Sudan University of Sciences and Technology
College of Engineering
Electrical Engineering

Smart Solar Streets Lighting System

نظام إضاءة الشوارع بالطاقة الشمسية الذكي

A Project Submitted In Partial Fulfillment for the Requirements of the Degree of B.Sc. (Honor) In Electrical Engineering

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الآية

﴿ اللَّهُ نُورُ السَّمَاوَاتِ وَالأَرْضِ مَثَلُ نُورِهِ كَمِشْكَاة فِيهَا مِصْبَاحٌ
الْمِصْبَاحُ فِي زُجَاجَةٍ الزُّجَاجَةُ كَأَنَّهَا كَوْكَبٌ دُرِّيٌّ يُوقَدُ مِنْ
شَجَرَةٍ مُبَارَكَةٍ زَيْتُونَةٍ لا شَرْقِيَّةٍ وَلا غَرْبِيَّةٍ يَكَادُ زَيْتُهَا يُضِيءُ
وَلَوْ لَمْ تَمْسَسْهُ نَارٌ نُورٌ عَلَى نُورٍ يَهْدِي اللَّهُ لِنُورِهِ مَنْ يَشَاءُ
وَيَضْرِبُ اللَّهُ الأَمْثَالَ لِلنَّاسِ وَاللَّهُ بِكُلِّ شَيْءٍ عَلِيمٌ ﴾

[النور: 35]

DEDICATION

TO Our Mothers, who are the most deserving of the people with good companionship and who accompanied us with their prayers at all times, to those under their feet Paradise.

To Our Fathers, who taught us life and that there is no impossible if we put our trust in Allah.

To the one who was trusted in me and believe in my abilities, who was advised and has the virtue of me, To my companion to heaven.

To the one who was lighting the way for me, my second and appointed after God, To my older brother.

To all great people in our life's, To our relatives and friends, specially USM "our second family". Thank you for being always there

ACKNOWLEDGEMENT

First we thank god almighty (Allah SWT), the completion of this project could not have been possible without his blessing and assistance.

Then all thanks and appreciation to our supervisor Dr. Salah Aldeen Gasim Mohammed for his patience and valuable advises.

Lastly thanks to our teachers in electrical engineering school for their effort, without them we wouldn’t be able to reach this far.

ABSTRACT

The energy consumption in lighting is increasing day by day. Lot of efforts have been made in order to minimize the energy consumption in lighting. Photovoltaic (PV) is the best solution for the energy requirements in the future. The project is designed for LED based street lights with an auto-intensity control that uses solar power from photovoltaic cells. A charge controller circuit is used to control the charging of the battery, and an LDR is used to sense the ambient light on day time, The street lights are switched on at the dusk and then switched off at the dawn automatically by using a sensing device LDR .The intensity of street lights is required to be kept high during the peak hours. As the traffic on the roads tends to decrease slowly in late nights, the intensity can be reduce using PIR sensor by detecting the movement to save energy. LED lights are the future of lighting, because of their low energy consumption and long life they are fast replacing conventional lights world over. White light emitting diode (LED) replaces the HID lamps where intensity control is possible by pulse width modulation.

المستخلص

الطاقة المستهلكة في الإضاءة تزداد كل يوم. و تم بذل الكثير من المجهودات لتقليل إستهلاك الطاقة في الإضاءة. الطاقة الكهروضوئية (PV) هي الحل الأمثل لمتطلبات الطاقة في المستقبل. تم تصميم هذا المشروع لأنظمة الإضاءة التي تعتمد على مصابيح(LED) مع التحكم التلقائي في شدة الإضاءة و الذي يستخدم الطاقة الشمسية من الخلايا الكهروضوئية. يتم إستخدام دائرة منظم الشحن للتحكم في شحن البطاريات، ومحساس (LDR) لتحسس الإضاءة خلال اليوم بحيث يتم تشغيل المصابيح عند المغيب و إيقاف عملها عند الفجر تلقائيا. من المطلوب أن تكون شدة الإضاءة عالية في أوقات الذروة، وبما ان حركة المرور في الطرق تقل في الأوقات المتأخرة من الليل يمكن تقليل شدة الإضاءة بإستخدام مستشعر الحركة (PIR) لتوفير الطاقة. مصابيح (LED)هي مستقبل الإضاءة نظرا لإستهلاكها المنخفض للطاقة و فترة عملها الطويلة، فهي ستحل محل المصابيح التقليدية في جميع أنحاء العالم. مصابيح (LED) تحل محل مصابيح (HID) حيث يمكن التحكم في شدة الإضاءة بواسطة تشكيل عرض الموجة.

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LIST OF ABBREVIATIONS

SAS	Stand Alone System
OTG	Off The Grid
PV	Photo voltaic
DC-AC	Direct Current-Alternator Current
TFSC	Thin-Film Solar cell
ISC	Short Circuit Current
MPP	Maximum Power Point
NiCd	Nickel-Cadmium
NiMH	Nickel-Metal Hydride
Li-ion	Lithium-ion
Li-poly	Lithium-polymer
C/D	Charge /Discharge
PWM	Pulse width modulation
MPPT	Maximum Power Point tracking
LCCA	Live Cycle Cost Assessment
CCT	Correlated Color Temperature
CRI	Color Rendering index
GLS	General Lighting Service
PCA	Poly Crystalline Sintered Alumina
LED	Light Emitting Diode
SSL	Solid State Lighting
OLED	Organic Light Emitting Diode
LEP	Light Emitting Polymer
GAP	Gallium Arsenide Phosphate
HID	High Intensity Discharge
LDR	Light Dependent Resistor
PIR	Passive Infrared Sensor
SOC	State of Charge
P-type	Positive Type
N-type	Negative Type
PIC	Programmable Integrated circuit
PLC	Programmable Logic Controller
IR	Infrared Radiating
EPP	Energy Payback Period

CHAPTER ONE

INTRODUCTION

1.1 Overview

Energy requirement of the mankind is continue growing, it is forecasted that by the middle of our century the global energy demand will at least double. Our world has been powered primarily by carbon fuels for more than two centuries, with some demand met by nuclear power plants over the last five decades.

The increasing environmental concerns in recent years about global warming and the harmful effects of carbon emissions have created a new demand for clean and sustainable energy sources, such as wind, sea, sun, biomass, and geothermal power.

Renewable energy is energy that is collected from renewable resources that naturally replenish themselves and never run out such as sunlight, wind, rain, tides, waves, and geothermal heat. Just as there are many natural sources of energy, there are many renewable energy technologies. Solar is one of the most well known, wind power is one of the most widespread, and hydropower is one of the oldest. Other renewable technologies harness geothermal energy, bio-energy or ocean energy to produce heat or electricity.

Over 80% of the total energy consumed by humans is derived from fossil fuels however renewable are the fastest growing source of energy in the world. Renewable energy has many benefits:

•First it can combat climate change because it creates no direct greenhouse gas emissions the only emissions that they produce are indirect meaning those that result from manufacturing parts installation operation and maintenance but even those are minimal

•Second renewable energy can decrease pollution and therefore reduce threats to our health . Wind solar and hydroelectric systems create no air pollution emissions. and geothermal and biomass energy systems emissions are much lower than non-renewable energy sources

•Third renewable energy is a reliable source of power because renewable energy sources are well renewable they will never run out once built renewable facilities cost very little to operate and the fuel is often free as a result

Renewable energy prices tend to be stable over time while renewable energy has many advantages it is not without downsides it is difficult for renewable energy sources to generate power on the same large scale as fossil fuels building wind farms and dams can disrupt wildlife and migration patterns and lead to ecological destruction.

Both solar and wind energy are intermittent they only generate power while the sun is shining or while the wind is blowing batteries can store excess energy for later use however they are often costly.

While renewable energy presents some challenges it also offers an environmentally friendly alternative to the greenhouse gas emissions and pollution of fossil fuels .and as advances in technology make renewable energy more accessible affordable and efficient an end to climate change could be within our reach.

1.2 Problem statement

One of the current problems facing the world is the problem of energy consumption. One of these systems streets lighting system . These lamps work throughout the night even when there are no pedestrians and cars. This is a waste of energy. The idea of this project came to solve this problem by canceling the load from the network and relying on renewable energy (solar energy) and the operation of a control system to operate and extinguish the springs depending on the sun and also reduce and increase lighting by pedestrians and cars. Another problem is the traditional street lamp e.g. Sodium vapor, Metal halide Incandescent, Fluorescent lamps consumes more power as compared to new advanced Led Lights.

The Proposed Solution is to design a new system for the streetlight that do not consume huge amount of electricity and illuminate large areas with the highest intensity of light by using energy efficiency technologies and design mechanism which can reduce cost of the street lighting drastically.

1.3 Objective

1. Study the pervious works.
2. Study and understand solar photovoltaic.
3. Study and understand battery and led.
4. Study and understand microcontroller and sensors.
5. To study solar Photovoltaic (PV) system for the streets.
6. To decrease the electricity power by using LED lamps for lighting.
7. To design and implement a smart lighting system by Arduino UNO.
8. To implement these designs in simulation software.
9. To calculate the energy consumed in case of using the HID lamps.
10. To calculate the energy consumed in case of smart lighting.
11. To provide an economic study of the proposed system.

1.4 Methodology

The thesis methodology is undertaken according to these steps:

1. Proteus software is used to build the complete system.
2. Evaluate system performance based on simulation result.
3. Build Arduino microcontroller program to control the system.
4. Proposed design had been constructed.
5. Energy consumption was Calculated and comparing for the lamps taken in the study.

1.5 Project layout

The project include five chapters organized as follows Chapter one include overview, Problem statement, Objective, Methodology and Thesis layout, chapter two include Introduction, Solar Power Systems, Components of solar system, Solar cell, V-I Characteristic of Solar Cell, Batteries, Solar charger controller, Lighting technologies, chapter three include System description, Hardware Equipment, System Flow Chart, chapter four include System Fabrication, System Component Cost, Energy Utilization, chapter five include conclusion and recommendation.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Energy is the primary and most universal measure of all kinds of work of human beings and nature. Energy is a crucial commodity in the process of economic, social and industrial development. As conventional energy sources are depleting day by day, utilization of alternative energy source is the only solution. The increased power demand, depleting fossil fuel resources and grow in environmental pollution have led the world to think seriously for other alternative source of energy and save this energy as much as possible

2.2 Solar Power Systems

Solar power system can be classified as two types depending on the connection to the system: on a grid system and off grid systems (stand-alone system). Grid connected photovoltaic power system is a power systems energized by photovoltaic panels which are connected to the utility grid. The term off grid refers to not being connected to the grid, mainly used in terms of not being connected to the main and national transmission of electricity. In electricity off-grid can be Stand-Alone System (SAS) or mini grid typically to provide a smaller community with electricity. The term Off-The Grid (OTG) can refer to living in a self-sufficient manner without reliance on one or more public utilization.

