HARDWARE IMPLEMENTATION AND DESIGN OF PV OFF- GRID FOR SMART STREET LIGHTING SYSTEM

Dissertation Submitted in partial fulfillment of the requirement for the award of the degree of

MASTER OF ENGINEERING

IN

POWER SYSTEMS

Submitted By:

Satwinder Singh

Regd. No. 801241020

Under the supervision of:

Mrs. Suman Bhullar

Assistant Professor, EIED

ELECTRICAL AND INSTRUMENTATION ENGINEERING DEPARTMENT,

THAPAR UNIVERSITY

PATIALA (PUNJAB) -147004

July-2014

CERTIFICATE

I hereby certify that the work which is being presented in the dissertation entitled **"Hardware Implementation and Design of PV off-Grid for Smart Street Lighting system"** in partial fulfillment of requirement for the award of the master degree in Power Systems submitted in the Electrical and Instrumentation Engineering Department, Thapar University, Patiala is an authentic record of my own work carried under the guidance of **Mrs. Suman Bhullar**, (Assistant Professor EIED, Thapar University, Patiala).

The matter presented in this dissertation has not been submitted for the award of any other degree of this or any other university.

Date -15-7-14

Satwinder Singh

(Satwinder Singh)

801241020

This is to certify that the above statement made by the candidate is correct and true of the best of my knowledge & belief.

Bhullar 15/7/14

(Mrs. Suman Bhullar)

Assistant Professor

Electrical & Instrumentation Engg. Department

Thapar University, Patiala

Countersigned by:

(Dr. RAVINDER AGGARWAL)

Professor & Head

Electrical & Instrumentation Engg. Department

Thapar University, Patiala

(Dr. S.K. MOHAPATRA)

Sr. Professor & Dean (Academic Affairs)

Thapar University, Patiala

ACKNOWLEDGEMENT

I would like to thank Thapar University for giving me the opportunity to use their resources & work in a challenging environment.

First and foremost, I take this opportunity to express my deepest sense of gratitude to my guide **Mrs. Suman Bhullar**, Assistant Professor, Thapar University, Patiala for her able guidance during my Dissertation. This dissertation would not have been possible without her help and the valuable time that she has given me amidst of her busy schedule.

I would like to express my deepest sense of gratitude toward **Dr. Ravinder Aggarwal,** Professor and Head, **Ms. Manbir Kaur,** Associate Professor (P. G. Coordinator), EIED, Thapar University, Patiala who has been a constant source of inspiration for me throughout this Dissertation.

I would also like to extend my gratitude towards **Dr. Santosh Sonar,** Assistant Professor, Thapar University, Patiala for his guidance and support throughout my dissertation work.

I would also like to extend my gratitude to my parents, friends and senior students of department who have always encouraged and supported me in doing my work.

Last but not the least I would like to thank to all the staff members of the Department of Electrical & Instrumentation Engineering, who have been very cooperative with me.

Satwinder Singh

SATWINDER SINGH

Regd. No. 801241020

ABSTRACT

Street light is a raised source of light that is commonly used along walkways and streets when the surrounding turns dark. By using the latest technology light emitting diode, the control of light intensity is possible by using sensors which can detect the movement of vehicles. As the vehicles move forward, the light intensity goes on increasing for a few seconds and as it passes away the intensity decreases. LED lamps have several advantages. For a fixed input power it provides more lumen and less Co_2 compared to conventional lamps like CFL, Fluorescent, tungsten etc. By using the auto switching system, we can also control power consumption at the streets and eliminating manpower. The production and use of photo-voltaic cell to generate electricity are an increasingly popular resource solution globally. The focus of proposed work is to make the most efficient use of the energy received from the sun to power street lights. Solar energy is collected with the aid of solar panel and battery is charged during day time and this energy is used for power street lights during night. In addition, if a solar tracker system is used we can attain maximum energy from the sun.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

LED	Light Emitting Diode
PV	Photovoltaic
HID	High Intensity Discharge
l m	Lumens
GPRS	General Packet Radio Service
SSL	Smart Street Lighting
PCS	Power Conditioning System
WSN	Wireless Sensor Network
PWM	Pulse Width Modulation
GSM	Global System for Mobile
ISL	Intelligent Street Lighting
PLC	Pulse Logic Controller
CFL	Compact fluorescent light
LDR	Light Dependent Resistor
EMR	Electromagnetic Radiation
CRI	Colour Rendering Index
IR	Infrared
NC	Normally Closed
NO	Normally Open
SPST	Single Pole Single Throw
GND	Ground
CTRL	Control
THR	Threshold
DIS	Discharge
HPS	High Pressure Sodium
LPS	Low Pressure Sodium
MH	Metal Halide
nm	Nanometer

LIST OF FLOW CHART

LIST OF GRAPHS

Chapter 1

INTRODUCTION

1.1 OVERVIEW

An electric light is a converter which produces light energy when electric current passes through it. The main purpose of road lighting is to make people, vehicles and objects on the road visible. In engineering field green issue has been raised where many researchers and engineers are involving themselves to find the techniques to reduce energy consumption, environment friendly equipment and to increase product efficiency. The best method is the smart system when it is applied in industrial, residential and commercial areas etc. Smart system is an autonomous operation which detects the change in environment with the help of sensors and act to correct the offset cause of the environment. The systems perform continually to reach the optimal solution. The main advantage of the street light is the extension of human life quality for the dark period of the day. Life quality comprises the crime prevention, traffic safety on road, aesthetic impact, behavior of human and many more. Street lighting consumes two percent of global energy and also responsible for the annual exhaust of millions of Co_2.

Many researches and techniques are made by engineering students, faculty of universities, colleges and research organizations to make the outdoor lighting system less power consuming. The latest technology, which is used globally in these days is light emitting diode based system, it is treated as energy efficient and reliable lighting technology, which reduced the public lighting cost as well as energy consumption up to 80% and also responsible for the reduction of carbon dioxide emissions. LED lamps last about 50 times longer than other Conventional light bulbs. A Constant lighting is the best solution in busy areas; however, it is definitely not in rural residential areas. In former cases, many people are walking around midnight when they come from, their shops, cinemas, restaurants etc. but in the latter case, only a few numbers of people using the streets during night. So, there is a temporary need for lighting streets or road, in relation to a continuous illumination of streets or road in urban areas. For energy saving on street lights we can install an automatic system which can turn on or off lighting system or the brightness of lamps increase or decrease according to detection of traffic on the road. Today world is facing energy shortages due to the increase of the average consumption of energy per capita and this has led to continuous decrease of the world reserves of natural gas and oil. Non-Conventional energy technologies have drawn tremendous interest worldwide to find solutions for energy crisis. Recently, photovoltaic systems have found fairly wide applications. One of the PV applications is the Standalone Street lighting system which is using most efficient and the cost effective LED lamps. This system doesn't require any power source plus it is free of pollution. It can install anywhere, where grid availability is not possible, i.e. in hilly areas, etc. Sun is used as a power source which is recognized as being an environmentally clean source from energy production point of view. We can also add sun tracker system in standalone system to attain maximum energy from sun for charging of battery. This system will automatically ON-OFF through electronic circuitry which save energy and make our lighting system more reliable and modern.

In India, in these days high intensity discharge lamps are used for street lighting. Recently, new street light modules have gained a lot of attention to reduce the amount of energy consumed by this type of lamp and also reduce the amount of Co_2 emissions. Latest technology light emitting diode lamp with their current performances has proved themselves to be the most suitable solution for street lighting. It offers many advantages such as: long life, less power consumption, no effect on the environment due to absence of lead, no external reflector and they have high efficiency. LEDs are good light source and their efficiency is 160 lm/W. By using this type of high efficiency lamps, we can reduce 50% of the energy used by HID lamps.

By applying the proposed system, streets can be illuminated with lower power consumption lamps, low operating cost, low Co_2 emissions and environmentally friendly.

1.2 LITERATURE REVIEW

Lee *et. al* (2006) surveyed various street light control systems and analyzed its characteristics. Through these efforts, they found that common drawbacks of most light control systems were uneasy of handling and difficulty of maintenance. To reduce uneasiness of handling and difficulty of maintenance on operating light control system, they designed new street light control system by using the Zigbee communication technique.

Ereú *et. al.* (2006) carried out a study with the aim of establishing the proper methodology to calculate the amount of energy consumed by the street lighting system. The study focused on a lamp's nominal power, the average loss in the ballast, the average loss due to lamp aging and the technical losses in the conductor as a result of the joule effect.

Pantoni *et. al.* (2010) studied and developed efficient technologies highlighted by the ReLuz (Brazilian National Program of Public Lightning and Efficient Light Signalization) program.

Zhang *et. al.* (2010) implemented a remote control system for urban road lighting joins in Computer Technology. Database technology, GIS and GPRS Mobile Network Technology were discussed and used in the application.

Yue *et. al*. (2010) improved street lighting control computer system composition, working principle and function; it could meet the increasing demand of the different holidays by different control strategies, and strengthen the relevant measures for energy-saving technologies, highlight characteristics such as energy-saving, environmental-protection, controllable etc.

Ali *et. al*. (2011) proposed a low cost, high efficiency stand-alone solar street LED light system. The proposed system conserved power by two ways, the source and the load. The source was a PV array that is a clean renewable energy. Also, a single microcontroller system has been proposed for the power management of the system. The proposed system introduced a solution to the peak load problem of the Egyptian system.

Mullner *et. al.* (2011) presented the SSL system, a framework for fast, reliable and power efficient street lamp switching based on pedestrians' location and personal desires of safety (increased or reduced illuminated area all around at passersby).

Popa *et. al.* (2012) focused on implementing a lighting control system that made street lighting to be an autonomous and efficient part of the urban environment. The paper presented an efficient street lighting system with reduced power consumption in comparison to classical lighting systems.

Siddiqui *et. al.* (2012) designed a system to reduce energy consumption of outdoor premises and demonstrated by developing a prototype to control street lamps. The system minimized energy consumption for the benefit of user and environment concurrently.

Priyasree *et. al* (2012) aimed at designing and implementation of an automatic system where in the street lights that were not required through the night could be dimmed. Thus, this paper once implemented on a large scale can bring in significant reductions in the power consumption caused by street lights.

Husin *et. al.* (2012) presented the automatic street lighting system; around 77% to 81% of power consumption could be reduced by using the proposed system.

Vitta *et. al.* (2012) demonstrated the concept of an intelligent solid-state street lighting system in real outdoor conditions. The two-level and two-zone illumination method was implemented based on psychophysical investigation.

Ahmed *et. al.* (2012) focused on the project to make the most efficient use of the energy received from the sun to power street lights in the city. A mounting angle of the panels had also been determined which would allow optimum efficiency for all four seasons of the year.

Zotos *et. al*. (2012) developed energy-efficient, intelligent outdoor lighting management and monitoring system with remote control. This paper presented the results of a case study of an experimental installation of an intelligent road lighting system.

Lian *et. al.* (2012) defined an intelligent lighting control system, combining Zigbee with GPRS. With the proposed control network, there was reduced power consumption, decreased management cost and monitored the status information of each street lighting unit.

Sarimin *et. al.* (2013) proposed an application for the controlling and monitoring of the smart street lighting system through the use of the Zigbee wireless communication protocol. The developed application used embedded programming to control the behavior of the overall system.

Amin *et. al*. (2013) described the use of wireless sensor networks using GSM for street light monitoring and controlling.

Natu *et. al.* (2013) suggested that the system was built to provide remote access to Street Lights by accessing them just through a server and saved the power consumption of the area under the system. This power could be diverted to different areas under load shedding and attempt to reduce the problem of load shedding could be achieved.

Yusoff *et. al.* (2013) discussed and presented preliminary work on the development of a smart street lighting system and also focused on the complete wireless smart street lighting system with extra security features to ensure secure data transfer from the sites to a central server.

Rajput *et al.* (2013) described the Intelligent Street Lighting system that integrated new technologies offering ease of maintenance and energy savings.

Castro *et.* al. (2013) presented the relevance of the smart lighting control to reach the sustainability of smarter cities. They had described the impact on the total power consumption of the lighting and consequently the interest to offer a higher control and optimization of its usage.

Srivastava *et. al.*(2013) designed Automatic Street lights that was a cost effective, practical, eco-friendly and the safest way to save energy.

Latha *et. al. (*2013) proposed an approach for controlling Street Lighting system using millennium 3 PLC. The simulated results were also verified experimentally by using a light dependent resistor.

Leccese *et. al.* (2013) described a new intelligent street lighting system which integrated new technologies available on the market to offer higher efficiency and considerable savings. This can be achieved using the highly efficient LED technology supplied by renewable energy from solar panels.

