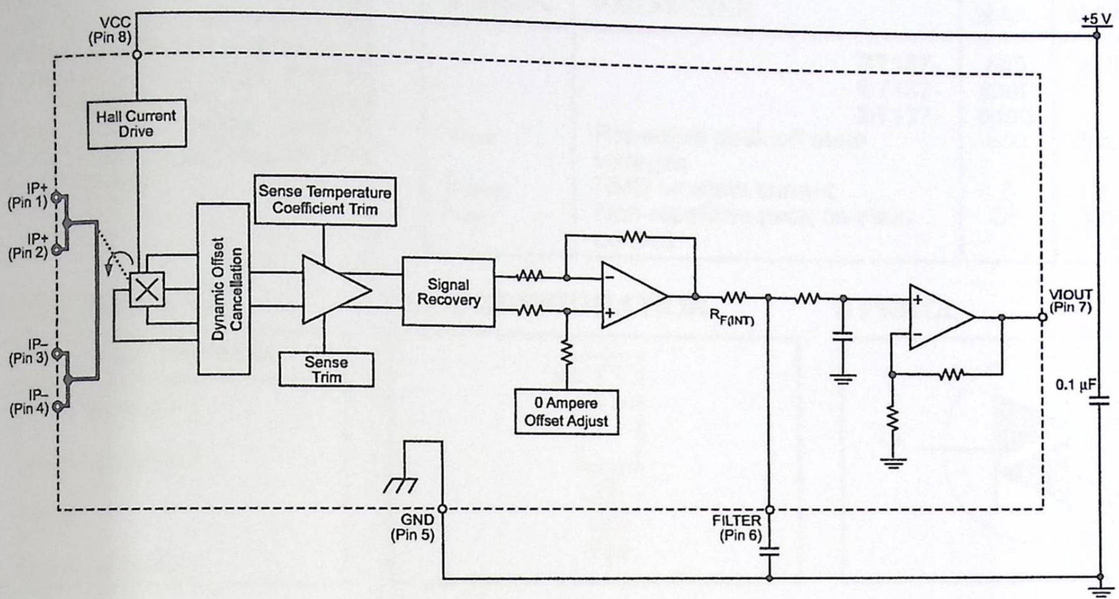
bsolute Maximum Ratings

Characteristic	Symbol	Notes	Rating	Units
upply Voltage	V_{CC}		8	V
everse Supply Voltage	V_{RCC}		–0.1	V
utput Voltage	V_{IOUT}		8	V
everse Output Voltage	V_{RIOUT}		–0.1	V
einforced Isolation Voltage	V_{ISO}	Pins 1-4 and 5-8; 60 Hz, 1 minute, T_A=25°C	2100	V
		Voltage applied to leadframe (Ip+ pins), based on IEC 60950	184	V_{peak}
asic Isolation Voltage	$V_{ISO(bsc)}$	Pins 1-4 and 5-8; 60 Hz, 1 minute, T_A=25°C	1500	V
		Voltage applied to leadframe (Ip+ pins), based on IEC 60950	354	V_{peak}
utput Current Source	$I_{IOUT(Source)}$		3	mA
utput Current Sink	$I_{IOUT(Sink)}$		10	mA
vercurrent Transient Tolerance	I_P	1 pulse, 100 ms	100	A
ominal Operating Ambient Temperature	T_A	Range E	–40 to 85	°C
aximum Junction Temperature	$T_J(max)$		165	°C
torage Temperature	T_{stg}		–65 to 170	°C

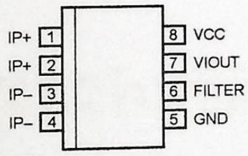
Parameter	Specification
Fire and Electric Shock	CAN/CSA-C22.2 No. 60950-1-03 UL 60950-1:2003 EN 60950-1:2001

Allegro MicroSystems, Inc.
115 Northeast Cutoff
Worcester, Massachusetts 01615-0036 U.S.A.
1.508.853.5000; www.allegromicro.com

Functional Block Diagram



Pin-out Diagram



Terminal List Table

Number	Name	Description
1 and 2	IP+	Terminals for current being sensed; fused internally
3 and 4	IP–	Terminals for current being sensed; fused internally
5	GND	Signal ground terminal
6	FILTER	Terminal for external capacitor that sets bandwidth
7	VIOUT	Analog output signal
8	VCC	Device power supply terminal

GENERAL DESCRIPTION

Passivated triacs in a plastic envelope, intended for use in applications requiring high bidirectional transient and blocking voltage capability and high thermal cycling performance. Typical applications include motor control, industrial and domestic lighting, heating and static switching.