2.2.1 On-Grid System

On-Grid Systems are solar PV systems that only generate power when the utility power grid is available. They must connect to the grid to function .

A grid connected system is connected to a larger independent grid (typically the public electricity grid) and feeds energy directly into the grid. The feeding of electricity into the grid requires the transformation of DC into AC. As shown in Figure 2.1

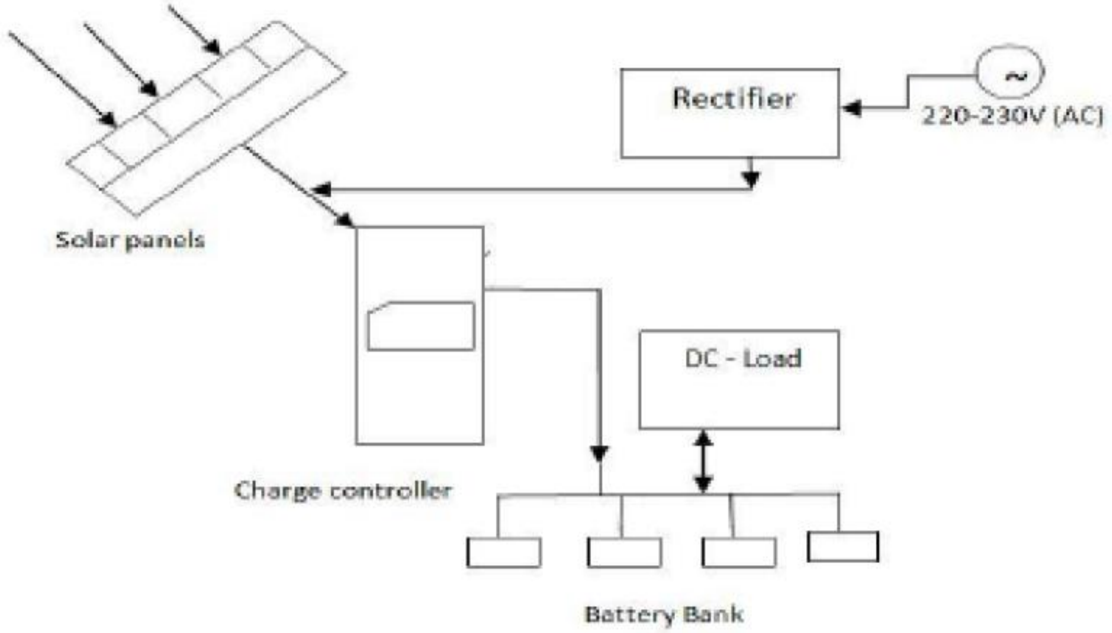

Figure 2.1: On grid system

2.2.2 off-Grid/Hybrid System

Stand-alone systems rely on solar power only. These systems can consist of the PV modules and a load only or they can include batteries for energy storage. These systems allow you to store your solar power in batteries for use when the power grid goes down or if you are not on the grid. Hybrid systems provide power to offset the grid power whenever the sun is shining and will even send excess power to the grid for credit for later use. When using batteries charge regulators are included, which switch off the PV modules when batteries are fully charged and may switch off the load to prevent the batteries from being discharged below a certain limit. The batteries must have enough capacity to store the energy produced during the day to be used at night and during periods of poor weather. As shown in Figure 2.2

2.3 Components of solar System

Many components are required for a working system; these components are:

• A mounting structure is used to fix the modules and to direct them towards the sun.

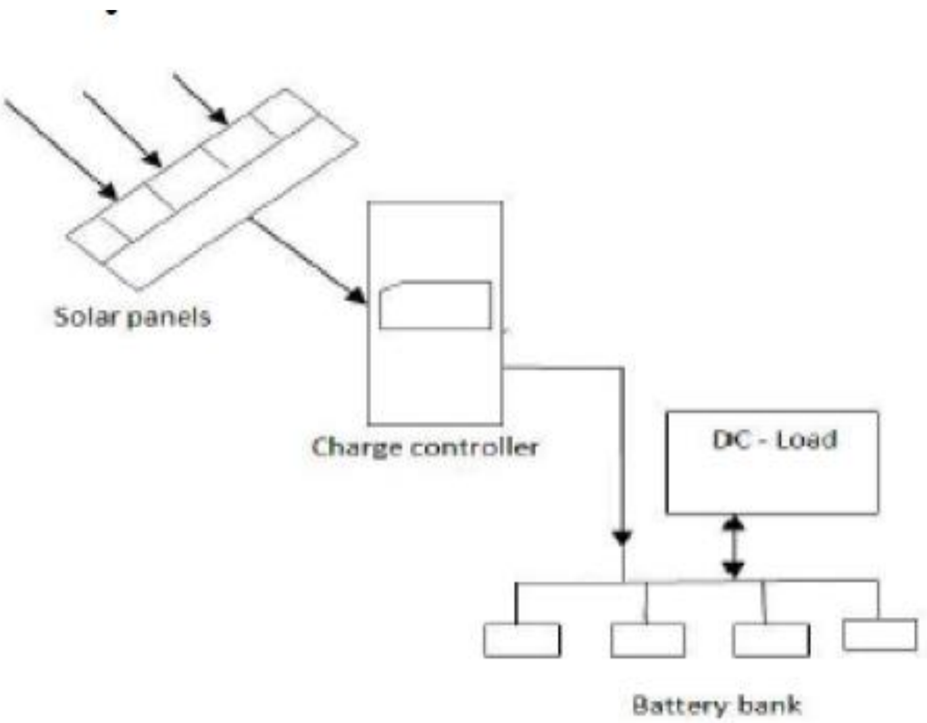

Figure 2.2: Off grid system

• Energy storage is a vital part of stand-alone system because it assures that the system can deliver electricity during the night and in periods of bad weather. Usually, batteries are used as energy storage units.

• DC-DC converters are used to convert the module output, which will have a -variable voltage depending on the time of the day and the weather conditions to a fixed voltage output that can be used to charge a battery or is used as input for an inverter in a grid-connected system.

• Inverters or DC-AC converters are used in grid connected systems to convert the DC electricity originating from the PV modules into AC electricity that can be fed into the electricity grid.

• Cables are used to connect the different components of the PV system with each other and to the electrical load. It is important to choose cables of sufficient thickness in order to minimize resistive losses.

2.4 Solar Cells

Solar cells are the building block of Photo Voltaic (PV) system. It is a form of photoelectric cell which, when exposed to light, can generate and support an electric current without being attached to any external voltage source. Solar cells produce direct current electricity from sunlight, which can be used to power equipment or to charge a battery. Solar cells require protection from the environments and are usually packaged tightly behind a glass sheet. When more power is required than a single cell can deliver, cells are electrically connected together to form photovoltaic modules or solar panels as shown in Fig. 2.3. Solar cells are often electrically connected and encapsulated as a module. Solar cells have many applications. They have been used in situations where electrical power from the grid is unavailable, such as in remote area power system as well as the urban area power system. The power produced by the PV cells fluctuates with the intensity of the sunshine. It is to be used to charge batteries first and then the batteries used.

Figure 2.3: Solar Panel

2.4.1 Module and Array

The solar cell is the basic building block of the PV power system. Typically, it's a few square inches in size and produces about one watt of power. To obtain high power, numerous such cells are connected in series and parallel circuits on a panel (module) area of several square feet/meter, the solar array or panel is defined as a group of several modules electrically connected in series or parallel combination to generate the required current and voltage. As shown in Figure 2.4.

2.4.2 Solar Module Types

There are different types of solar modules: Mono-Crystalline Silicon , Poly-Crystalline Silicon and Thin Film as shown in Figure 2.5

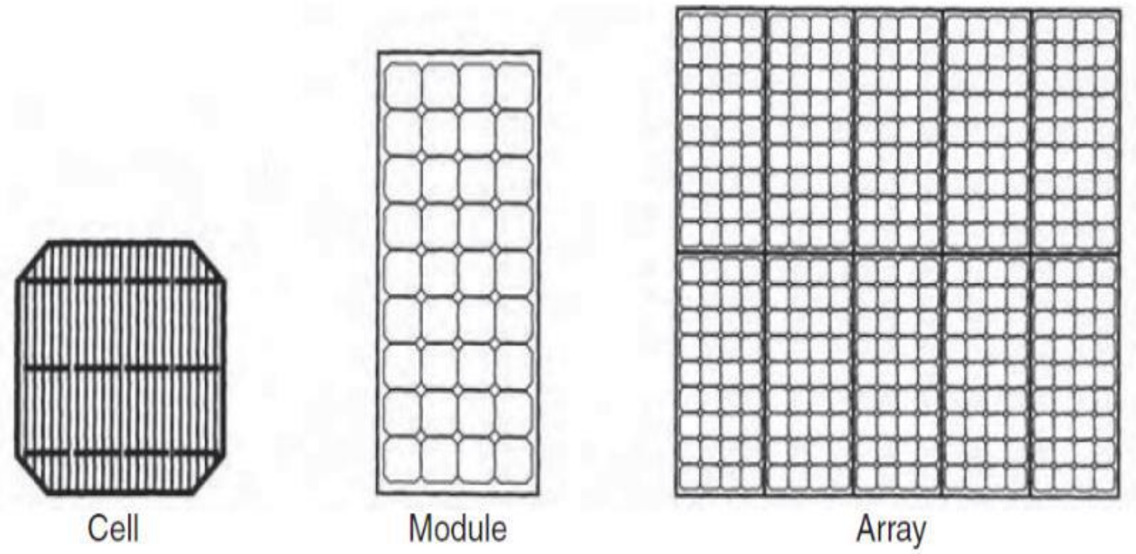

Figure 2.4: Several PV cells make a module, and several modules make an array.

occurs due to the manufacturing process of these highly-pure ingots. The wafers are cut out of the cylindrical ingots to make the wafers. They usually have a much more uniform, dark color to them compared to poly-crystalline modules.

2. Poly-Crystalline Silicon

Poly (Multi) crystalline, these modules are manufactured slightly differently than mono-crystalline modules. The silicon is first melted into a rectangular form before the wafers are cut into squares, the wafers have right-angle corners, unlike the mono-crystalline, this is a great indicator of what type of solar module you have, the color is usually lighter and broken up more so than a mono-crystalline solar module.