1.3 OBJECTIVE OF THE WORK: The objective of the dissertation is to develop a Smart Street Lighting System that is powered by two sources, battery and solar system and is operated at the required intensity such that they are economically viable for the energy sector. The aim of this dissertation is to limit the energy wastage and also reduce carbon dioxide emissions.

1.4 METHODOLOGY USED: Hardware implementation of Auto light intensity and Auto switching system control for Smart Street lighting system is proposed. Also, sun seeker tracker is used to make efficient use of solar energy.

1.5 ORGANISATION OF DISSERTATION: This dissertation consists of five chapters.

The first chapter includes introduction, Literature review, Objective of the work, Methodology used and organization of the dissertation.

The second chapter is based on a smart street lighting system which consists of structure, the difference between conventional and smart street lighting system and description of components which are used to implement the hardware.

The third chapter deals with circuit diagram, flow chart and working of auto light intensity control of LED lamps, Auto switching of street light and sun seeker system.

The fourth chapter deals with the comparison between the HPS lamp and LED lamp, Design of off-Grid PV system, graphs and charging-discharging characteristics of battery. In this chapter, we calculate ratings of components required for off-Grid system.

The fifth chapter includes the experimental results, conclusion and future scope of the work.

Chapter 2

SMART STREET LIGHTS

2.1 LIGHT: Light is in the form of radiation, which is visible to the human eye and is responsible for the sense of light. It is also called as electromagnetic radiation (EMR) which is having a wavelength in the range of 400 nm to 700 nm- between the infrared, with longer wavelengths and the ultraviolet, with shorter wavelengths. The ranges mentioned above do not represent the absolute limits of human vision, but it gives the approximate range in which people can see well. Visible light as narrowly as 420nm to 680 nm to as broadly as 380nm to 800nm be defined by various sources. People can see infrared up to 1050nm and in case of ultraviolet, children and young people can see down to about 310 to 313nm. Intensity, propagation direction, frequency, wavelength spectrum and polarization are the primary properties of visible light and the speed of light is 3×10^8 m/s. The visible light with these all types of EMR move at this velocity in a vacuum. In all types of EMR, visible light is emitted and absorbed in tiny particles called photons and exhibit properties of wave and particles. Street light is placed on the road to make visible everything on the road at night to prevent accidents and to increase safety of people.

2.2 CONVENTIONAL LIGHTING SYSTEM: An electric light is a device that produces light when electricity passes through it. Our forefathers used kerosene oil lamp and candles for lighting system at night. Incandescent lamps were made in the early and middle 19^{th} century but had less use now days.

Types:

There are several kinds of light bulbs.

- **Incandescent** - the most common light bulb in the house until about 2003.
- **Gas discharge lamp** - a type of light bulb that includes the fluorescent light. Compact fluorescent lights (CFLs) have now replaced incandescent light bulbs in the house.
- **Low Pressure Sodium –** It is the most efficient light source which is used in street lighting. LPS lamp is producing a monochromatic orange-yellow light and is also a good way to reduce sky glow. The drawback of this lamp is only CRI. Everything around it looks yellow-orange when the lamp is in ON position and its uses more wattage as the age of lamp increases.

- **High Intensity Discharge –** It requires an external ballast to operate. It takes 3 to 5 minutes to reach its full intensity. The lamp will be shut off if there is a dip in electricity. HPS must cool sufficiently to restrict, which usually takes about 1 minute to 10 minutes.

  HPS lamps are of following types:

  - **Mercury vapor:** It is a high intensity discharge lamp. It uses an arc through vaporized mercury in a high pressure lamp to create a weaker light that mainly creates UV light to excite the phosphors. Lamps have a good efficiency and Color rendering is better than that of high pressure sodium street lights.
  - **Metal halide:** It consists of an arc tube with an outer bulb. It may be made of either quartz or ceramic and contains an argon gas, mercury and metal halide salts. Traditional quartz MH arc tubes are similar in shape to mercury vapor arc tubes, but they operate at high temperatures and pressures. They are more energy efficient than mercury vapor and greater lumen output.
  - **High pressure sodium:** It is the most common lamp for street lighting and this is an improvement over the LPS lamp i.e. it has a more CRI with greater efficiency of a sodium lamp.

2.3 MODERN LIGHTING: LIGHT EMITTING DIODE: Solid states LEDs have been popular as indicator lights since the 1970s. In recent years, efficacy and output have risen to the point where LEDs are now being used in niche lighting applications. Indicator LEDs are known for their extremely longer life, up to 100,000 hours, but lighting LEDs are operated much less conservatively (due to high LED cost per watt), and consequently have much shorter lives than indicator LEDs. Due to the relatively high cost per watt, LED lighting is most useful at very low powers; typically for lamp assemblies of fewer than 10 W.

LEDs are currently most useful and cost-effective in low power applications, such as night lights and flashlights. Coloured LEDs can also be used for accent lighting, such as for glass objects. They are also being increasingly used as holiday lighting. LED efficiencies vary over a very wide range. Some have lower efficiency than filament lamps, and some significantly higher. LED performance in this respect is prone to being misinterpreted, as the inherent directionality of LEDs gives them a much higher light intensity in one direction per given total light output. LED technology is useful for lighting designers because of its low power consumption, low heat generation and instantaneous on/off control. For general domestic lighting, total cost of ownership of LED lighting is still much higher than for other well established lighting types.

Leading the Revolution - LEDs has become the driving force in the evolution of street lighting. The combination of improved night time visibility and safety, reduced maintenance/operational costs, no toxic chemicals and a decrease in carbon emissions have made LED lighting systems, a top consideration for municipalities and utility companies everywhere.

Smart Operational Control – Roadway lighting covers a broad range of locations, from low-traffic residential neighbourhoods and rural roads. All have their own requirements for acceptable light levels and distribution patterns and this is where LED street light systems with "smart control" can be the most effective. The light can be easily controlled with intelligent systems. The light can be turned on and off instantly and can be dimmed for added energy savings at dawn, dusk, and also during hours of low traffic. Switching on-off and dimming does not affect the lifetime of the lamp.

Quality of Life – Because of its capability for dynamic control, LED street lighting can address issues of dark sky and light pollution in residential areas during the late night hours. Alternately, where and when needed, LED's nearly white light makes it feel like day time, which can significantly help in reducing criminal activity. The improved illumination can also improve safety for drivers, cyclists and pedestrians.

Carbon Footprints – LED lights contain no toxic materials and are 100% recyclable. Because of their long life, they can significantly reduce landfills and bulb disposal costs compared to conventional street lights.

2.4 DIFFERENCE BETWEEN CONVENTIONAL AND SMART STREET LIGHT:

A Street light is a raised source of light on the edge of a road or walkway, which is turned ON at a certain time every night. In conventional street lights, the bulbs which are used, they consume more power and at that time there is no controlling technique available. So, energy wastage was more. The street lights remain switched ON even when there is no traffic. In smart street light technologies such as LED, emit a white light that provides a high level of scotopic Lumens allowing Street Lights with lower wattages and lower photopic Lumens to replace existing street lights. In these days, smart street lights are controlled by various techniques such as wireless sensor network, Zigbee based street light control system, microcontroller based control scheme and much more. For instance, in the Zigbee control system, street light control is composed of three parts, centralized control center, remote concentrator and street light control terminals. Centralized control center resides in a local government office usually. At the centralized control center, operators monitor and control street lights by using the operator's terminal. Centralized control center computers communicate with remote concentrator which control lights installed alongside every road.

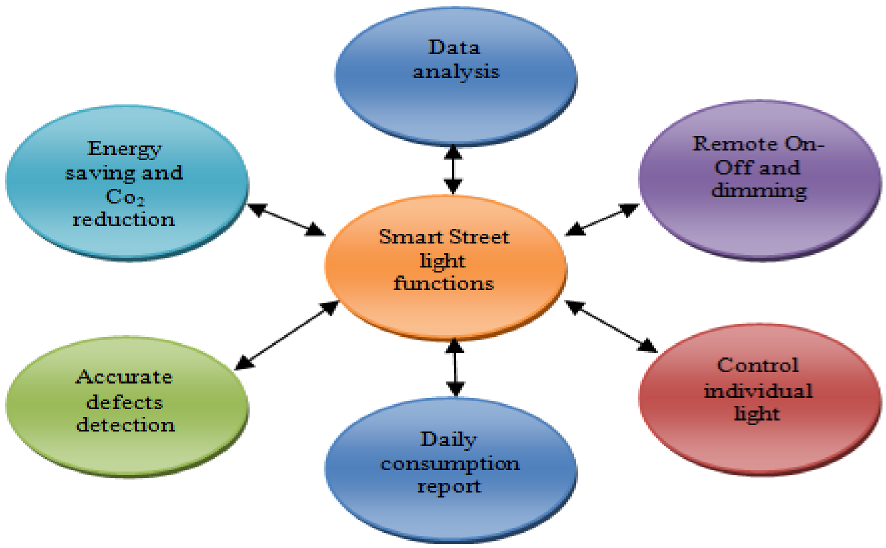


Figure 2.1: Representation of intelligent Street light functions

Remote concentrators control lights and gather status information. Third, components of a street light control system is street light control terminals. To control each light individually, this street light control terminal is needed. It is installed to every street light pole to detect status of light and to control lighting. It communicates with remote concentrator to give and receive commands and status information for the control center. Zigbee is rising communication protocol, which is used for data transfer within centralized control center, remote concentrator and street light control terminals. With the help of these above mention control techniques, the energy consumption of street lighting can be reduced by the following methods.

- By switching the street lights in an organized manner.
- By controlling the light intensity of lamps from 0 to 100 percent.
- Switching off the lights at selected locations where there is no traffic after midnight.

2.5 STRUCTURE OF CONVENTIONAL STREET LIGHT: The conventional street light may be mounted on wooden pole or steel pole that is excited by an underground cable line that connects to the nearest power source line. At the beginning of the development of street lights, all the street lights were turn ON daily at night time and turn OFF at morning time. So this system required a worker to do this daily. Sometimes, street lights were remaining ON in day time, which increased the bill cost. After few years, smart based controller in the form of timer was used to turn ON and OFF based on a pre-set time within the street light. With the invention of sensors, the street lighting system evolved to a higher level with the use of LDR, photodiode etc. These sensors are used to detect the surrounding ambient lighting and turn ON and OFF according to how much light intensity sensed. These are mounted on the top of the street light.

Conventional street lighting system structure consists of following components.

1. Lamp
2. Ballast
3. Capacitor
4. Ignitor
5. Photo resistor

The lamp emits luminous light and normally consists of Sodium vapor. When the sensor detects dark in surroundings, then it sends signal to invoke the igniter. The function of igniter is as a time delay switch whereby it heats up the coated tungsten electrodes on both ends. The ionization by the mixture of gases and the electrodes heated up, results in formation of charges. The capacitor holds the charged to be released and that will start the arc and start up the lamp. The function of ballast is to maintain the current of the light which has been turned ON by limiting the current to an appropriate amount suitable for the lamp.

2.6 STRUCTURE OF SMART STREET LIGHTING SYSTEM: The smart street lighting system consists of three types of circuitries, Zigbee module, microcontroller, sensor circuit and LED. It is based on wireless sensor network application that utilizes Zigbee communication by providing communication capabilities. This system is mostly powered by battery. So, there is no need of the underground cable system. The brain of the overall system called microcontroller that is controlling the inside and out going data. When these smart controllers detect surrounding as dark or bright then it immediately send a HIGH or LOW signal to turn ON and OFF the street light. With the help of Zigbee transceiver, the microcontroller reports every activity and status of the street light to the control station wirelessly. The host of the control station is able to monitor and control the street light 24 hrs.

In smart street lighting system, we can also check the status of the lamp like healthy, unhealthy and faulty. In healthy condition street light operates in a normal working condition by turning ON and OFF automatically for night and day light, but in unhealthy condition the street light does not turn ON or OFF and it sends a feedback message to control room to notify the host. The host is able to turn ON or OFF the street light manually and wirelessly with the help of graphical user interface. In a fault condition, the street light sends an error message to the control room to alert the host or operator regarding the fault. The operator is notified and takes further action to carry out repair works. As compared to the conventional street lighting system, the smart street system offers high reliability, low maintenance with the deployment of feedback system. The feedback system allows the street light to respond with the control room reporting its daily status and condition. Instead of the above scheme, many other controlling techniques that are used for smart street lighting system are follows:-

1. Street Light Control System Design by using Zigbee Communication Protocol.
2. GSM Based Autonomous Street Illumination System for Efficient Power Management.
3. PLC based Smart Street Lighting Control using LDR.
4. Remote-Control System of High Efficiency and Intelligent Street Lighting Using a Zigbee Network of Devices and Sensors.
5. Wireless Dimming System for LED Street Lamp Based on Zigbee and GPRS.