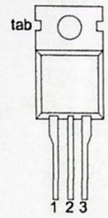
QUICK REFERENCE DATA

SYMBOL	PARAMETER	MAX.	MAX.	UNIT
	BT137-	600	800	
	BT137-	600F		
	BT137-	600G		
V_{DRM}	Repetitive peak off-state voltages	600	800	V
$I_{T(RMS)}$	RMS on-state current	8	8	A
I_{TSM}	Non-repetitive peak on-state current	65	65	A

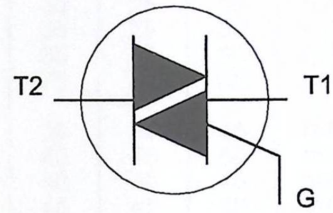
PINNING - TO220AB

PIN	DESCRIPTION
1	main terminal 1
2	main terminal 2
3	gate
tab	main terminal 2

PIN CONFIGURATION



SYMBOL



LIMITING VALUES

Limiting values in accordance with the Absolute Maximum System (IEC 134).

SYMBOL	PARAMETER	CONDITIONS	MIN.	MAX.		UNIT
				-600	-800	
V_{DRM}	Repetitive peak off-state voltages		-	600[1]	800	V
$I_{T(RMS)}$	RMS on-state current	full sine wave; $T_{mb} \leq 102$ ˚C	-	8		A
I_{TSM}	Non-repetitive peak on-state current	full sine wave; $T_j = 25$ ˚C prior to surge				
		t = 20 ms	-	65		A
		t = 16.7 ms	-	71		A
I^2t	I^2t for fusing	t = 10 ms	-	21		A^2s
dI_T/dt	Repetitive rate of rise of on-state current after triggering	$I_{TM} = 12$ A; $I_G = 0.2$ A; $dI_G/dt = 0.2$ A/µs				
		T2+ G+	-	50		A/µs
		T2+ G-	-	50		A/µs
		T2- G-	-	50		A/µs
		T2- G+	-	10		A/µs
I_{GM}	Peak gate current		-	2		A
V_{GM}	Peak gate voltage		-	5		V
P_{GM}	Peak gate power		-	5		W
$P_{G(AV)}$	Average gate power	over any 20 ms period	-	0.5		W
T_{stg}	Storage temperature		-40	150		˚C
T_j	Operating junction temperature		-	125		˚C

1 Although not recommended, off-state voltages up to 800V may be applied without damage, but the triac may switch to the on-state. The rate of rise of current should not exceed 6 A/µs.

THERMAL RESISTANCES

SYMBOL	PARAMETER	CONDITIONS	MIN.	TYP.	MAX.	UNIT
$R_{th\ j\text{-}mb}$	Thermal resistance junction to mounting base	full cycle	-	-	2.0	K/W
		half cycle	-	-	2.4	K/W
$R_{th\ j\text{-}a}$	Thermal resistance junction to ambient	in free air	-	60	-	K/W