3. Thin Film

Thin-Film Solar Cells (TFSC), these modules are manufactured by layering photovoltaic material onto a substrate, the number of layers can vary, the most common photovoltaic materials are categorized by their photovoltaic material such as amorphous Silicon, Cadmium telluride, Copper indium gallium selenide

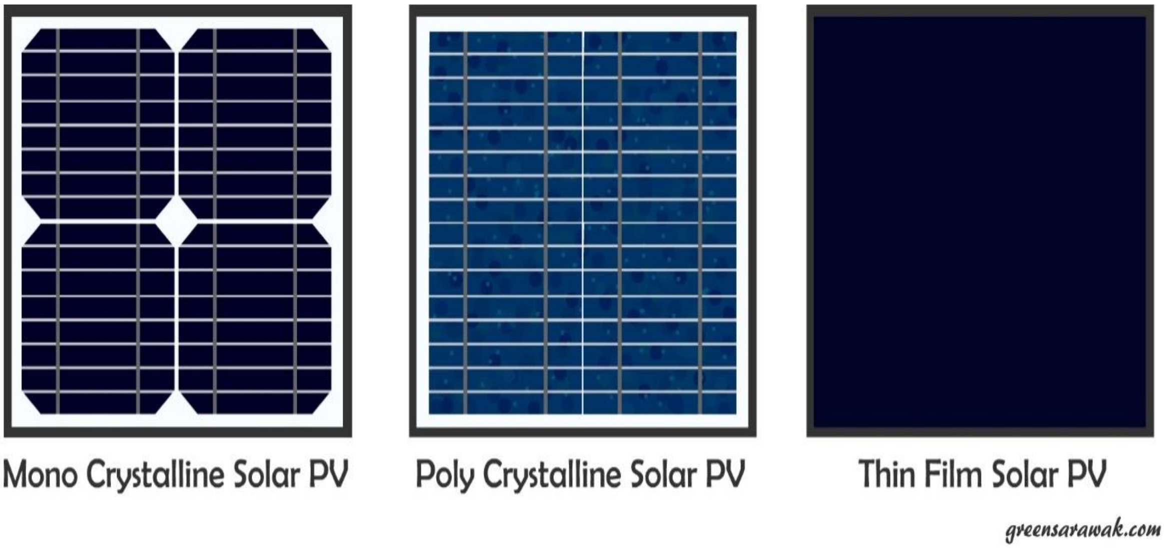

Figure 2.5: Solar module types

2.5 V-I Characteristic of Solar Cell

Figure 2.6shows the V-I characteristic curve and output power of a solar panel. The curve has two parts, one indicates the trend of current with respect to increasing voltage. The other curve is the power-voltage curve and is obtained by the equation

P=V*I. If no load is connected with the solar panel which is working in sun light, an open-circuit voltage Voc will be produced but no current follows. If the terminals of the solar panel are shorted together, the short-circuit current ISC will flow but the output voltage will be zero. In both cases, when a load is connected, we need to consider V-I curve of the panel and V-I curve of the load to find out how much power can be transmitted to the load. The maximum power point (MPP) is the spot near the knee of the V-I curve as shown in Figure 2.6, and the voltage and current at the MPP are designated as Vm and Im. For a particular load, the maximum point is varying following insulation, shading and temperature. It is important to operate panels at their maximum power Conditions.

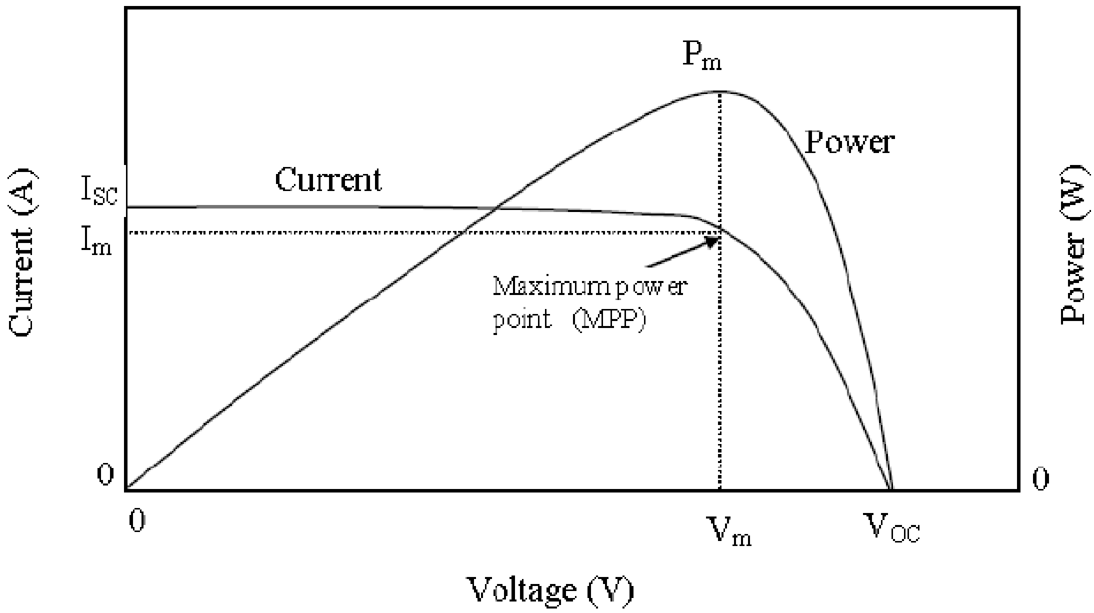

Figure 2.6: V-I curve of a solar panel

2.6 Battery

All Batteries contain voltaic cells , the battery stores energy in an electrochemical form and is the most widely used device for energy storage in a verity of applications . The electrochemical energy is in a semi ordered form , which is in between the electrical and thermal forms . It has a one way conversion efficiency of 85 to 90% .

There are two basic types of electrochemical batteries :

- ✓ The primary battery:

It converts chemical energy into electrical energy, and the electrochemical reaction in this type is non-reversible, and the battery is discarded after a full time use is required.

- ✓ The secondary battery:

It also known as "rechargeable battery". The electrochemical reaction in the secondary battery is reversible. And after a discharge, it can be recharged by injecting a direct current from an external source. This type of battery converts chemical energy into electrical energy in the discharge mode. In the charge mode it converts the electric energy into chemical energy. In both modes a small fraction of energy is converted into heat, which is dissipated to the surrounding medium. The round trip conversion efficiency is between 70 to 80%.

2.6.1 Types of Batteries

There are at least six major rechargeable electro chemistries available today. They are as follows:

- Lead-acid (pb-acid)
- Nickel-cadmium (NiCd)
- Nickel-metal hydride (NiMH)
- Lithium-ion (Li-ion)
- Lithium-polymer (Li-poly)
- Zinc-air

Some construction and operating feature of these electro chemistries are presented in the following sections:

- ✓ NICKEL-CADMIUM :

The NiCd is a matured electrochemistry, in which the positive electrode is made of cadmium and the negative electrode of nickel hydroxide. The two electrodes are separated by Nylon 'TM separators and placed in potassium hydroxide electrolyte in a stainless steel casing. With a sealed cell and half the weight of the conventional Pb-acid, the NiCd battery has been used to power most rechargeable consumer applications. It has longer deep-cycle life and is more temperature tolerant than the Pb-acid battery. However this electrochemistry has a memory effect, which degrades the capacity if not used for long time. Moreover cadmium has recently come under environmental regulatory scrutiny. For these reasons, NiCd is being replaced by NiMH and Li-ion batteries in laptops computers and other similar high-priced consumer electronics.

- ✓ LITHIUM-ION:

The Li-ion technology is a new development, which offers three times the energy density over that of Pb-acid. Such a large improvement in energy density comes from mechanic's law atomic weight of 6.9 vs., 207 for lead. Moreover, Li-ion has a higher cell voltage, 3.5 V vs, 2.0 V for Pb-acid and 1.2 V for other electro chemistries. This requires fewer cell in series for a given battery voltage, thus reducing the manufacturing cost.

- ✓ LITHIUM-POLYMER:

This is a lithium battery with solid polymer electrolytes. It is constructed with a film of metallic lithium bonded to a thin layer of solid polymer electrolyte. The solid polymer enhances the cell's specific energy by acting as both the electrolyte and the separator. Moreover, the metal in solid electrolyte reacts less than it does with a liquid electrolyte.

2.6.2 Performance Characteristics

The basic performance characteristics, which influence the battery design, are as follows:

- Charge/discharge (C/D) voltages.
- C/D ratio.
- Round-trip energy efficiency.
- Charge efficiency.
- Internal impedance.
- Temperature rise.
- Life in number of C/D cycles.

The Specific and energy density of various type of batteries is shown in table 2.1

2.7 Solar Charger Controller

A solar charge controller is needed in virtually all solar power systems that utilize batteries. The job of the solar charge controller is to regulate the power going from the solar panels to the batteries. Overcharging batteries will at the least significantly reduce battery life and at worst damage the batteries to the point that they are unusable**.**

Table2.1 : Specific and energy density of various batteries

Electrochemistry	Specific Energy (Wh/kg)	Energy Density(Wh/I)	Specific POWER(W/kg)	Power Density (W/I)
Lead Acid	30-40	70-75	-200	-400
Nickel-cadmium	40-60	70-100	150-200	220-350
Nickel-metal Hydride	50-65	140-200	-200	450-500
Lithium-ion	90-120	200-250	>500	500-600
lithium-polymer	100-200	150-300	>200	>350
Zinc-air	140-180	200-200	>150	-200

Overcharging batteries will at the least significantly reduce battery life and at worst damage the batteries to the point that they are unusable***.***

2.7.1 Features of Solar Charge Controller

-Protects the battery (12V) from over charging.

- Reduces system maintenance and increases battery lifetime.

-Auto charged indication.

-Reliability is high.

- 10 Amp to 40 Amp of charging current.

-Monitors the reverse current flow.

2.7.2 Types of Solar Charger Controller

1- Shunt Regulator.

2- Series Regulator.

3- PWM Regulator.

4 **-**MPPT Charge Controller.

- ✓ Shunt Regulator

Shunt regulators function by short circuiting the solar array when the battery reaches a set voltage. When the battery voltage drops, the array is un-shorted and current is allowed to flow to the battery again. This is also sometimes referred to as a pulse regulator, since the current can be “pulsed” to the battery as the array current is regulated. As the charge regulation is either on or off, it's simply a single stage charge controller. As the regulator sees the full current from the solar array during regulation, As shown in Figure 2.7. the shunt regulators get hot and are generally only used for small solar arrays. Shunt regulators are generally solid-state and contain a blocking diode and a transistor. The solar array is shorted by a transistor (or relay) and the blocking diode prevents the battery from being shorted at the same time. Shunt regulators are generally for negatively grounded systems only as the block diode is usually in the positive line.