2.7 BENEFITS OF STREET LIGHTING:

Modern well designed installed and maintained street lighting provides many benefits.

1. Helpful in reducing the fear of street crime to some extent.
2. Preventing night time personal injury accidents.
3. It allows the effective use of CCTV systems in cities at night.
4. Assisting the emergency services to identify locations and carry out their duties.
5. Promoting sustainable transport, public transport, cycling and walking.
6. Promoting economic development by support at 24 hrs leisure economy.
7. Facilitating social inclusion by providing the freedom to use our street after dark.

2.8 COMPARISON BETWEEN DIFFERENT STREET LIGHTING TECHNOLOGIES:

TECHNOLOGIES: The comparison between different types of lighting lamps is based on some important features as given below:

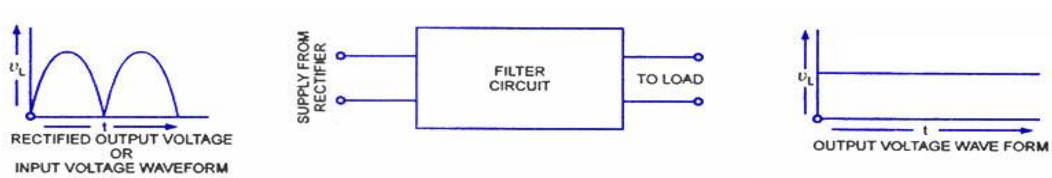
Table 2.1 shows a comparison between different street lighting technologies

Light Technology	Life Time (hrs)	Lumens per watt	Color temperature	CRI	Ignition time	Considerations
Incandescent light	1000 -5000	11 – 15	2800K	40	Instant	very inefficient, short life time
Mercury vapor light	12000 –24000	13 – 48	4000K	15 – 55	up to 15 min	contains mercury
Metal halide light	10000– 15000	60 – 100	3000-4300K	80	up to 15 min	contains mercury and lead
High pressure sodium light	12000– 24000	45 – 130	2000K	25	up to 15 min	Low CRI, contains mercury and lead
Low pressure sodium light	10000– 18000	80 – 180	1800K	0	up to 15 min	Low CRI, contains mercury and lead
Fluorescent light	10000– 20000	60 – 100	2700-6200K	70 – 90	up to 15 min	UV radiation, contains mercury
Compact fluorescent light	12000– 20000	50 – 72	2700-6200K	85	up to 15 min	Low life / burnout, dimmer in cold weather
Induction light	60000-100000	70 – 90	2700-6500K	80	Instant	Higher initial cost, negatively affected by heat
Light emitting diode	50000–100000	70 – 150	3200-6400K	85 – 90	Instant	Relatively higher initial cost

2.9 DESIGN OF STREET LIGHTING: Street light must be designed in such a way that it must be energy efficient, reliable and safe, technically advance, cost effective, convenient for maintenance etc.

2.10 LIST AND DESCRIPTION OF COMPONENT USED:

1. **Input AC Supply:** The 220V, 50 Hz AC supply fed as the primary winding of the step down transformer.
2. **Step-down transformer:** It is a Static device which transfers electrical energy from one circuit to another without changing any frequency. Step down transformer is used for Stepping down the 220V to 12V supply.
3. **Rectifier:** A rectifier is an electrical device that converts alternating current which periodically reverses direction to unidirectional direct current. The process is known as rectification. The p-n junction diode conducts only in one direction. It conducts when forward biased while practically it does not conduct when reverse biased. Thus the conduction occurs only during the positive half cycle. Thus p-n junction diode subjected to an AC voltage act as a rectifier, converting alternating voltage to a pulsating DC voltage. The full wave rectifier conducts during the positive half cycle and negative cycle of input AC supply. In order to rectify both the half cycles of AC input, two diodes are used in this circuit. The diodes feed a common load with the help of the center tap transformer. The AC voltage is applied through a suitable power transformer with a proper turn ratio. Efficiency is high and low ripple factor are is the advantages of full wave rectifier.
4. **Filter:** We know the output of half wave or full wave rectifier circuit is not pure DC, it contains fluctuations or ripples, which are undesired. The ripples are removed with the help of filters.



(a) (b) (c)

Figure 2.2: (a) Output of full wave rectifier (b) Filter circuit (c) Filtered output of rectifier

Ideally the output of the filter should be pure DC. Practically the filter circuit tries to minimize the ripples from the output, as far as possible. Basically the ripple is an AC, i.e. varying with time, while DC is constant w.r.t time. Hence, in order to separate DC from ripple, the filter circuit uses components such as inductance and capacitance which have widely different impedance for AC and DC. The inductance acts as a short circuit for DC but it has large impedance for AC. Similarly, the capacitor acts as open for DC and almost short for ac if the value of the capacitor is large enough. Thus, a filter is an electronic circuit composed of inductor, capacitor or a combination of both and connected between the rectifier and load so as to convert pulsating DC to Pure DC.

5. 7805 Voltage Regulator IC:

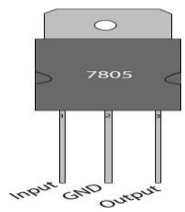


Figure 2.3: Pin configuration of IC 7805

Pin Description:

Pin No.	Function	Name
1	Input voltage (5V-18V)	Input
2	Ground (0V)	Ground
3	Regulated output: 5V (4.8V-5.2V)	Output

Features:

- Output Current up to 1A
- Output Voltages of 5, 6, 8, 9, 10, 12, 15, 18
- Thermal Overload Protection
- Short Circuit Protection

Description: The 78xx is a family of self-contained fixed linear voltage regulator integrated circuits which is commonly used in electronic circuits requiring a regulated power supply due to their ease-of-use and low cost. The 78xx lines are positive voltage regulators: they produce a voltage that is positive relative to a common ground.78xx series ICs have built-in protection against a circuit drawing too much power. They have protection against overheating and short-circuits, making them quite robust in most applications. In some cases, the current-limiting features of the 78xx devices can provide protection not only for the 78xx itself, but also for other parts of the circuit. This IC is designed as fixed voltage regulator and with adequate heat sinking can deliver output current in excess of 1A.

6. **Transmitter:**

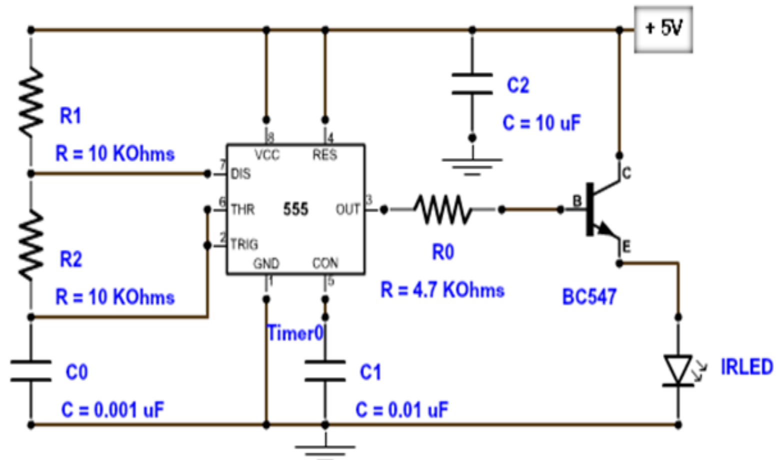


Figure 2.4: Circuit diagram of Transmitter

The 10µF capacitor (C_2) is used to reduce ripples in the power supply. 1st pin is GND and V_{cc} 5V is connected with 8th pin. 4th pin is the reset pin which is an active low input, hence it is connected to V_{cc}. 5th pin is the Control Voltage pin which is not used in this application and hence it is grounded via a capacitor to avoid high frequency noises through that pin. Capacitor C_0, Resistors R_1, R_2 determines the time period of oscillation. Capacitor C_0 charges to V_{cc} via resistors R_1 and R_2. It discharges through Resistor R_2 and 7th pin of 555. The voltage across capacitor C_0 is connected to the internal comparators via 2nd and 6th pins of 555. The output is taken from the 3rd pin of the IC. Charging time constant of the capacitor (output HIGH period) is determined by the expression 0.693 (R_1+R_2) C_0 and discharging time constant (output LOW period) is determined by $0.693R_2C_0$, they are approximately equal.

7. **IR Receiver:** For receiving signals send by the transmitter we need only TSOP382. V_s is Connect to 5V and Ground to GND pin of TSOP382.Output of TSOP382 will be LOW when no signals fall on it and the output will be HIGH when 38 KHz infrared rays fall on it.

8. **Transistor BC547:** BC547 is a NPN bi-polar junction transistor. A transistor, stands for transfer of resistances, is commonly used to amplify current. A small current at its base controls a larger current at collector & emitter terminals. It is mainly used for amplification and switching purposes. It has a maximum current gain of 800. Its equivalent transistors are BC548 and BC549.

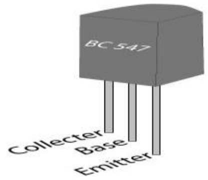


Figure 2.5: Pin configuration of NPN Transistor

The transistor terminals require a fixed DC voltage to operate in the desired region of its characteristic curves. This is known as the biasing. For amplification applications, the transistor is biased such that it is partly on for all input conditions. The input signal at the base is amplified and taken at the emitter. BC547 is used in a common emitter configuration for amplifiers. The voltage divider is the commonly used biasing mode. For switching applications, the transistor is biased so that it remains fully on if there is a signal at its base. In the absence of base signal, it gets completely off.

9. **IR LED:**

Figure 2.6: Infrared LED

An IR LED, also known as IR transmitter, is a special purpose LED that transmits infrared rays in the range of 760 nm wavelength. Such LEDs are usually made of Gallium Arsenide or Aluminum Gallium Arsenide. They, along with IR receivers, are commonly used as sensors. The appearance is same as a common LED. Since the human eye cannot see the infrared radiations, it is not possible for a person to identify whether the IR LED is working or not, unlike a common LED. To overcome this problem, the camera on a cell phone can be used. The camera can show us the IR rays being emanated from the IR LED in a circuit.

10. Preset:

Figure 2.7: Preset used for variable resistance

A preset is a three legged electronic component which can be made to offer varying resistance in a circuit. The resistance is varied by adjusting the rotary control over it. The adjustment can be done by using a small screwdriver or a similar tool.

11. Capacitor:

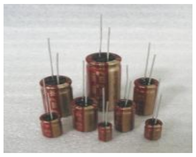


Figure 2.8: Electrolyte Capacitor

A capacitor is a passive component used to store charge. Capacitors offer infinite reactance to zero frequency so they are used for blocking DC components or by passing the AC signals. The capacitor undergoes through a recursive cycle of charging and discharging in AC circuits where the voltage and current across it depends on the RC time constant. For this reason, capacitors are used for smoothing Power supply variations. Since the capacitors store charge, they must be carefully discharged before troubleshooting the circuits. The maximum voltage rating of the capacitors used must always be greater than the supply voltage.

12. Resistor: A resistor is a two-terminal commonly used electronic component designed to oppose an electric current by producing a voltage drop between its terminals in proportion to the current, that is, in accordance with Ohm's law:

$$V = IR$$

13. SPDT Relay: The relay is an electromagnetic device which is used to isolate two circuits electrically and connect them magnetically. They are often used to interface an electronic circuit to electrical circuit which works at very high voltage. For example, a relay can make a 5V DC battery circuit to switch a 230V AC mains circuit. Thus a small sensor circuit can drive, say, a fan or an electric bulb.

Figure 2.9: SPDT Relay

A relay switch can be divided into two parts: input and output. The input section has a coil which generates magnetic field, When a small voltage from an electronic circuit is applied to it. This voltage is called the operating voltage. Commonly used relays are available in different configuration of operating voltages like 6V, 9V, 12V, 24V etc. The output section consists of contractors which connect or disconnect mechanism. In a basic relay, there are three contacts: normally open (NO), normally closed (NC) and common (COM). At no input state, the COM is connected to NO. When the operating voltage is applied the relay coil gets energized and the COM changes contact to NC. Different relay configurations are available like SPST, SPDT etc., which have different numbers of changeover contacts. By using the proper combination of contractors, the electrical circuit can be switched on and off.