STATIC CHARACTERISTICS

T_j = 25 ˚C unless otherwise stated

SYMBOL	PARAMETER	CONDITIONS	MIN.	TYP.	MAX.			UNIT
		BT137-			...	...F	...G	
I_{GT}	Gate trigger current	V_D = 12 V; I_T = 0.1 A						
		T2+ G+	-	5	35	25	50	mA
		T2+ G-	-	8	35	25	50	mA
		T2- G-	-	11	35	25	50	mA
		T2- G+	-	30	70	70	100	mA
I_L	Latching current	V_D = 12 V; I_{GT} = 0.1 A						
		T2+ G+	-	7	30	30	45	mA
		T2+ G-	-	16	45	45	60	mA
		T2- G-	-	5	30	30	45	mA
		T2- G+	-	7	45	45	60	mA
I_H	Holding current	V_D = 12 V; I_{GT} = 0.1 A	-	5	20	20	40	mA
V_T	On-state voltage	I_T = 10 A	-	1.3	1.65			V
V_{GT}	Gate trigger voltage	V_D = 12 V; I_T = 0.1 A	-	0.7	1.5			V
		V_D = 400 V; I_T = 0.1 A; T_j = 125 ˚C	0.25	0.4	-			V
I_D	Off-state leakage current	$V_D = V_{DRM(max)}$; T_j = 125 ˚C	-	0.1	0.5			mA

DYNAMIC CHARACTERISTICS

T_j = 25 ˚C unless otherwise stated

SYMBOL	PARAMETER	CONDITIONS	MIN.			TYP.	MAX.	UNIT
		BT137-	...	...F	...G			
dV_D/dt	Critical rate of rise of off-state voltage	V_{DM} = 67% $V_{DRM(max)}$; T_j = 125 ˚C; exponential waveform; gate open circuit	100	50	200	250	-	V/µs
dV_{com}/dt	Critical rate of change of commutating voltage	V_{DM} = 400 V; T_j = 95 ˚C; $I_{T(RMS)}$ = 8 A; dI_{com}/dt = 3.6 A/ms; gate open circuit	-	-	10	20	-	V/µs
t_{gt}	Gate controlled turn-on time	I_{TM} = 12 A; $V_D = V_{DRM(max)}$; I_G = 0.1 A; dI_G/dt = 5 A/µs	-	-	-	2	-	µs

LM35 Precision Centigrade Temperature Sensors

1 Features

- Calibrated Directly in Celsius (Centigrade)
- Linear + 10-mV/°C Scale Factor
- 0.5°C Ensured Accuracy (at 25°C)
- Rated for Full −55°C to 150°C Range
- Suitable for Remote Applications
- Low-Cost Due to Wafer-Level Trimming
- Operates from 4 V to 30 V
- Less than 60-μA Current Drain
- Low Self-Heating, 0.08°C in Still Air
- Non-Linearity Only ±¼°C Typical
- Low-Impedance Output, 0.1 Ω for 1-mA Load

2 Applications

- Power Supplies
- Battery Management
- HVAC
- Appliances

3 Description

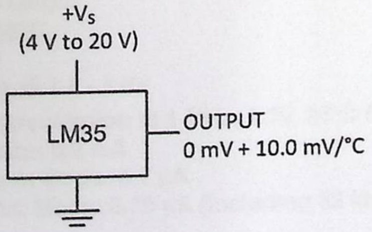
The LM35 series are precision integrated-circuit temperature devices with an output voltage linearly-proportional to the Centigrade temperature. The LM35 device has an advantage over linear temperature sensors calibrated in Kelvin, as the user is not required to subtract a large constant voltage from the output to obtain convenient Centigrade scaling. The LM35 device does not require any external calibration or trimming to provide typical accuracies of ±¼°C at room temperature and ±¾°C over a full −55°C to 150°C temperature range. Lower cost is assured by trimming and calibration at the wafer level. The low-output impedance, linear output, and precise inherent calibration of the LM35 device makes interfacing to readout or control circuitry especially easy. The device is used with single power supplies, or with plus and minus supplies. As the LM35 device draws only 60 μA from the supply, it has very low self-heating of less than 0.1°C in still air. The LM35 device is rated to operate over a −55°C to 150°C temperature range, while the LM35C device is rated for a −40°C to 110°C range (−10° with improved accuracy). The LM35-series devices are available packaged in hermetic TO transistor packages, while the LM35C, LM35CA, and LM35D devices are available in the plastic TO-92 transistor package. The LM35D device is available in an 8-lead surface-mount small-outline package and a plastic TO-220 package.