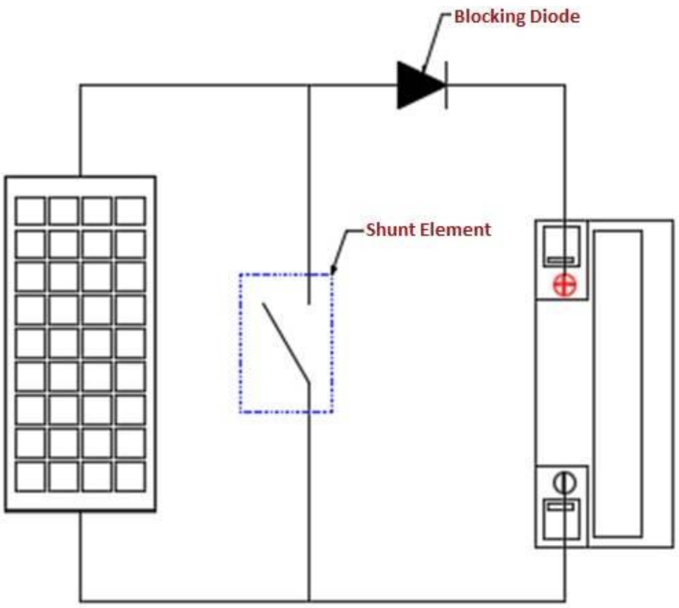

Figure 2.7: Shunt Regulator

- ✓ Series Regulator

Series regulators function by open circuiting the solar array when the battery reaches a set voltage. When the battery voltage drops, the array is reconnected and current is allowed to flow to the battery again.

Series regulators generally use a relay or transistor to connect and disconnect the solar array. As the relay (or transistor) can be placed in either the positive or negative line, Series regulators can be used in positive and negative ground systems. As shown in Figure 2.8.

✓ PWM Regulator

Quite a few charge controls have a "PWM" mode. PWM stands for Pulse Width Modulation. PWM is often used as one method of float charging. Instead of a steady output from the controller, it sends out a series of short charging pulses to the battery - a very rapid "on-off" switch. The controller constantly checks the state of the battery to determine how fast to send pulses, and how long (wide) the pulses will be. In a fully charged battery with no load, it may just "tick" every few seconds and send a short pulse to the battery. In a discharged battery, the pulses would be very long and almost continuous, or the controller may go into "full on" mode. The controller checks the state of charge on the battery between pulses and adjusts itself each time.

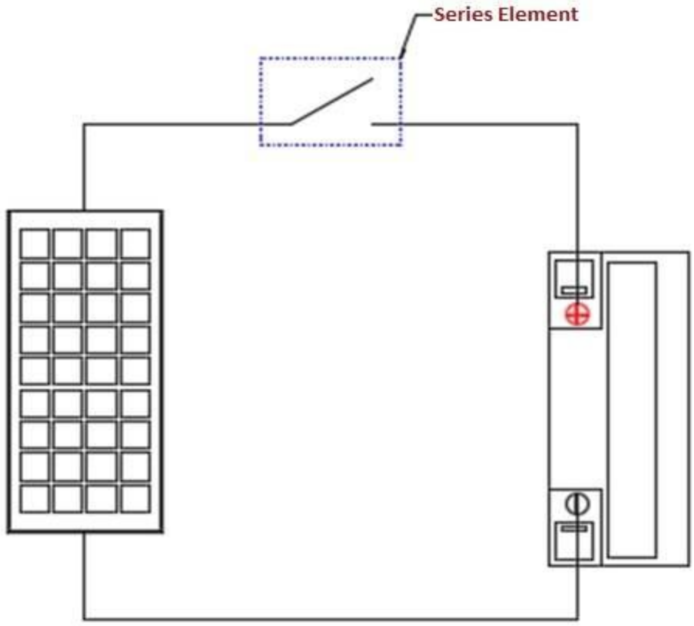

Figure 2.8: Series Regulator

✓ MPPT Charge Control

The Maximum Power Point Tracking (MPPT) charge controller takes the PWM to the next level, by allowing the array voltage to vary from the battery voltage. By varying the array input, the charge controller can find the point at which the solar array produces the maximum power. The MPPT process works like this.

Imagine having a battery that is low, at 12 V. A MPPT takes a voltage of 17.6 volts at 7.4 amps and converts it down, so that what the battery gets is now 10.8 amps at 12 volts. MPPT controllers takes the DC input from the solar panels, convert it to high frequency AC, and then change it once again to a different DC voltage and current. The point is the voltage will exactly adhere to the requirements of the battery. As the MPPT charge controller uses the negative line as a reference and then switches the positive line, they can be used in negative ground systems only. It is crucial to understand that voltage is a potential difference; the ‘difference’ refers to the difference between ground potential and some potential. This means that the starting point is below zero, but this is only used as a reference point. As shown in Figure 2.9

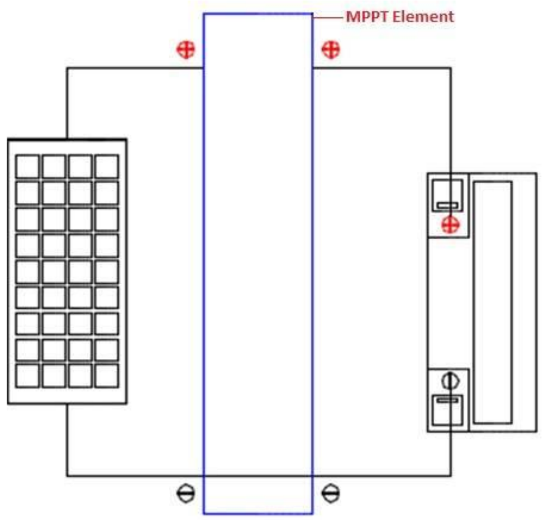

Figure 2.9: MPPT Charger Controller

2.8 Lighting Technologies

lighting is being used more and more in the world and this usage is quite non-homogeneous and has influences on global energy consumption and indirectly, on environment. Therefore, energy saving in lighting, and the methods of achieving this goal should be considered at different levels (state, region, town, enterprise) and by supranational organizations , too .People stay in indoor environment for most of the day, and Characteristics of light in indoor environment are much different than that of natural outdoor environment. On the other hand people do not stop activities after sunset .The artificial lighting has therefore impact on their well-being The needed artificial light has to be provided in energy efficient and environmentally conscious way. It is important to search for the technological solutions which meet human needs with the lowest impact on the environment during operation, when most of the impacts take place. The environmental impacts also include production and disposal of lamps, and related materials.

In the case of new buildings the integration of daylight is important in order to reduce the energy consumption. To summarize, energy savings / efficiency and economics are dependent on:

-Improvement of lighting technologies.

-Making better use of available cost-effective and energy efficient lighting technologies .

-Lighting design (identify needs, avoid misuses, proper interaction of technologies , automatic controls, daylight integration) .

-Building design (daylight integration and architecture) .

-Knowledge dissemination to operators (designers, sellers, decision, makers).

-Reduction of resources by recycling and proper disposal, size reduction, using less aluminum , mercury, etc.

-Life Cycle Cost Assessment LCCA.

2.8.1 Light Sources

Following characteristics are to be considered when choosing a lamp for an application

a. Luminous efficacy

-Luminous flux -Lamp power and ballast losses

b. Lamp life

-Lumen depreciation during burning hours -Mortality

c. Quality of light

-Spectrum -Correlated color temperature (CCT)

-Color rendering index (CRI)

d. Effect of ambient circumstances

-Voltage variations -Ambient temperature

-Switching frequency -Burning position

-Switch-on and prestrike Tim -Vibration

e. Luminaries

-Lamp size, weight and shape -Luminance

-Auxiliaries needed (ballast, starter, etc.)

-Total luminous flux -Directionality of the light, size of the luminous element

f. Purchase and operation costs

-Lamp price

-Lamp life

-Luminous efficacy

-Lamp replacement (relighting) costs

-Electricity price and burning hours are not lamp characteristics, but have an effect on operation costs.

2.8.2 Lamps

- ✓ Incandescent lamp

In incandescent lamp, which is also called General Lighting Service Lamp (GLS), light is produced by leading current through a tungsten wire . The working temperature of tungsten filaments in incandescent lamps is about 2700 K. Therefore the main emission occurs in the infrared region. The typical luminous efficacy of different types of incandescent lamps is in the range between 5 and15 lm/W. Figure 2.10 show the main types of lamps.

- ✓ High Intensity Discharge lamps (High Pressure)

Without any temperature limitations (e.g. melting point of tungsten) it is possible to use gas discharges (plasmas) to generate optical radiation. Unlike thermal solid sources with continuous spectral emission, radiation from the gas discharge occurs predominantly in form of single spectral lines.

These lines may be used directly or after spectral conversion by phosphors for emission of light. Discharge lamps generate light of different color quality, according to how the spectral lines are distributed in the visible range. To prevent runaway current and ensure stable operation from a constant voltage supply, the negative current-voltage characteristics of gas discharge lamps must be counterbalanced by a circuit element such as conventional magnetic or electronic ballasts. In all cases, higher voltages are needed for igniting the discharge.

The power conversion per unit volume in high pressure arc discharge lamps is 100 to 1000 times higher than that of low pressure lamps, which leads to considerable thermal loadings on the discharge tube walls. The wall temperatures may be in the region of 1000°C. The discharge tubes are typically made of quartz or PCA (polycrystalline sintered alumina: Al2O3). The arc discharge is provided with electrical power via tungsten pin electrodes. In most cases the main constituent of the plasma is mercury. To reach operating pressures of 1-10 bars, the vaporization of filling materials requires a warm-up time of up to 5 minutes after ignition. For starting high pressure lamps (except mercury lamps) superimposed pulses of some kVs from external ignition circuits or internal ferroelectric capacitors are used. An immediate re-start after short power break demands voltages of more than 20 kV. Many types of high pressure discharge lamps can’t be dimmed, others only in a power range of 50% to 100%.

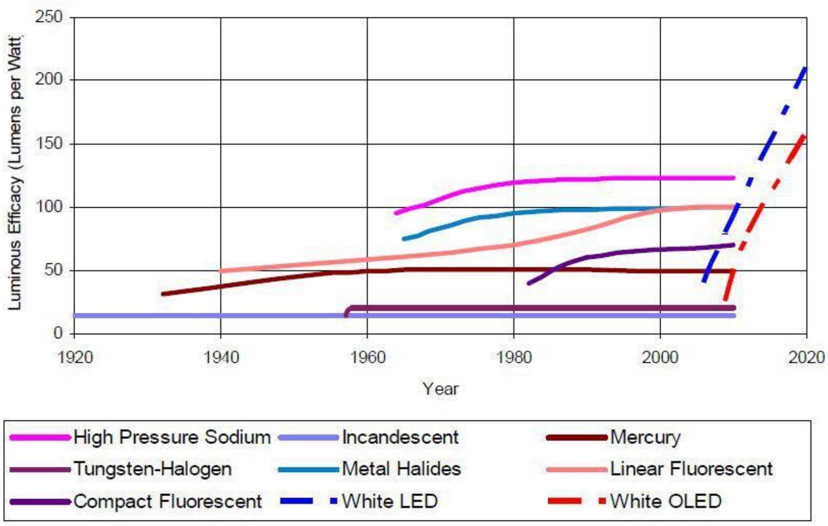

Figure 2.10: Main Types of Lamps

✓ High pressure sodium lamps

In a high pressure sodium lamp light is produced by sodium vapor, the gas pressure being about 15 KPa . The golden-yellowish emission spectrum applies to wide parts of the visible area. The CRI is low (≈ 20), but the luminous efficacy is high. The most common application today is in street and road lighting. Luminous efficacy of the lamps is 80-100 lm/W, and lamp life is 12 000 h (16 000 h). The CCT is 2000 K.