14. **LED:** LEDs are semiconductor devices. Like transistors, and other diodes, LEDs are made of silicon. What makes an LED give off light are the small amounts of chemical impurities that are added to the silicon, such as Gallium, Arsenide, Indium and Nitride**.** When current passes through the LED, it emits photons as a byproduct. Normal light bulbs produce light by heating a metal filament until it is white hot. LEDs produce photons directly and not via heat, they are far more efficient than incandescent bulbs.

Typical LED (a) **circuit symbol** (b)

Figure 2.10 (a) Typical LED (b) Circuit symbol of LED

15. **NE 555 TIMER IC:** The NE 555 timer IC is an integrated circuit (chip) used in a variety of timer, pulse generation, and oscillator applications. It can be used to provide time delays, as an oscillator, and as a flip-flop element.

Figure 2.11: NE555 Timer IC

PIN DIAGRAM:

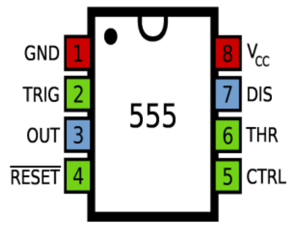


Fig. 2.12: Pin Diagram of NE 555 Timer IC

The connection of the pins for a DIP package is as follows:

PIN	NAME	PURPOSE
1	GND	Ground reference voltage, low level (0 V)
2	TRIG	The OUT pin goes high and a timing interval starts when this input falls below 1/2 of CTRL voltage (which is typically 1/3 of *V*CC, when CTRL is open)
3	OUT	This output is driven to approx. 1.7 V below +*V*CC or GND.
4	RESET	A time interval may be reset by driving this input to GND, but the timing does not begin again until RESET rises above approximately 0.7 volts.
5	CTRL	Provides "control" access to the internal voltage divider (by default, 2/3 *V*CC).
6	THR	The timing (OUT high) interval ends when the voltage at THR is greater than that at CTRL (2/3 *V*CC if CTRL is open).
7	DIS	Open collector output which may discharge a capacitor between intervals.
8	V_{cc}	Positive supply voltage, which is usually between 3 and 15 V depending on the variation.

Modes:

The 555 has following operating modes:

• **Monostable mode:** In this mode, the 555 functions as a "one-shot" pulse generator. Applications include timers, missing pulse detection, bounce free switches, touch switches, frequency divider, capacitance measurement, pulse-width modulation (PWM) and so on.

• **Astable (free-running) mode:** The 555 can operate as an oscillator. Uses include LED and lamp flashers, pulse generation, logic clocks, tone generation, security alarms, pulse position modulation.

Specifications:

Supply voltage (V_{cc}) 4.5 to 15 V	4.5 to 15 V
Supply current (V_{cc}) = +5 V)	3 to 6 mA
Supply current (V_{cc}) = +15 V)	10 to 15 mA
Output current (maximum)	200 mA
Maximum Power dissipation	600 mW
Power consumption (minimum operating)	30 mW@5V, 225 mW@15V
Operating temperature	0 to 70^{o} C

Chapter 3

HARDWARE IMPLEMENTATION

3.1 AUTO LIGHT INTENSITY CONTROL OF LED LAMP:

3.1.1 CIRCUIT DIGRAM:

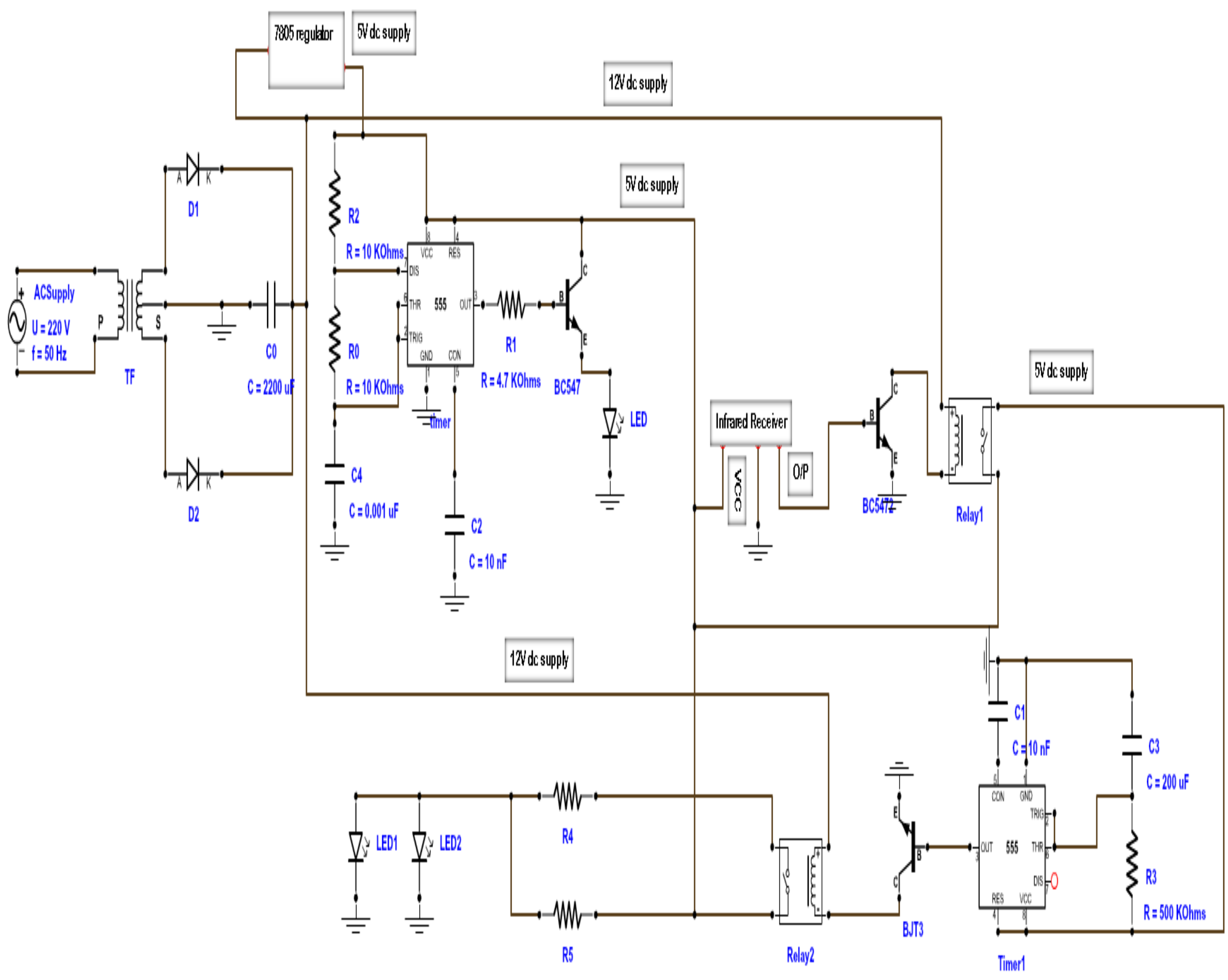
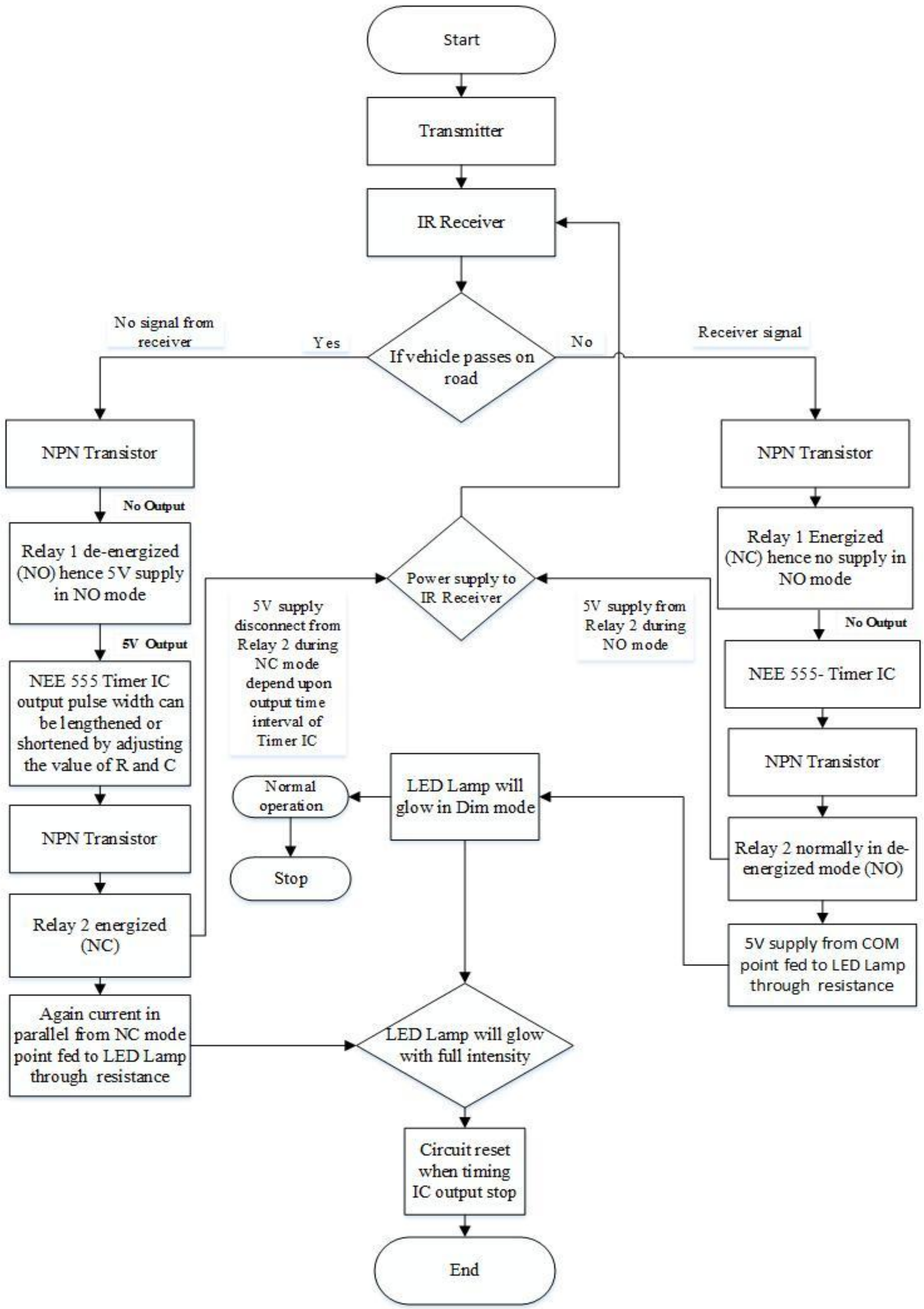


Figure 3.1: Circuit diagram of auto light intensity control of LED lamp

3.1.2 FLOW CHART: The following flow chart explains the operation of auto street light intensity control of the LED lamp.



Flow chart no. 3.1: Auto light intensity control of LED lamp

3.1.3 WORKING:

INPUT: The input 220V, 50 Hz AC supply is fed as the primary of the transformer and 12V supply is obtained at the output of the transformer. The output of the transformer is still AC. So, it converted into DC supply with the help of full wave rectifier. The output of the rectifier is in the form of DC pulsating. So, capacitor is used in parallel to remove ripples from the supply and pure DC is obtained. This 12V supply is converted into 5V with the help of IC 7805, used for components which operate on 5V. A transmitter which is placed on one side of the road and IR Receiver placed opposite to transmitter near street light towers. The transmitter sends signal all time i.e. both are communicating with each other when no vehicle passes on the road and IR receiver output will be LOW when no signal falls on it and the output will be HIGH when 38 KHz infrared rays fall on it.

OUTPUT: The output modes are explained in detail as given below:

DIM MODE: When no vehicle passes on a road, during that time, both transmitter and receiver will communicate with each other all the time, i.e. transmitter signal continues to fall on the receiver, Hence the output of the receiver will be HIGH. So, the signal from the IR receiver fed to relay 1 (12V) at their pin. no. 2, then it will energize and operate in normally closed (NC) mode. The pin no. 1 of relay 1 is directly connected with 12V DC supply. The LED lamps will operate in dim mode and supply given to LED lamps directly connected from common pin-3 of relay 2 that is connected with 5V supply, by adding resistance in series. In this mode, LED will glow at half intensity.

FULL MODE: In this mode, when any vehicle passes on a road, the communication link between transmitter and receiver will break i.e. no signal falls on receiver, hence the output of IR receiver will be LOW for that instant only Hence, no output fed to the base of BC 547 transistor and relay 1gets de-energized and starts operating in NO mode.