Device Information(1)

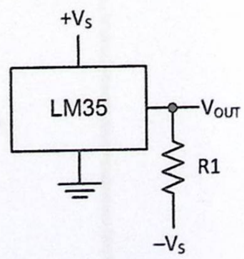
PART NUMBER	PACKAGE	BODY SIZE (NOM)
LM35	TO-CAN (3)	4.699 mm × 4.699 mm
	TO-92 (3)	4.30 mm × 4.30 mm
	SOIC (8)	4.90 mm × 3.91 mm
	TO-220 (3)	14.986 mm × 10.16 mm

(1) For all available packages, see the orderable addendum at the end of the datasheet.

Basic Centigrade Temperature Sensor (2°C to 150°C)



Full-Range Centigrade Temperature Sensor



Choose $R_1 = -V_S / 50\ \mu A$
V_{OUT} = 1500 mV at 150°C
V_{OUT} = 250 mV at 25°C
V_{OUT} = –550 mV at –55°C

Features

- High Performance, Low Power AVR® 8-Bit Microcontroller
- Advanced RISC Architecture
  - 131 Powerful Instructions – Most Single Clock Cycle Execution
  - 32 x 8 General Purpose Working Registers
  - Fully Static Operation
  - Up to 20 MIPS Throughput at 20 MHz
  - On-chip 2-cycle Multiplier
- High Endurance Non-volatile Memory Segments
  - 4/8/16/32K Bytes of In-System Self-Programmable Flash progam memory (ATmega48PA/88PA/168PA/328P)
  - 256/512/512/1K Bytes EEPROM (ATmega48PA/88PA/168PA/328P)
  - 512/1K/1K/2K Bytes Internal SRAM (ATmega48PA/88PA/168PA/328P)
  - Write/Erase Cycles: 10,000 Flash/100,000 EEPROM
  - Data retention: 20 years at 85°C/100 years at 25°C[1]
  - Optional Boot Code Section with Independent Lock Bits
    In-System Programming by On-chip Boot Program
    True Read-While-Write Operation
  - Programming Lock for Software Security
- Peripheral Features
  - Two 8-bit Timer/Counters with Separate Prescaler and Compare Mode
  - One 16-bit Timer/Counter with Separate Prescaler, Compare Mode, and Capture Mode
  - Real Time Counter with Separate Oscillator
  - Six PWM Channels
  - 8-channel 10-bit ADC in TQFP and QFN/MLF package
    Temperature Measurement
  - 6-channel 10-bit ADC in PDIP Package
    Temperature Measurement
  - Programmable Serial USART
  - Master/Slave SPI Serial Interface
  - Byte-oriented 2-wire Serial Interface (Philips I^2C compatible)
  - Programmable Watchdog Timer with Separate On-chip Oscillator
  - On-chip Analog Comparator
  - Interrupt and Wake-up on Pin Change
- Special Microcontroller Features
  - Power-on Reset and Programmable Brown-out Detection
  - Internal Calibrated Oscillator
  - External and Internal Interrupt Sources
  - Six Sleep Modes: Idle, ADC Noise Reduction, Power-save, Power-down, Standby, and Extended Standby
- I/O and Packages
  - 23 Programmable I/O Lines
  - 28-pin PDIP, 32-lead TQFP, 28-pad QFN/MLF and 32-pad QFN/MLF
- Operating Voltage:
  - 1.8 - 5.5V for ATmega48PA/88PA/168PA/328P
- Temperature Range:
  - -40°C to 85°C
- Speed Grade:
  - 0 - 20 MHz @ 1.8 - 5.5V
- Low Power Consumption at 1 MHz, 1.8V, 25°C for ATmega48PA/88PA/168PA/328P:
  - Active Mode: 0.2 mA
  - Power-down Mode: 0.1 µA
  - Power-save Mode: 0.75 µA (Including 32 kHz RTC)

8-bit AVR® Microcontroller with 4/8/16/32K Bytes In-System Programmable Flash

ATmega48PA
ATmega88PA
ATmega168PA
ATmega328P

Summary

Rev. 8161CS–AVR–05/09

1. Pin Configurations

Figure 1-1. Pinout ATmega48PA/88PA/168PA/328P