An improvement of the CRI is possible by pulse operation or elevated pressure but this reduces the luminous efficacy. Color improved high pressure sodium lamps have CRI of about 65 and white high pressure sodium lamps of more than 80. Their CCT is 2200 and 2700, respectively.

- Advantages of high pressure sodium lamp

- Very good luminous efficacy.
- Long lamp life (12 000 h or 16 000 h).
- High luminous flux from one unit for street and area lighting.

✓ Light-emitting diodes (LEDs)

Solid-state lighting (SSL) is commonly referring to lighting with light-emitting diodes (LED), organic light-emitting diodes (OLED) and light-emitting polymers (LEP). At the moment there is still no official definition for solid-state lighting, the expression “solid-state” refers to the semiconductor crystal where charge carriers (electrons and holes) are flowing and originate photons (i.e., light) after radiative recombination's

The history of commercially available LEDs started in the early 1960`s with the first red LED with peak emission at 650 nm (Holon yak, Bevacqua 1962). The semiconductor material utilized was GAASP (Gallium Arsenide Phosphate).

Advantages of LEDs:

- Small size (heat sink can be large).
- Physically robust.
- Long lifetime expectancy (with proper thermal management).
- Switching has no effect on life, very short rise time.

- Contains no mercury.
- Excellent low ambient temperature operation.
- High luminous efficacy (LEDs are developing fast and their range of luminous efficacies is wide).
- New luminaries design possibilities.
- Possibility to change colors.
- No optical heat on radiation.

Disadvantages of LEDs:

- High price.
- Low luminous flux / package.
- CRI can be low.
- Risk of glare due to high output with small lamp size.
- Need for thermal management.
- Lack of standardization

CHAPTER THREE

METHODS AND SYSTEM COMPONENTS

3.1 System description

This project shows a design of street lighting system powered by solar energy and using led technique with control system to achieve energy saving and also disposal of incandescent lamps. The block diagram shown in Figure 3.1 describes sequence of system control operations and explains the process. The solar panel charge the battery during daytime and when night time begins Arduino receive signals from LDR sensor and makes the light irradiates 20% of light intensity and when PIR sensor detect any motion in the range it send a signal to arduino to increase light intensity.

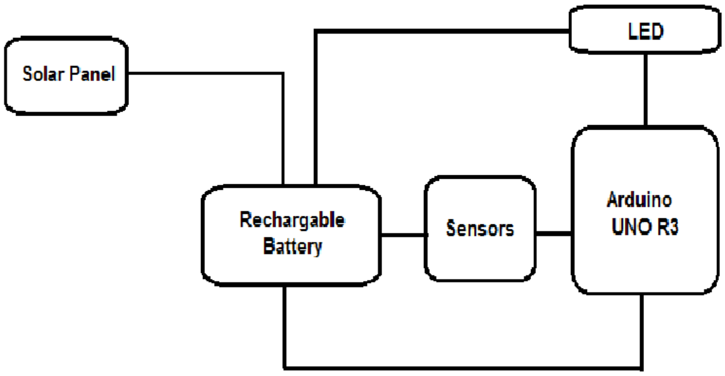

Figure 3.1: System block diagram

3.2 System Hardware

The hardware equipment's of system are:

- ✓ Solar panel
- ✓ Battery
- ✓ Battery charger
- ✓ Diode
- ✓ Arduino UNO R3

- ✓ PIR sensor
- ✓ LDR sensor
- ✓ LEDs

3.2.1 Solar panel

As the name implies, these are cells that are grown from a single crystal. The Mono crystalline solar PV panel is more efficient than polycrystalline panel. Efficiency is about 18%. High Efficient Mono crystalline solar panel generates electricity during day time and it is stored in battery. In figure 3.2 the panel provides 8 w, in the designed system we used two panels and connecting them in series to provide the desired power to operate the system.

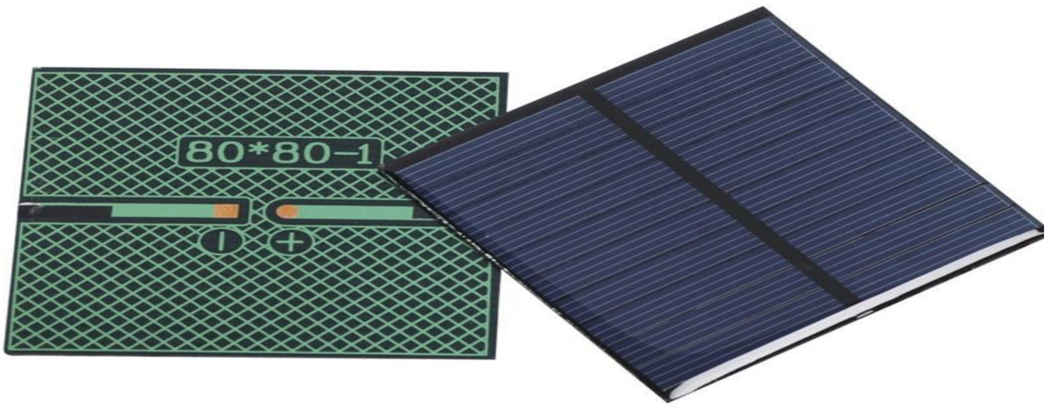

Figure 3.2: Mini solar panel 5V 160mA

3.2.2 Battery

Solar electric plants shall be understood to be photovoltaic energy converters that are able to self-sufficiently satisfy a mean energy demand over a significant period of time, be it an appliance that is permanently hooked up or just for sporadic power supply of appliances. Such plants have in common that their input and output quantities fluctuate widely. They can therefore only be dimensioned on the basis of a mean value and are not able to satisfy this demand without the possibility to store energy.

The battery is made of numerous electrochemical cells connected in a series–parallel combination to obtain the desired battery voltage and current. The higher the battery voltage, the higher the number of cells required in series.

The battery rating is stated in terms of the average voltage during discharge and the ampere-hour capacity it can deliver before the voltage drops below the specified limit. The product of the voltage and ampere-hour forms the watt-hour (Wh) energy rating the battery can deliver to a load from the fully charged condition. The battery charge and discharge rates are stated in units of its capacity in Ah. For example, charging a 100-Ah battery at *C*/10 rate means charging at 100/10 = 10 A. Discharging that battery at *C*/2 rate means drawing 100/2 = 50 A, at which rate the battery will be fully discharged in 2 h. The state of charge (*SOC*) of the battery at any time is defined as shown in equation 3.1 bellow:

$$SOC = \frac{\text{Ah capacity remaining in the battery}}{\text{Rated Ah capacity}} \qquad (3.1)$$

3.2.3 Battery Charger

A solar panel can produce a range of charging voltages depending upon sunlight intensity, so a voltage regulator must be included in the charging circuit so as to not over-charge (overvoltage) a device such as a 12-volt car battery. As shown in Figure 3.3

3.2.4 Diode

A *diode* is an electronics component made from a combination of a P-type and N-type semiconductor material, known as a p-n junction, with leads attached to the two ends. These leads allow you to easily incorporate the diode into your electronic circuits.

The lead attached to the n-type semiconductor is called the cathode. As shown in figure 3.4 bellow thus, the cathode is the negative side of the diode and the positive side of the diode is called the anode. When a voltage source is connected to a diode such that the positive side of the voltage source is on the anode and the negative side is on the cathode,

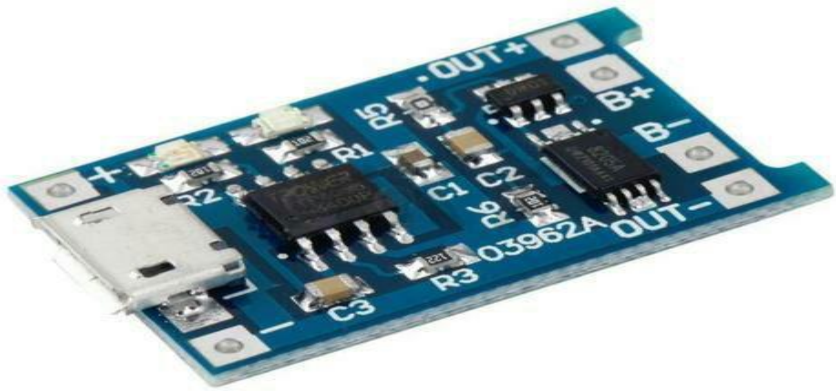

Figure 3.3: Battery charger

the diode becomes a conductor and allows current to flow. Voltage connected to the diode in this direction is called forward bias. But if you reverse the voltage direction, applying the positive side to the cathode and the negative side to the anode, current doesn’t flow. In effect, the diode becomes an insulator. Voltage connected to the diode in this direction is called reverse bias.

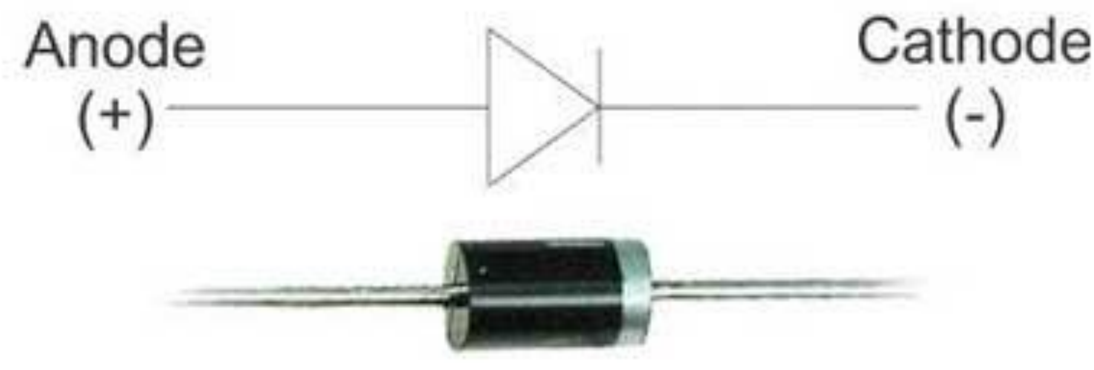

Figure 3.4: Diode

3.2.5 Arduino UNO R3

Arduino Uno has been selected as the controller for this system due to its low cost, compact size, compatibility, easy interfacing over several other type of controller including Programmable Integrated Circuit (PIC), Programmable Logic Controller (PLC) and others. Arduino is an open-source hardware kit with 8-bit Atmel AVR pre-programmed on-board microcontroller kit. It comes with boot loader which uploads programs into microcontroller memory. figure 3.5 bellow represent Arduino uno board.