In NO mode, the common pin no. 3 (5V) of relay 1 gets connects with pin no. 5. So, this 5V supply fed to NE 555 timer IC as input at their pin no. 8 (V_{cc}). Here, timing IC operates in Monostable mode. The output signal from pin no. 3 of timer IC fed at base of the second transistor and the output signal is received at the collector (emitter is grounded). This signal is fed to the pin no. 2 of relay 2. The pin no. 1 is directly connected with 12V

DC supply, Hence relays 2 operates, changing from normally open mode to normally close mode. The supply goes to IR receiver from pin no. 4 of relay 2 when the relay is in the normally open mode and disconnects when relay 2 mode changes from NO to NC. The common pin no. 3 of relay 2 gets connected with pin no. 5; this will disconnect the supply to receiver and again send current in parallel to LED lamps through resistance in series. This addition of current will increase the light intensity of LED lamps from half to full intensity. The coil-energized period of relay 2 depends upon the output interval of timing IC555 which can be increased or decreased through resistance-500kΩ (Preset) used in IC555. After a few seconds the circuit will reset at its previous position, i.e. into dim mode.

The advantages by using these two modes is

1. Saving of energy
2. Reduced light pollution

3.2 AUTO SWITCHING OF SMART STREET LIGHTING SYSTEM

3.2.1 CIRCUIT DIAGRAM:

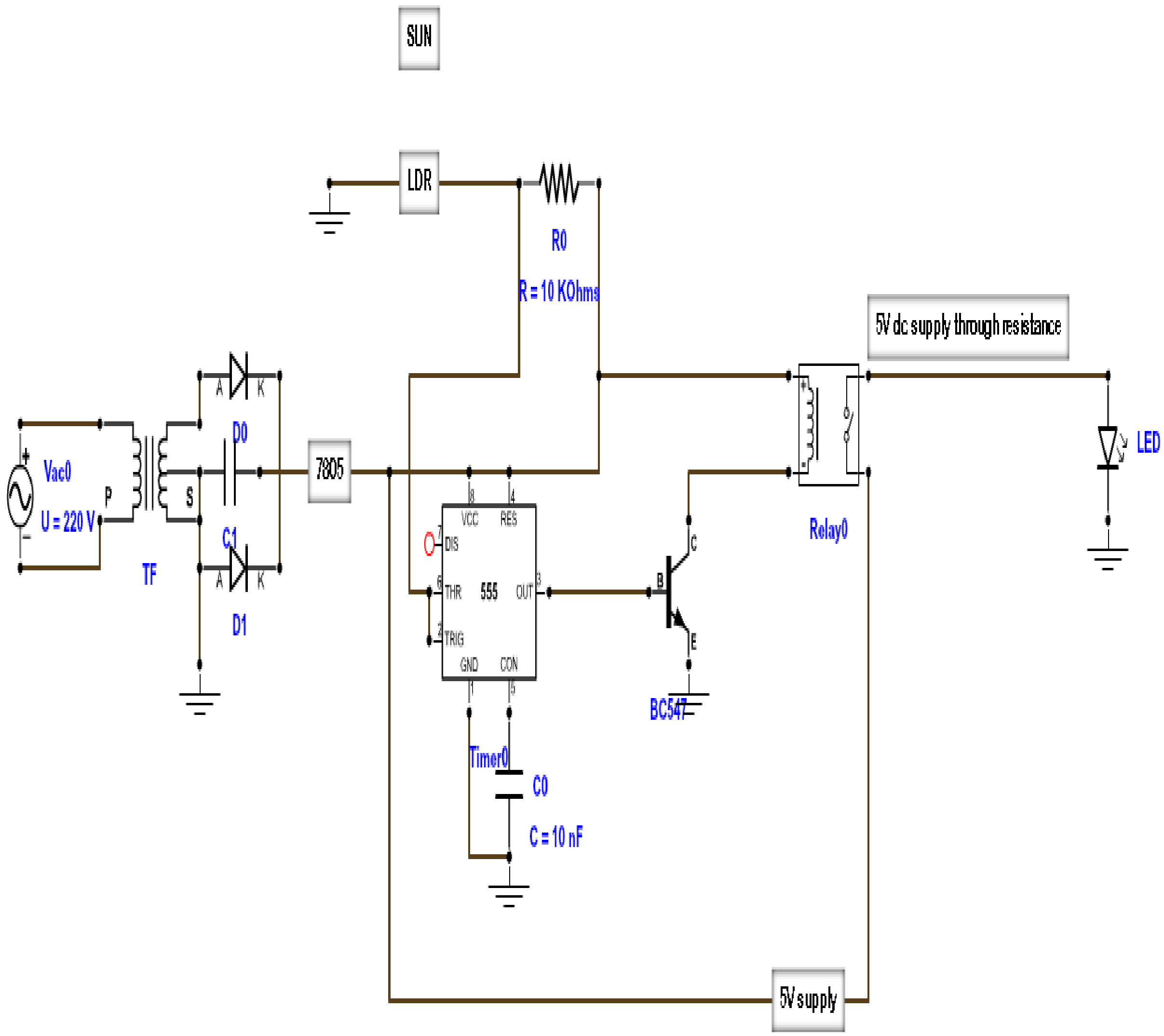
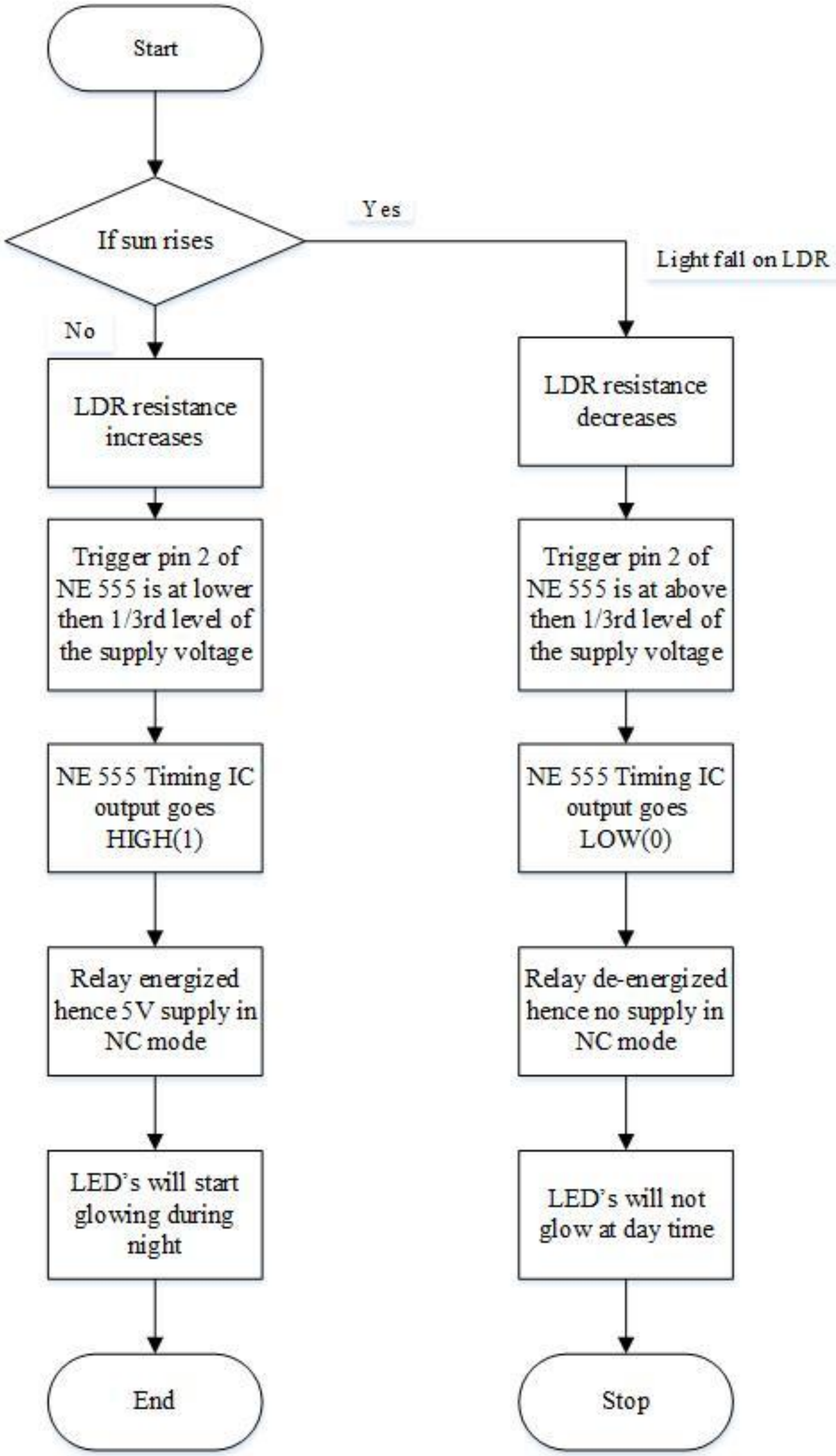


Figure 3.2: Circuit diagram of auto switching of street light system

3.2.2 FLOW CHART: The following flow chart explains the operation of the auto switching system of Smart Street light**.**



Flow chart no. 3.2: Auto switching of the smart street lighting system

3.2.3 WORKING: The above circuit is made to design the auto switching system of Smart Street Light. The working of the circuit depends upon the conditions of day and night.

During the day: The sun rays are continue falling on LDR and its resistance decreases, which results in an increase of the voltage at pin 2 of the IC 555. IC 555 has got comparator inbuilt, which compares between the input voltage from pin2 and 1/3rd of the power supply voltage. The input rises above $1/3^{rd}$, output is set LOW and the relay gets de-energized. During the de - energized mode, the relay will operate in NO mode; hence there is no supply in NC mode So, the street light will not turn ON at day time.

During the night: At night time, when there is no light fall on LDR i.e. its resistance increases, which results in a decrease of the voltage at pin 2 of the IC 555. The timing IC output goes HIGH and the relay gets energized and starts operating in NC mode. Hence, the power supply from the COM point of relay gets connected with street lights and it will switch ON during the night.

In next day when the sun rises, then light will turn OFF automatically.

3.2.4 BENEFITS:

1. By using the auto switching system of Smart Street light we can also reduce energy consumption because manually operating lighting system are not switched ON earlier before sunset and also not switched OFF properly after the sun rise.
2. Complete elimination of man power.
3. Reduction in carbon dioxide emissions.
4. Reduction in cost.
5. Higher community satisfaction.
6. Reduce energy costs