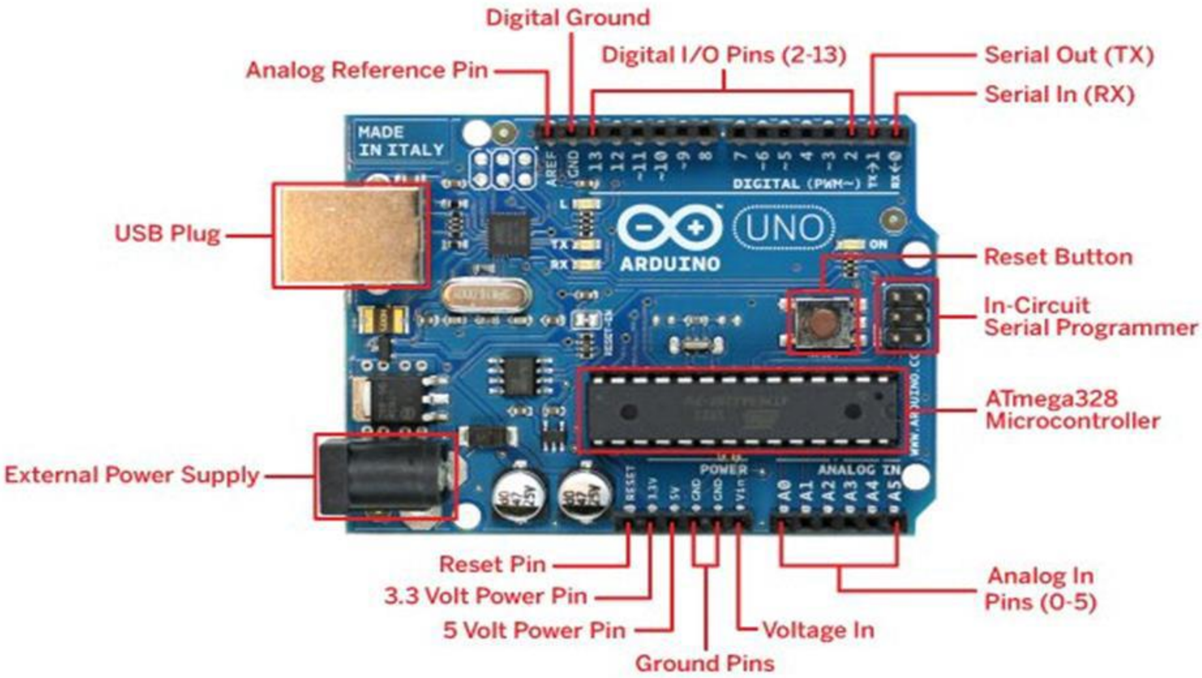

Figure 3.5: Arduino UNO board

3.2.6 PIR sensor

A passive infrared sensor is an electronic sensor that measures infrared (IR) light radiating from objects in its field of view.

The IR sensor itself is housed in a hermetically sealed metal can to improve noise/temperature/humidity immunity. There is a window made of IR-trans missive material (typically coated silicon since that is very easy to come by) that protects the sensing element. Behind the window are the two balanced sensors as shown in figure 3.6 bellow:

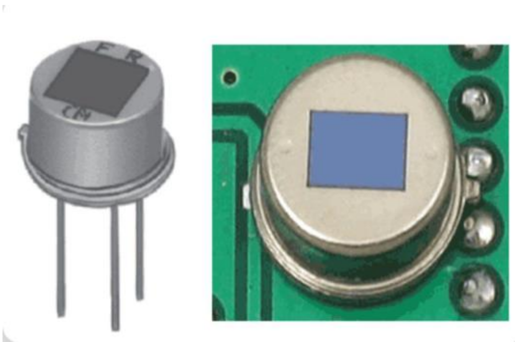

Figure 3.6: cover of sensor

The PIR sensor itself has two slots in it, each slot is made of a special material that is sensitive to IR. The lens used here is not really doing much and so we see that the two slots can 'see' out past some distance (basically the sensitivity of the sensor). When the sensor is idle, both slots detect the same amount of IR, the ambient amount radiated from the room or walls or outdoors. When a warm body like a human or animal passes by, it first intercepts one half of the PIR sensor, which causes a positive differential change between the two halves. When the warm body leaves the sensing area, the reverse happens, whereby the sensor generates a negative differential change. These change pulses are what is detected.

PIR modules have a 3-pin connection at the side or bottom. One pin will be ground, another will be signal and the final one will be power. Power is usually 3-5VDC input but may be as high as 12V. and figure 3.7 bellow represent the PIR shape with its three pins.

When the sensor detects a body that sends a signal to arduino and the lamp turns on 100% and when there is no object, the light is 20%.

Figure 3.7: PIR sensor

3.2.7 LDR sensor

Light dependent resistor is also known as photo resistor, photocell, photo conductor. It is a one type of resistor whose resistance varies depending on the amount of light falling on its surface. Figure 3.8 bellow shown the LDR construction . In the dark, their resistance is very high, sometimes up to 1MΩ, but when the LDR sensor is exposed to light, the resistance drops dramatically, even down to a few ohms, depending on the light intensity. LDRs have a sensitivity that varies with the wavelength of the light applied and are nonlinear devices. LDR is made of a high resistance semiconductor. If incident light on a photo resistor exceeds a certain frequency, photons absorbed by the semiconductor give bound electrons enough energy to jump into the conduction band. The resulting free electrons conduct electricity, thereby lowering resistance.

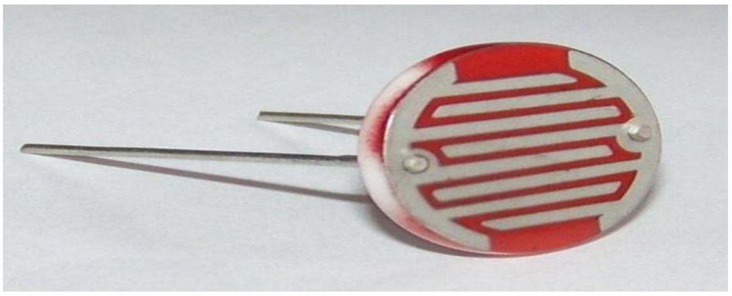

Figure 3.8: LDR sensor

3.2.8 LEDs

LED lighting is also called solid-state lighting, because the light is emitted from a semiconductor material rather than from a vacuum or gas tube as shown in figure 3.9 bellow. LED technology has existed since the 1960s. The early LED technology application was for indicator lights, which had efficacy of only 0.01 lumen/watt. Recently, LEDs are used in multitude of applications and are available in several colors and packages. LEDs for street lighting applications package a number of LED chips onto a coated printed circuit board and enclose them in housing suitable for the outdoor environment. Lamp performance is measured by a variety of metrics, but the most significant metric is lamp efficacy (lumens generated per watt of energy consumed).

Figure 3.9: LED

Table 3.1: The performance of LED lamp against high-pressure sodium and mercury vapor lamp.

Parameters	**Type of Lamp**		
	LED lamp	*High pressure sodium lamp*	*Mercury vapor lamp*
Flux (lm)	3,325	5,510	4,340
Power Consumption (W)	67	90	138
System Efficacy (lm/W)	50	61	31
Average Lux	14	19	14
Utilization Factor	0.0042	0.0034	0.0032
Lux/W	0.21	0.21	0.10
Min/Avg Lux Ratio	0.40	0.32	0.23
Lifetime (hours)	60,000	20,000 - 30,000	6,000 – 10,000

3.3 System Software

The microcontroller required a program to operate and execute the process associated with the proposed design. Arduino programming has been used to construct the program which much easy, user friendly, simple to understand and a person knowing only C language can also program. In this software development, sensors are integrated and the decision for every sensor will determine the process or operation of the system. It starts with analyzing the dark sensor and followed by the motion sensor and charge controller. The system is start by determine the level of surrounding light, Day light and night have been set as two surrounding light level. During the day light as sufficient light falls on light sensor, LED light is switch off. During the night time the light start to operate with other sub conditions. If there is no motion detected then lamp will ON with 20% of its maximum intensity. And after detecting the motion, light bright up 100% intensity. Or the system can be programmed in such a way that light will be ON with 100% of intensity from dusk to preset time up to 11 p.m. or 12 p.m. and after this system depends on motion sensor. At the time of dawn/morning output of the light sensor can be used to turn off the light. In such way system can be programmed for efficient and optimum utilization of energy.

3.3.1 System Flow Chart

The complete flowchart which indicates the whole operation of the system and controlled by two modes is as shown in Figure 3.10.

These modes are controlled by two sensors which are LDR and PIR sensor. The focus of this project is only a one-way road at a junction and it will detect any movement either vehicle or pedestrian. Firstly, Mode 1 will be selected when LDR detect day or night. If it senses night, automatically the street lights at the junction of the road (L1, L2, L3 and L4) and all PIR sensors will be switched on. Next, Mode 2 will take over when each PIR sensor at any point senses the motion or any movement of the vehicle within specified range. Arduino microcontroller will switch on the street lights at the edge of the road. The street lights will turn on until the PIR sensor does not sense any movement within specified time, therefore street lights will be turned at 20% of the light. When LDR sensor senses the intensity of light from the sun, the system will turn off both street lights and PIR sensor. Lastly, the system will loop to the initial condition.

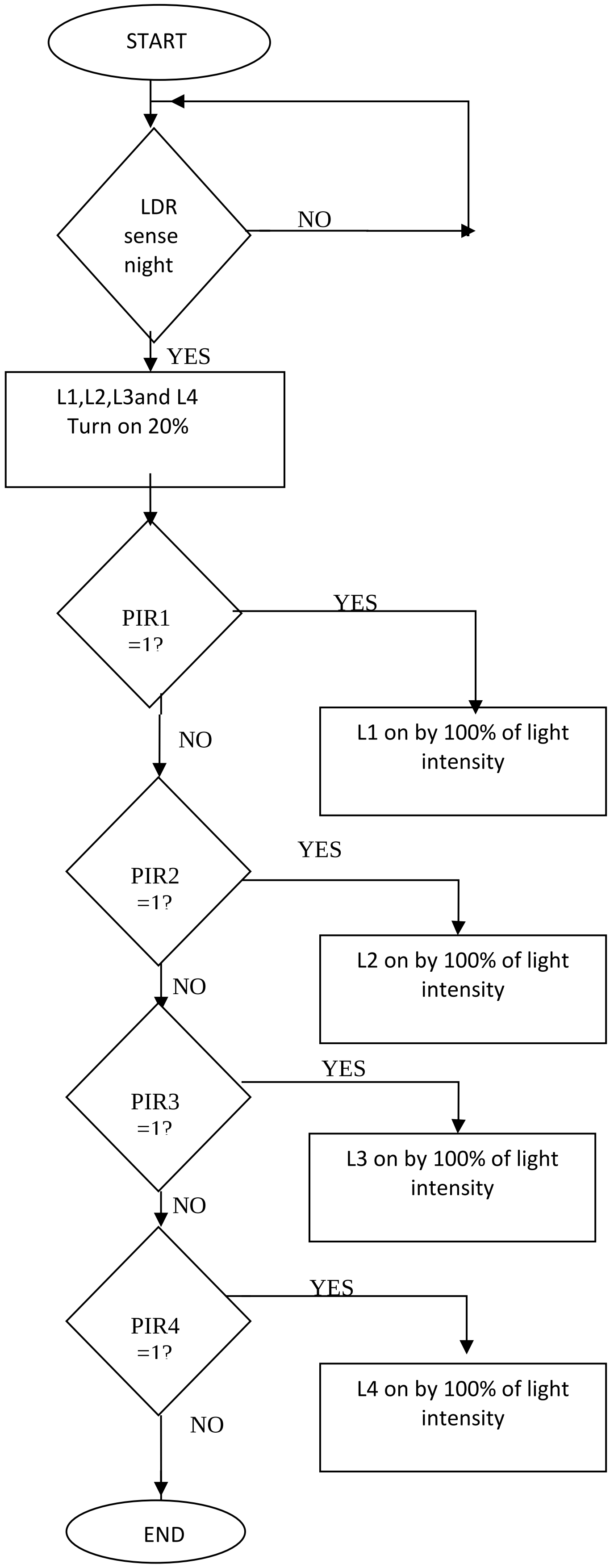

Figure 3.10: system flow chart

3.3.2 System Schematic diagram

The complete schematic diagram of proposed design system is as shown in Figure 3.11.