3.2.5 APPLICATIONS:

1. Street lights
2. Parking lights
3. Garden lights

3.2.6 CONCLUSION: This technique is a cost effective, eco-friendly and easiest way of saving energy.

3.3.1 CIRCUIT DIAGRAM:

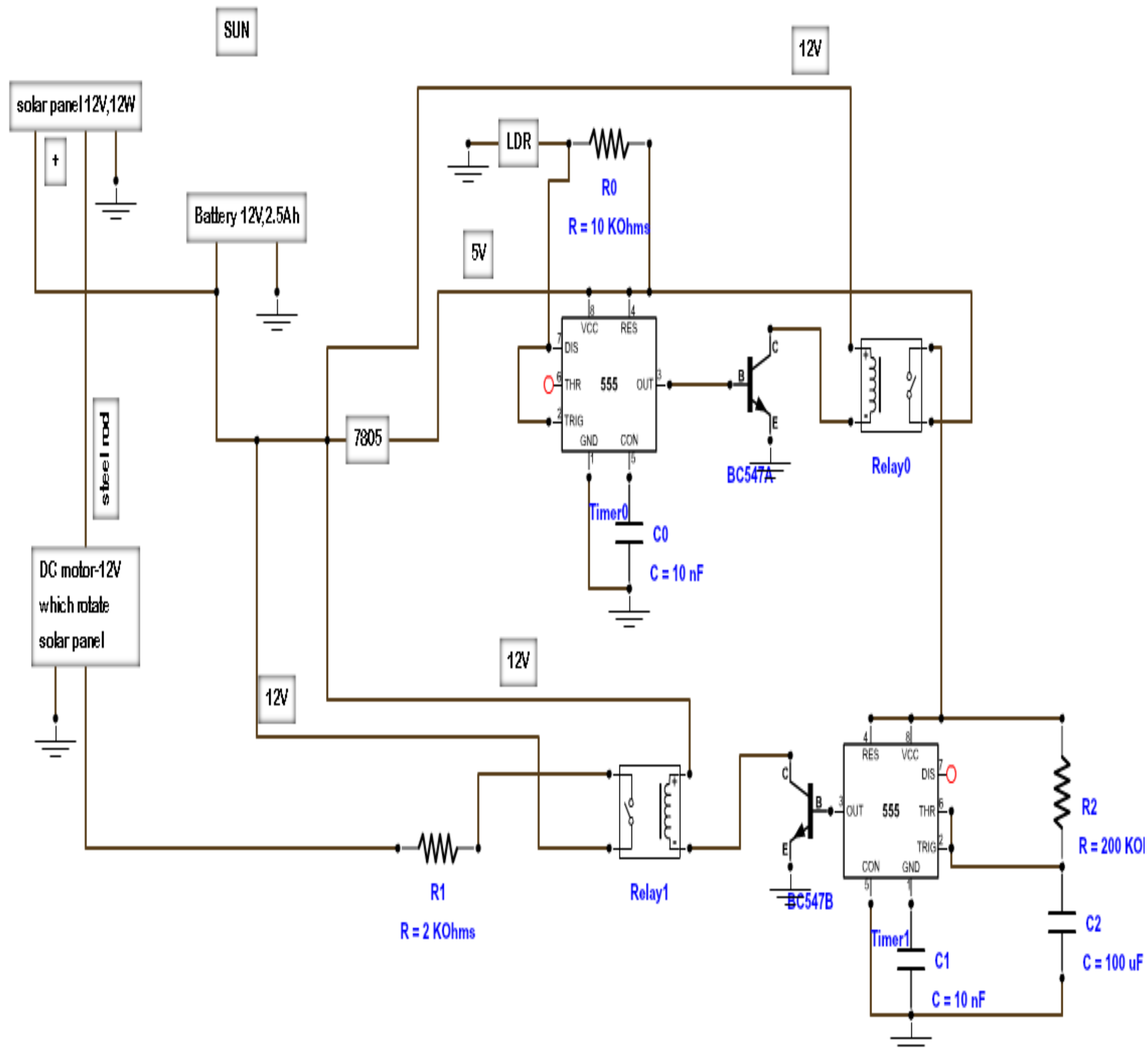
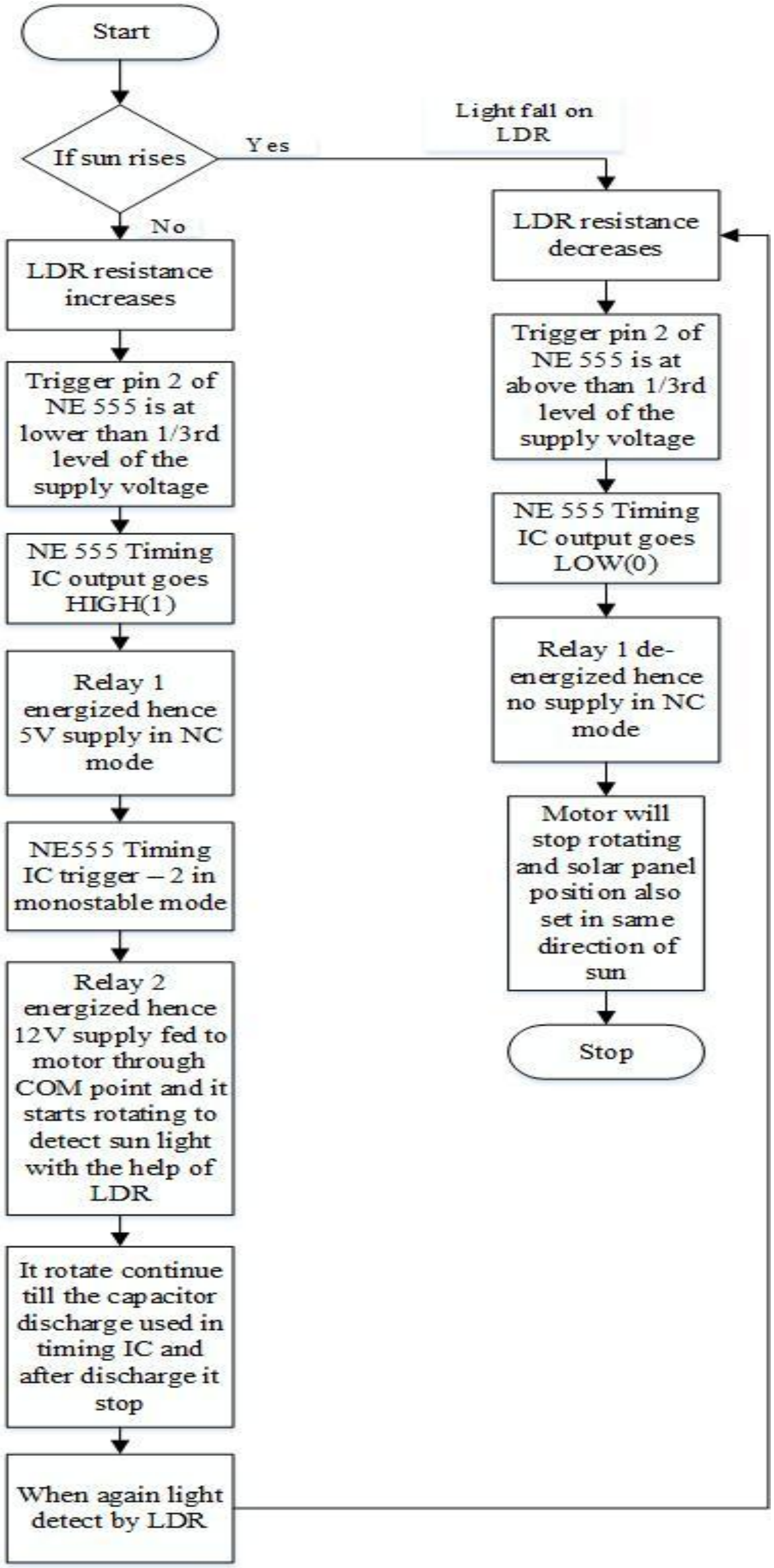


Figure 3.3: Circuit diagram of Sun Seeker

3.3.2 FLOW CHART: The following flow chart explains the operation of sun seeker system.



Flow chart no. 3.3: Sun Seeker

3.3.3 WORKING: The above circuit is made for sun seeker tracker system which attains maximum energy from the sun at day time and solar energy is used for charging the battery, which is used for lighting at night time.

AT DAY TIME WHEN SUN RISES: When light falls on LDR, its resistance decreases hence the voltage at pin no. 2 of NE 555 timing IC-1 is above than 1/3 level of the supply voltage. So, the output of the IC goes LOW (0) and hence relay 1 is stable in de-energized mode. During de-energized mode, there is no supply in NC mode. So, motor will stop rotating in that direction from where, it detects sun light.

AT NIGHT TIME WHEN SUN IS ABOUT TO SET: At night time, when the sun sets, it mean no light falls on LDR and its resistance increases, then the voltage at pin no. 2 of NE 555 timing IC-1 is lower than 1/3 level of the supply voltage. So, the output of the IC goes HIGH (1) and relay 1 gets energized. Hence, there is 5V supply in NC mode. When the relay starts operate in NC mode, then NE 555 timing IC-2 also triggers and starts operation in Monostable mode. During this period, relay 2 is also energized and starts operation in NC mode. From NC mode of relay, 12V supply goes to DC motor and it starts rotating to detect the sun with the help of LDR. Motor rotates continue depending upon the timing period, which further depends on the resistance and capacitor used for Monostable mode. During the night, it stops rotating and in the morning, again starts working and detects the sun to attain maximum sun's energy.

POWER FED FROM BATTERY TO LED LAMPS: The energy produced by PV module saved in battery during day time and supplies to LED lamps during the night. SPDT Relay is used to interface the battery power and power from a grid source with LED street lighting. When grid is used as a source, then the relay is energized and the powers from the battery side automatically cuts off when power from the grid source gets switched off, then relay de-energized and connects power from battery to LED street lights.

The advantages of tracking system are continually orient PV panels towards the sun and attain maximum energy; they are beneficial as the sun position in the sky will change gradually over the length of a day and over the seasons throughout the year.

Chapter 4

ANALYSIS BETWEEN HPS AND LED AND DESIGN OF PV OFF-GRID SYSTEM

4.1 COMPARISON:

Figure 4.1: Night time lighting view of the HPS and LED lamp of different rating

The above picture shows the difference between High Pressure Sodium Lamp (250W) and Light Emitting Diode (120W). The white LED street light seems brighter due to its higher CRI>80 (color rendering index) and objects illuminated could be identified clearly. Objects are hard to be identified in case of HPS because of low CRI-40, though HPS produces much more lumens. Therefore, no need for LED lights to reach same Lux levels as HPS to achieve the equivalent luminous effect.

The specifications of HPS and LED lamps are following here.

LED Lamp, 120W specification:

- Power = 120W
- Input voltage = AC 85-265V
- Working frequency = 50-60 Hz
- Working temperature = -45^{o} to 50^{o}C
- Lamp efficiency: >95%
- Harmonic Distortion: <10%
- Power factor: >0.95
- LED luminous efficiency: 90-100 lm/W
- Luminous flux: >10200 lm

- Colour (CRI): cool white / white: Ra>80, warm white: Ra>70
- Colour temperature: 6000-7000K, warm white:3000-4000K
- Beam angle: 120^0, 90^0

HPSV LAMP, 250W SPECIFICATIONS:

- Power = 250W
- Colour temperature = 1900/2000K
- High CRI = 40
- Lamp voltage = 127/253V
- Luminous flux = 2800lm/3200lm
- Colour of light – Pink orange

4.2 TOTAL INITIAL COST OF LED LAMP: At **Thapar University**, approximately 200 Street Light, lamps are used which consists of 95% Sodium vapour lamp (250W) and 5% Metal halide lamps. If we replace these lamps with LED lamps then we can save large amount of energy, electricity bills and also reduce Co_2 emissions per year.

The cost of one 120W LED lamp = Rs 12000

Cost of 200 pieces of 120W LED lamp = Rs 12000×200 = Rs 24, 00,000

4.3 ENERGY SAVING PER YEAR IF HPS LAMP REPLACE WITH LED:

- **HIGH PRESSURE SODIUM LAMP:**

1. Lamp: High Pressure Sodium Lamp (250W)
2. Working life: 24000 hrs
3. Startup speed: quite low(over 10 min)
4. Environmental pollution: contains a lead element
5. Maintenance: frequent maintenance required

Calculation:

1. The Power consumed by 250W per day with 1 fixture for 10 hrs burning = (250/1000) ×10 hrs = 2.5 kWh = 2.5 units
2. The Power consumed by 250W per day for 200 fixtures for 10 hrs burning = (250/1000) ×10 hrs ×200 = 500 kWh = 500 units
3. Total Co_2 emissions per year = 182 tones

- **LIGHT EMITTING DIODE:**

1. Lamp: Light Emitting Diode (120W)

2. Working life: Long > 50000hrs
3. Start speed: Rapid (2s)
4. Heating: Cold light
5. Environmental pollution: less as compared to HPS
6. Maintenance: Almost NIL

Calculation:

1. The Power consumed by 120W per day with 1 fixture for 10 hrs burning = (120/1000) ×10 hrs = 1.2 kWh = 1.2 units
2. The Power consumed by 120W per day for 200 fixtures for 10 hrs burning = (120/1000) ×10 hrs ×200 = 240 kWh = 240 units
3. Total Co_2 emissions per year = 87.36 tones

- **POWER SAVING:**

1. Per day Power saving with 200 LED fixtures = 500-240 = 260kWh = 260 units
2. Per month Power saving with 200 LED fixtures = 260×30 = 7800 units
3. Per year, Power saving = 7800×12 = 93600 units

- **MONEY SAVING:**

1. Total money saving per year = Total no. of units × unit cost per kWh
2. Unit cost per kWh of public lighting = Rs 6.10 (according to Punjab Power Regulatory Commission report, 2014)
3. Total Saving = Rs 6.10×93,600 = Rs 570960

- **Co_2 REDUCTION:** Co_2 emissions reduction per year = 182- 87.6 tons = 94.64 tons per year
- **PAY BACK PERIOD:**

  Annually maintenance cost of LED = Nil

  Formula used = (Initial cost) / (annually saving) – Maintenance cost

  = 2400000/570960 = 4.2 yrs

4.4 DESIGN OF PV OFF-GRID SYSTEMS FOR STREET LIGHTS AT THAPAR UNIVERSITY:

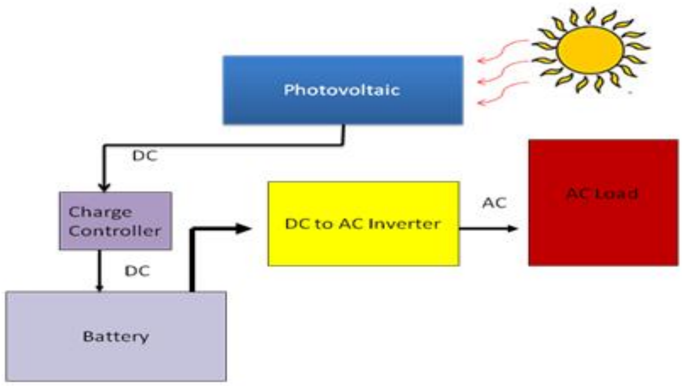


Figure 4.2: Stand-alone PV system with battery storage

At **Thapar University** near 200 street lights are used for lighting during night and each LED Lamp will be of 120W rating. The system components used are following.

i. **Solar panels:** A number of photovoltaic modules are connected in parallel or series, which gives a DC output of the incident irradiance. The important design parameters of PV modules are orientation and tilt as well as shading from surroundings obstructions. Different types of solar cells are there. e.g.

- **Monocrystalline Cells:** These are made using cells cut from a single cylindrical crystal of silicon. It offers the highest efficiency (18%) and their complex manufacturing process makes them slightly more expensive.
- **Polycrystalline Cells:** These are made by cutting micro-fine wafers from ingots of molten and crystallized silicon. These are cheaper to produce, but there is a slight compromise on efficiency (14%).

ii. **Solar charger controller:** It is the main component of PV off-grid system, also called brain of the system. It is responsible for performance, durability and functions. It is also known as solar regulator. It controls the flow of current to and from batteries to protect it from overcharging, after reaching the required voltage within the battery. It also protects again overcharging when the load causes critical/min voltage within the battery.

iii. **Batteries:** The battery bank used number of deep cycle batteries connected in series-parallel depending upon the requirement of voltage and current. The power produced by PV modules is saved in batteries and discharge it when we need it. The electrical power stored in batteries used for lighting during night.

iv. **Pure sine wave inverter:** A power converter that converts the DC power produced by solar modules into AC power. The characteristics of output signal should match the voltage, frequency and power quality limits in the network. The rating of the inverter is in watt or kilowatt.

v. **Load:** It is the component responsible to absorb this energy and transform it into work

- **DESIGN OF PV OFF-GRID SYSTEM:**

A. Determine power consumption demands: The first step in designing a solar PV system is to find out the total power and energy consumption of all loads that need to be supplied by the solar PV system as follows:

Total lighting load = 120W×200 = 24000W

The lamps used 10 hrs per day = 24000×10hrs = 240000 Wh/day

The total PV panels, energy needed = 240000×1.25 = 300000 Wh/day (+25% reserves energy and losses)

Sizing the PV generator:

Total W_p of PV panel capacity needed = 300000/7 = 42857 W_p

Factor **7** = Avg. Daily solar exposure in hrs in Patiala during summer but in winter it may be 4-5 hrs.

No. of PV panels needed = 42857/180W_p = 238 module of 180W_p

This system should be powered by at least 238 modules of 180W_p which will be connected in series-parallel connection.

B. Sizing the inverter:

Total wattage of Lighting load = 24000W

For safety, the inverter should be considered 25-30% bigger size.

The inverter size should be about 24000×1.3 = 31200W = 32000W or greater.

C. Sizing the battery:

Total Lighting load = 24000W×10hrs

Nominal battery voltage = 24V

Days of autonomy = 3 days

Battery loss = 0.85

Depth of discharge = 0.5

Battery Capacity (Ah) = total watt-hrs used by load× days of autonomy/ (battery loss× depth of discharge× nominal voltage)

Battery Capacity = (24000W×10hrs) × 3/ (0.85×0.5×24)

Total Amperes-hrs required= 70588Ah

So, the battery should be rated 24V and near 70588Ah for 3 day autonomy.

D. Sizing the charge controller:

Technical specifications of 180W_p module are as given below:

Power = 180W_p

Voltage = 24V

Current = 5A

Type – Polycrystalline

Module efficiency = 14.3%

Temperature = 25^o C

Dimension = 1593×790×50 mm

Area of single panel = 1258470 mm or 1.259 m^2

Tilt angle (slope) of PV module = 30^o 7’

Mounting – fixed type

Current (A): The rated current for solar charge controller = (238×5A) ×1.25 = 1487.5A (25% safety buffer).

Solar charge controller should be rated at 1487.5A or greater.

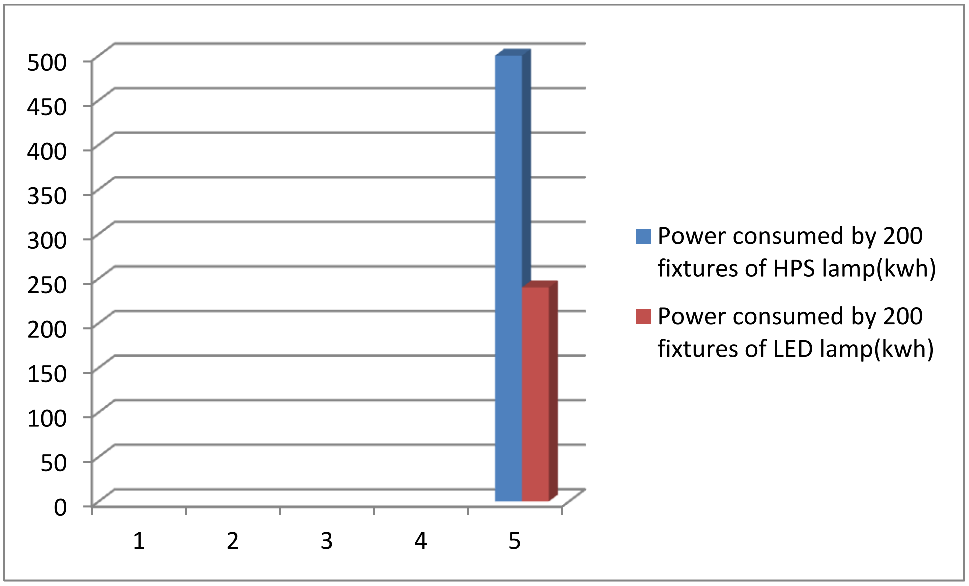
Voltage (V): The PV voltage (V_{oc}) of 238×180W_p panels, connected parallel will be 24×1.2 = 28.8V (20% safety buffer).

The maximum allowed voltage within a 24V PWM controller is 52V and it should not exceeded 28.8V.

According to the above calculation (238×180W_p) 1487.5A PWM charger controller for 24V system should be chosen.

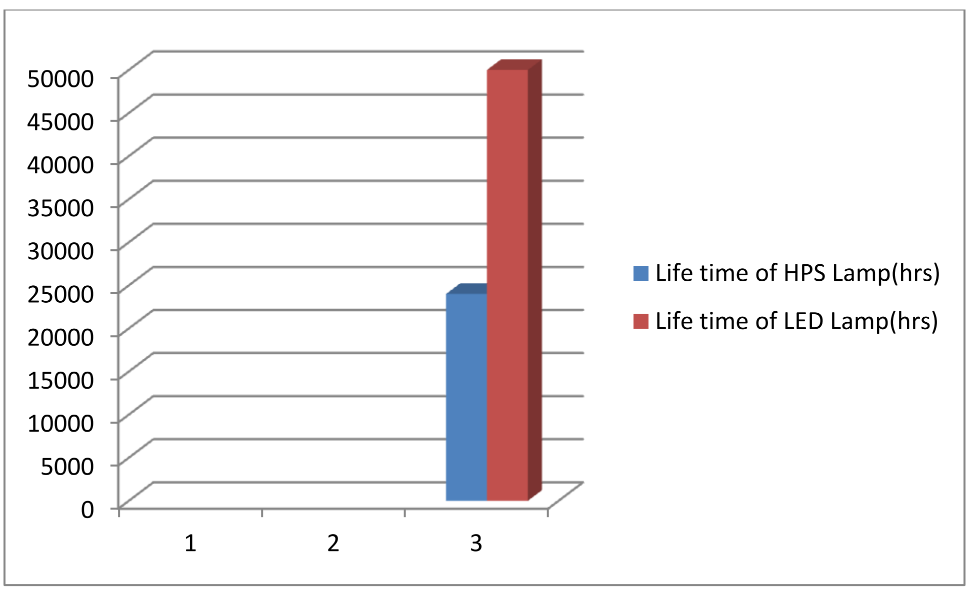
4.5 GRAPHICAL REPRESENTATION OF CALCULATIONS:

1. The graph 4.1 represents the power consumed by 200 fixtures per day by High Sodium Vapour Lamp and LED Lamp.



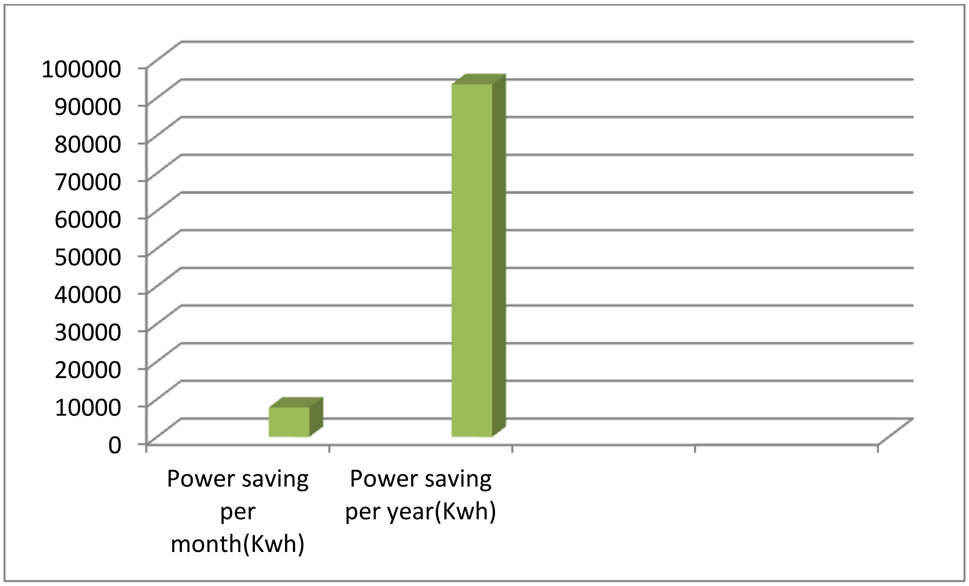
Graph 4.1: Power consumed by HPS Lamp and LED Lamp

2. The graph 4.2 represents the life time hrs of HPS and LED Lamp



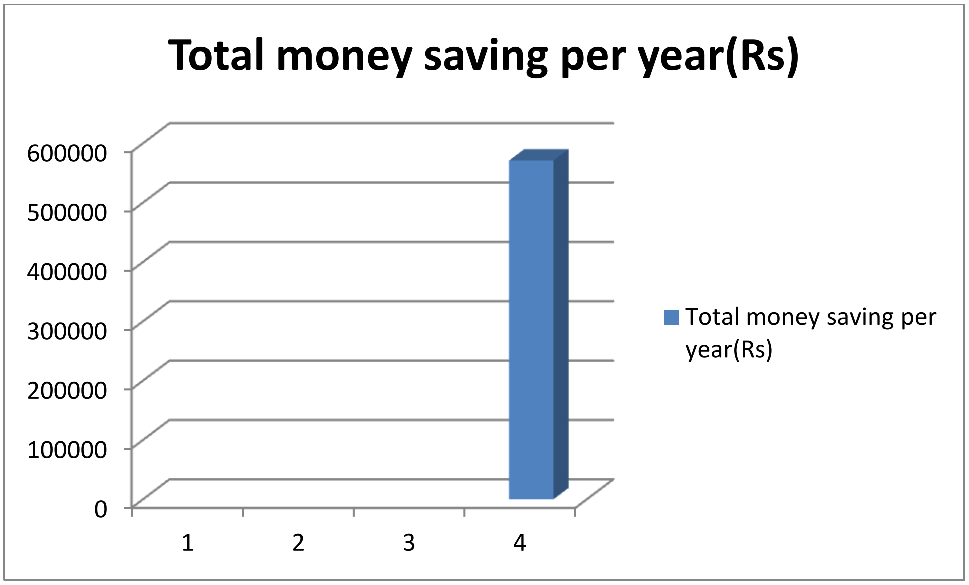
Graph 4.2: Life time hrs of HPS and LED Lamp