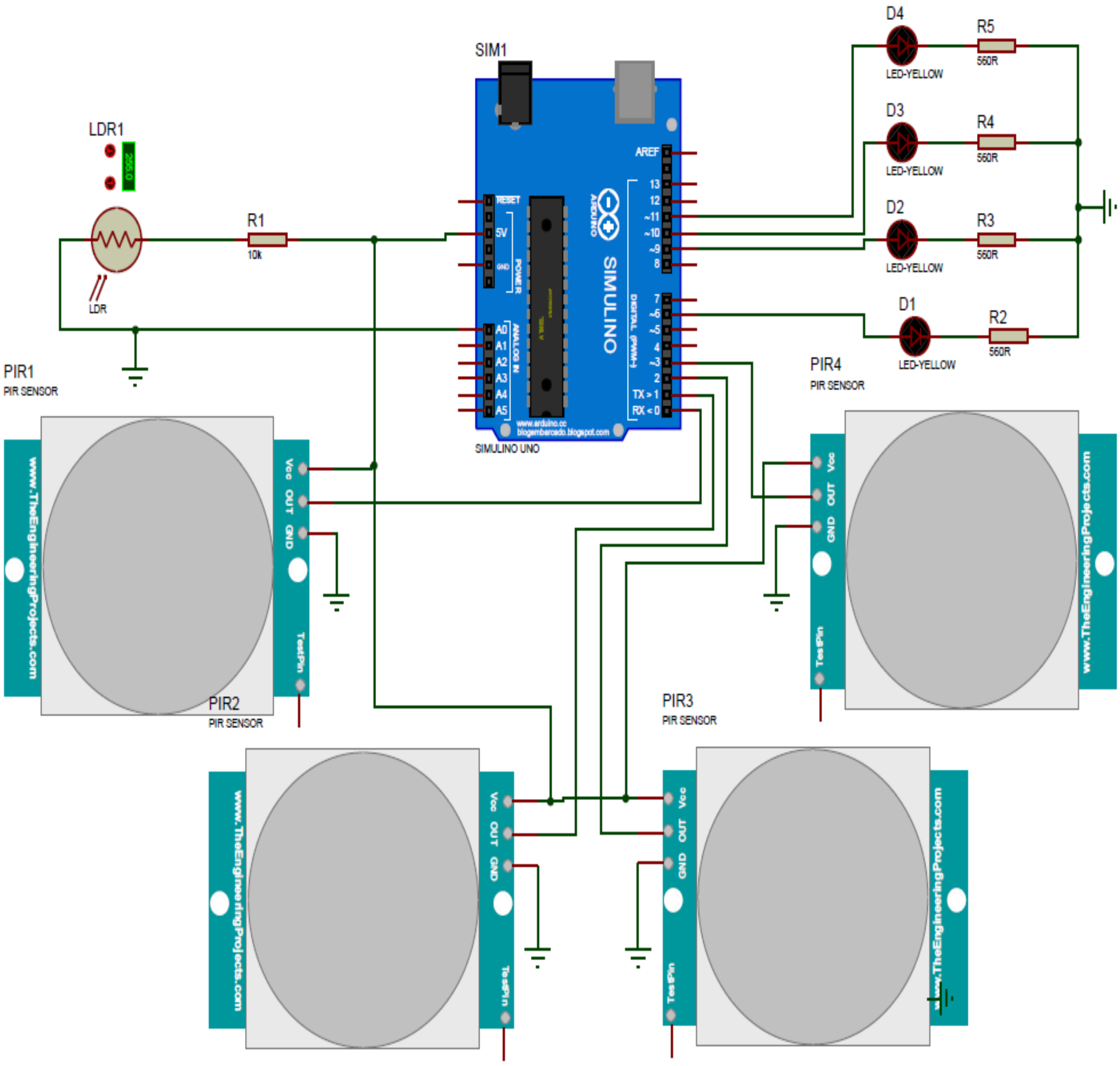

Figure 3.11: system schematic diagram

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 System Fabrication

Depending on the form of performance required for the system It had been consist from main part include lamp pole, solar panel, diode, battery charger and batteries. The control part which configured from Arduino board which has been selected as the controller for this system due to its low cost, compact size, compatibility, easy interfacing over several other type of controller. Two types of sensor used in this system as input devices which are Light Dependent Resistor (LDR) and Passive Infrared (PIR) sensor.

4.1.1 Main Part

The main part of the model as shown in figure 4.1 bellow consist of the following materials:

- ✓ Base support made of wood has length of (150cm) and width of (20cm).
- ✓ lamp pole made of wood has length of(30cm), width of (3cm) and distance between lamp poles is (20cm).
- ✓ LEDs.
- ✓ Solar Panel
- ✓ Battery and battery charger
- ✓ Diode

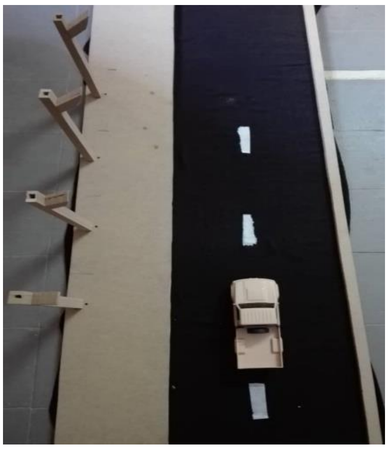

Figure4.1: Main shape of the design

4.1.2 System Control Part

The control circuit consist of Arduino UNO, PIR sensor and LDR sensor.LDR is connected as an Analog input which sense the light intensity here LDR connect to Arduino through pin A0 as shown in figure4.2 bellow:

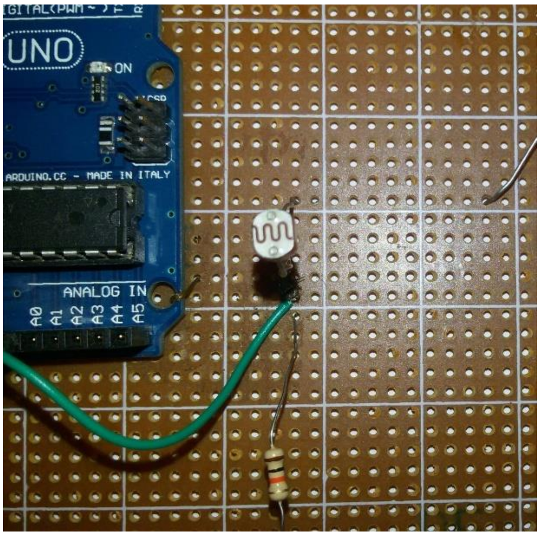

Figure 4.2: Connecting LDR with Arduino

PIR is connected with Arduino in three pins first to pin0 it represents the output of the PIR sensor which is an input for Arduino, the second pin is ground (GND) and the third is connected to 5v pin As shown in figure4.3 bellow:

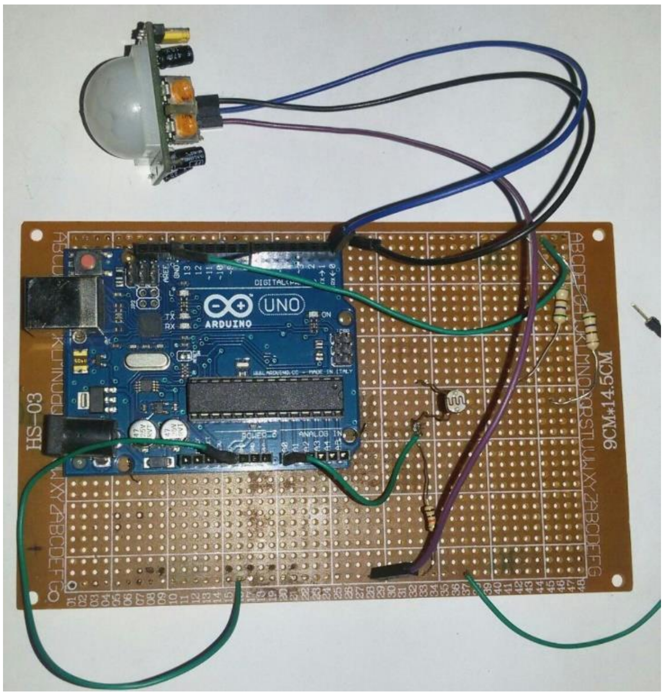

Figure 4.3 Connecting PIR and LDR with Arduino

4.1.3 Electrical System Connections

-Two solar cells each cell provides 5v and after connecting in series it provides about 10 v As shown in figure4.4 bellow:

Figure 4.4: Connecting solar cells in series

-The produced power charge the battery through the battery charger figure 4.5 bellow:

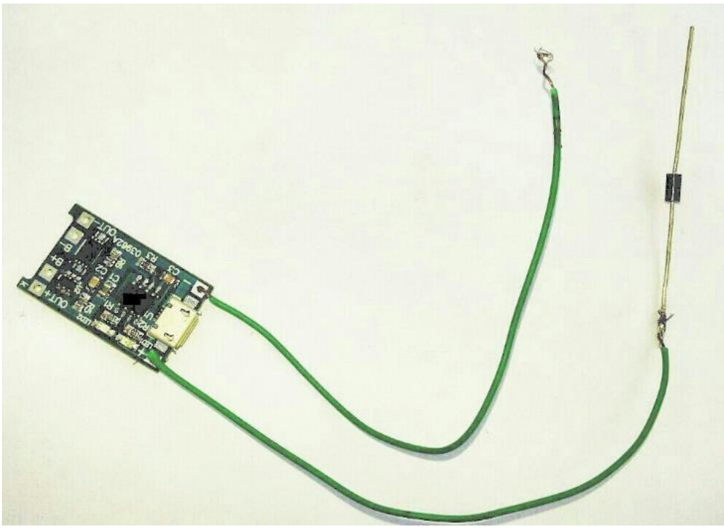

Figure 4.5: Connecting battery charger with diode

- then solar cell connected to battery charger as shown in figure 4.6.

- The battery used here was 3.7v each and after connecting three batteries together in series as shown in figure 4.7 bellow and it became 11v approximately.

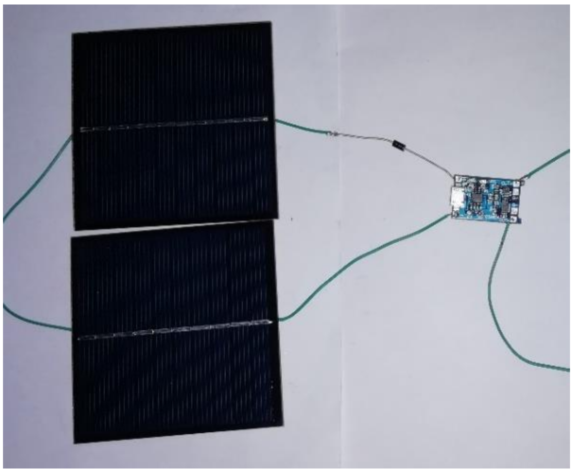

Figure 4.6: Connecting solar cells with battery charger

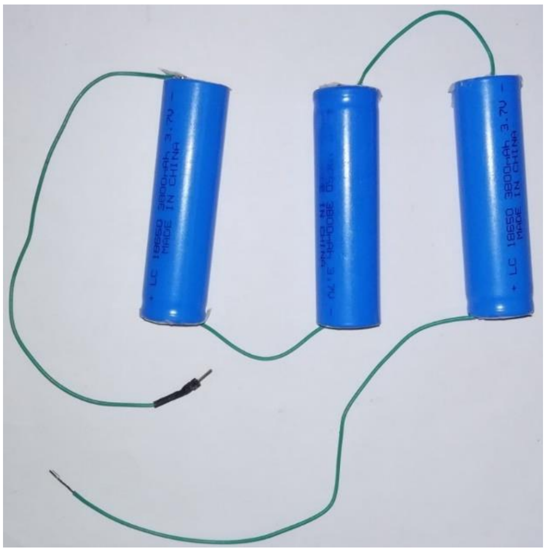

Figure 4.7: Connecting batteries in series

- Now all the charging components is representing as charging circuit for the batteries as shown figure 4.8 bellow:

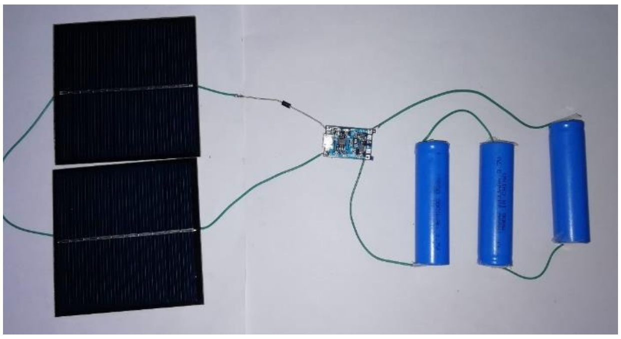

Figure 4.8: Connection of all charging circuit components

- The figure 4.9 below shows all hardware connection of the system.

Figure 4.9: The final design

4.2 System Component Cost

Table 4.1 bellow represent the cost of the system devices which provided as local market prices.

Table 4.1: Cost of the materials

ITEM	COST
Solar Panel 150w(SDG)	3750
Led 80w (SDG)	3500
Battery 100A, 12v(SDG)	4765
LDR (light sensor)(SDG)	120
Motion sensor(SDG)	150
Charge controller(SDG)	6000
Total (SDG/unit)	18285
Total for 100 unit(SDG)	1828500

4.3 Energy Utilization

For this street lighting automation system, the system had been powered by solar energy, so that we don’t need any power from the main network. Table 4.2 below shows comparison of power consumption and finance for two different street lighting systems.

Table 4.2: power saving and calculation

ITEM	Solar Street lightning by using LED lamp	Street lightning by using HIP lamp
Lightening power per lamp (w)	80	250
Total power consumed per hour (kwh)	26.8	83.75
Power saving per day (kwh)	683.4	0
Monthly energy charges(SDG/month)	0	15678
Yearly total energy savings (kwh/year)	246024	0
Yearly total energy savings (SDG/year)	188136	0
Life time energy saving (SDG)	3762720	0

$$\text{Energy payback period (EPP)} = \frac{\text{Energy consumed per solar street light (KW)}}{\text{Energy saved by solar street light per year (kw)}} \quad \ldots(4.1)$$

$$= \frac{417600\text{k}}{308188.8\text{K}} = 1.3 \text{ year}$$

Using high intensity discharge (HID)

Total power consumed by 1 HID = 250W

Number of nodes = 100

Number of working hours per day = 12

Power consumed per day = 12 x 100 x 250

= 300 kWh

= 300 units

300 x 30 = 9000 units per month = 9000 kWh/month

-Using LED (for street lighting automation system)

Total power consumed by 1 LED = 80w

Number of nodes = 100

(Fully light on for 6 hours- Assume: 06:00 p.m. – 12:00 a.m. (heavy traffic))

Number of nodes = 100

(Fully light on when sensor detect Movement for 3 hours (within 30 minutes vehicles pass through)-12:00 a.m. – 06:00 a.m.)

-Number of working hours per day:

Assume: 6.00 p.m. – 12.00 a.m. (heavy traffic)

= 6 hours

: 12.00 a.m. – 6.00 a.m.

= 3 hours (within 30 minutes vehicles pass

Through)

Total: 9 hours

Power consumed per day = (100 x 9) x 80

=72 kWh

= 72 units

72 x 30 = 2160 units per month = 2160 kWh/month

Energy saved between LED for automation system with HID for public street lighting:

9000– 2160 = 6840 kWh/month

(6840/9000) *100% = 76%

Calculation for energy saving has been utilized using High Intensity Discharge (HID) lamps and Light Emitting Diode (LED) with auto intensity control. From this calculation, the comparison in term of energy efficiency is obtained between High Intensity Discharge(HID) type of lamps which is commonly used in public street lighting with Light Emitting Diode (LED) for automation system which operate according traffic flow by sensing the movement within certain time.

Meanwhile, for the street lighting automation system, the assumption is made, whereby within 7.00 p.m. until 1.00 a.m. which is heavy traffic during the night, the system will turn on by full of light intensity for 6 hours. During midnight, at 1.00 a.m. until 7.00 a.m., assumed that every 30 minutes, there are vehicles used the road within each 1 hour since fewer people used the road during midnight.

From this calculation, comparison of the energy saved between HPS lamps and LED lamp is obtained. 72 % of energy can be saved when compared LED for street lighting automation system with HID. The difference value between usages of HID lamps quite high compared than the usage of LED. Consequently, usage of LED gives more energy saving compared than High Intensity Discharge (HID) lamps.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The smart solar powered LED street lights with auto intensity control is a cost effective, practical, eco-friendly and the safest way to save energy. It clearly tackles the two problems that world is facing today, saving of energy and also disposal of incandescent lamps, very efficiently. According the estimated data around 76% of power consumption can be reduced by using this system as compared with existing high intensity discharge streetlights.

The solar smart street light prototype had successfully been constructed by arduino UNO, LDR to sense light intensity of the atmosphere and PIR to sense movement and achieved its functionality; control circuit for the system had been simulated using Proteus software program. The economic study of the proposed system had been included. With the advances in technology and good re-source planning the cost of the project can be cut down.

5.2 Recommendations

After studying this project carefully we recommended:

- Study the ability of using ultra capacitors instead of batteries
- Using software programs as DIALux for street lighting design
- Increase PV system efficiency by using sun trackers.
- Connect the PV system to the electrical grid to benefit from surplus power generated by selling it or improving the electrical grid.

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APPENDIXES

APPENDIX A

Lamp Type And Their typical Characteristics

Lamp type	Characteristics							
	Luminous efficacy (lm/W)	Lamp life h	Dimming control	Re-strike time	CRI	Cost of installation	Cost of operation	Applications
GLS	5-15	1000	excellent	prompt	very good	low	very high	general lighting
Tungsten halogen	12-35	2000-4000	excellent	prompt	very good	low	high	general lighting
Mercury vapour	40-60	12000	not possible	2-5 min	poor to good	moderate	moderate	outdoor lighting
CFL	40-65	6000-12000	with special lamps	prompt	good	low	low	general lighting
Fluorescent lamp	50-100	10000-16000	good	prompt	good	low	low	general lighting
Induction lamp	60-80	60000-100000	not possible	prompt	good	high	low	places where access for maintenance is difficult
Metal halide	50-100	6000-12000	possible but not practical	5-10 min	good	high	low	shopping malls, commercial buildings
High pressure sodium (standard)	80-100	12000-16000	possible but not practical	2-5 min	fair	high	low	Outdoor, streets lighting, warehouse
High pressure sodium (colour improved)	40-60	6000-10000	possible but not practical	2-6 min	good	high	low	outdoor, commercial interior lighting
LEDs	20-120	20000-100000	excellent	prompt	good	high	low	all in near future

APPENDIX B

Arduino Microcontroller Code for Smart Solar Streets Light System

```
int led1 =6;
int led2 =9;
int led3 =10;
int led4 =11;
int ldr =A0 ;
int i;
int j;
int pir1=2;
int pir2=3;
int pir3=4;
int pir4=7;
int x1;  int x2; int x3;  int x4;
void setup() {
pinMode(pir1,INPUT);
pinMode(pir2,INPUT);
pinMode(pir3,INPUT);
pinMode(pir4,INPUT);
pinMode(led1,OUTPUT);
pinMode(led2,OUTPUT);
pinMode(led3,OUTPUT);
pinMode(led4,OUTPUT);
pinMode(ldr,INPUT);
Serial.begin(9600);
}
void loop() {
i=analogRead(ldr);
```

```
  x1=digitalRead(pir1);
  x2=digitalRead(pir2);
  x3=digitalRead(pir3);
  x4=digitalRead(pir4);
  if(i<=240)
{ analogWrite(led1,0);
analogWrite(led2,0);
analogWrite(led3,0);
analogWrite(led4,0);
  }
  else if(i>=250) {
   if(x1==1)
analogWrite(led1,255);
   else
analogWrite(led1,50);
  if(x2==1)
analogWrite(led2,255);
   else
analogWrite(led2,50);
   if(x3==1)
analogWrite(led3,255);
   else
analogWrite(led3,50);
   if(x4==1)
analogWrite(led4,255);
   else
analogWrite(led4,50);
}
}
```