3. The graph 4.3 represents the power saving per month and year by 200 fixtures if we replace HPS Lamp with LED



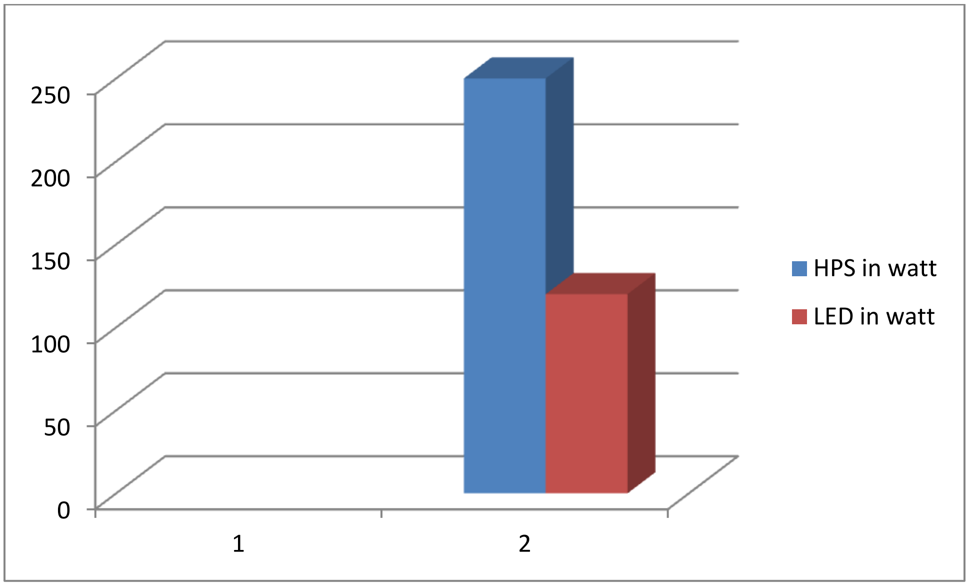
Graph 4.3: Annually Power saving

4. The graph 4.4 represents the money saving in a year.



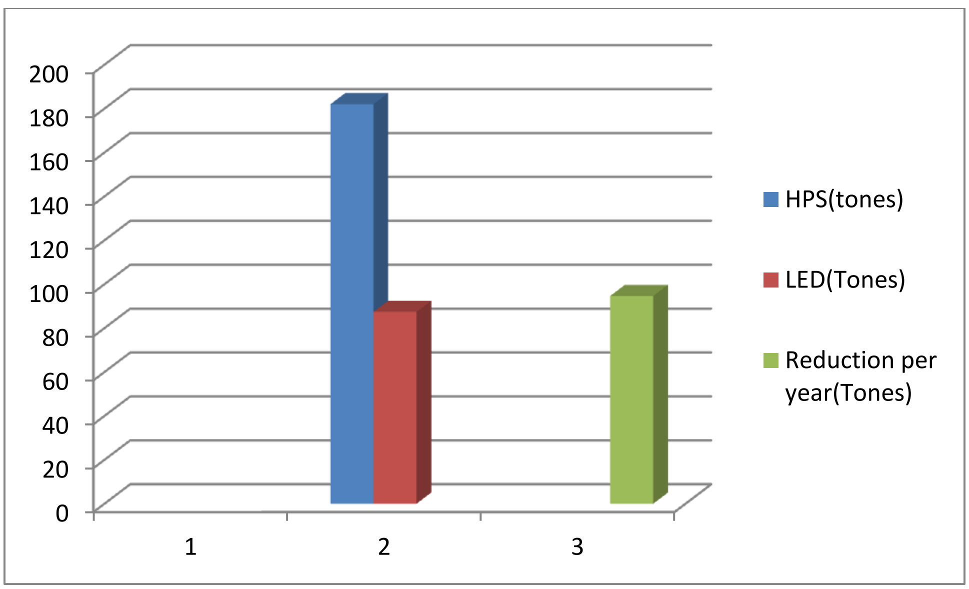
Graph 4.4: Annually money saving

5. The graph 4.5 represents the usable power of HPS and LED



Graph 4.5: Usable Power by HPS and LED

6. The graph 4.6 represents the reduction of Co_2 per year by replacing HPS with LED



Graph 4.6: Co_2 reduction per year

4.6 CHARGING AND DISCHARGING CHARACTERISTICS OF THE BATTERY USED WITH THE SOLAR PANEL:

- For any battery based electrical system, it is essential to study the charging and discharging characteristics of the battery to ensure satisfactory operation when it will be connected in actual operating conditions. For the system used in present work, both the characteristics are observed in a satisfactory irradiance conditions and those are stated below in the figure. 4.7 and figure 4.8.

  The charging voltage of the battery in four minute interval is shown in the table 4.1 and the observations are represented in the figure 4.7 as the charging characteristics. It is observed that the voltage is gradually increased with respect to time and reached to a 12.76V which remains constant after that. As per specification, the charging voltage which is the output of the solar panel is 13.7V in ideal operating condition. But as per the irradiance level on 8th July, 2014 of the observation, it is found as maximum 12.76V.
- The discharging characteristics as shown in figure 4.8 are drooping in nature as per the common discharge characteristics of the battery.
- Load current when LED Lamps blow in Dim mode = 0.12A

  Load current when LED Lamps blow in Full mode = 0.26A

  Battery voltage = 12V

  Power = voltage × current

  So, power of load during Dim mode = 0.12A × 12V = 1.44W

  Power of load during Full mode = 0.26A × 12V = 3.12W

4.6.1 Battery Specifications:

i. Battery type = Sealed maintenance free (SMF) Lead-Acid Battery

ii. Ah capacity = 2.5Ah

iii. Rated Voltage = 12V

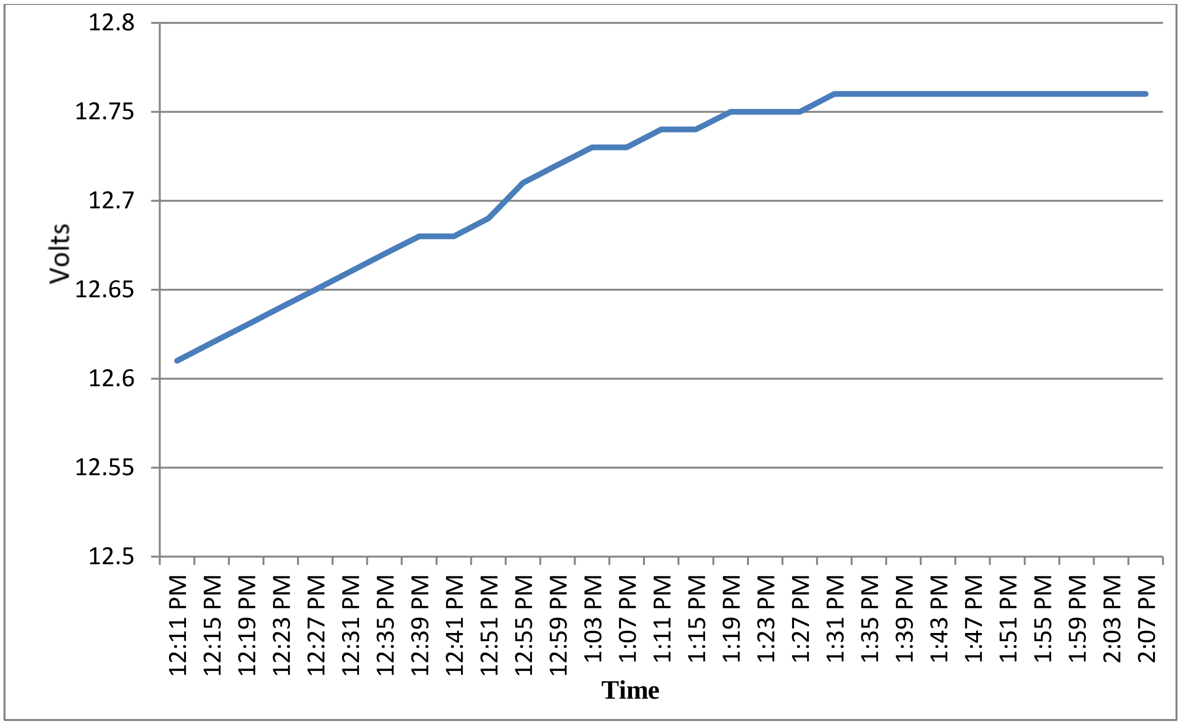
iv. Charging Voltage = 13.7V

v. Nominal current rating = 750mA

4.6.2 Charging Characteristics:

Table no. 4.1: Reading of battery voltage during charging

Sr. No.	Time (4 min. interval)	Voltage(V)
1	12:11PM	12.61
2	12:15 PM	12.62
3	12:19 PM	12.63
4	12:23 PM	12.64
5	12:27 PM	12.65
6	12:31PM	12.66
7	12:35 PM	12.67
8	12:39 PM	12.68
9	12:41 PM	12.68
10	12:51 PM	12.69
11	12:53 PM	12.71
12	12:55 PM	12.71
13	12:57 PM	12.72
14	1:01 PM	12.72
15	1:05 PM	12.73
16	1:09 PM	12.73
17	1:13 PM	12.73
18	1:17 PM	12.74
19	1:21 PM	12.75
20	1:25 PM	12.75
21	1:29 PM	12.76
22	1:33 PM	12.76
23	1:37 PM	12.76
24	1:41 PM	12.76
25	1:45 PM	12.76
26	1:49 PM	12.76
27	1:54 PM	12.76
28	1:59 PM	12.76
29	2:03 PM	12.76
30	2:07 PM	12.76

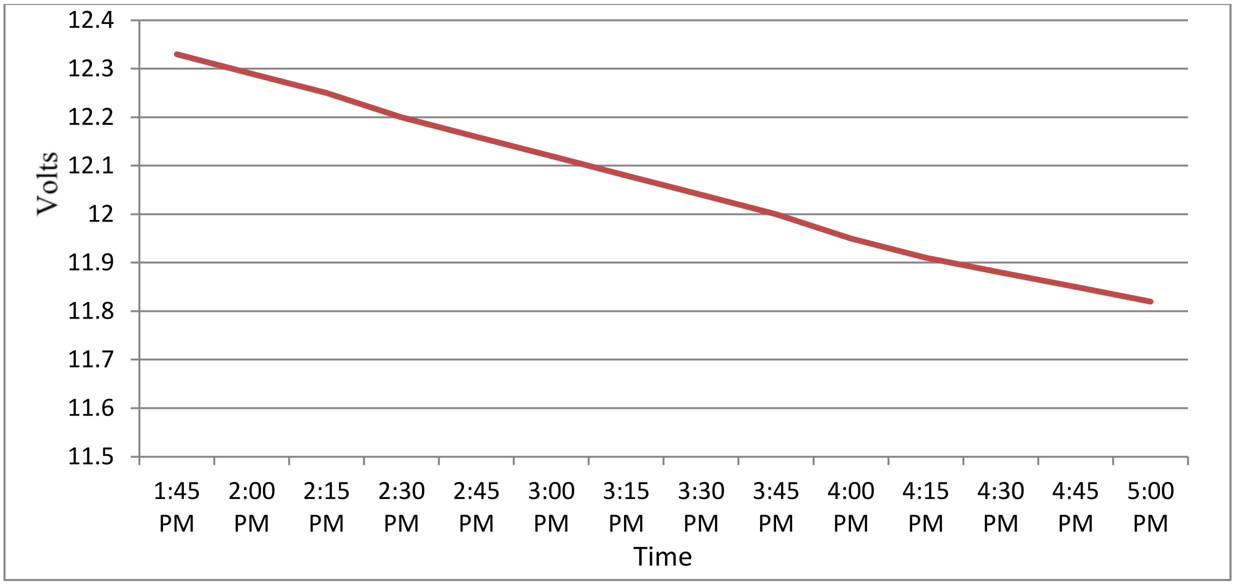


Graph 4.7: Battery charging characteristics

4.6.3 Discharge characteristics:

Table no. 4.2: Reading of battery during discharging when connected with load

Sr. No.	Time (15 min. interval)	Voltage (V)
1	1:55 PM	12.33
2	2:00 PM	12.29
3	2:15 PM	12.25
4	2:30 PM	12.20
5	2:45 PM	12.16
6	3:00 PM	12.12
7	3:15 PM	12.8
8	3:30 PM	12.4
9	3:45 PM	12
10	4:00 PM	11.95
11	4:15 PM	11.91
12	4:30 PM	11.88
13	4:45 PM	11.85
14	5:00 PM	11.82
15	5:15 PM	11.78



Graph 4.8: Battery discharge characteristics

Chapter 5

RESULTS AND CONCLUSION

5.1 EXPERIMENTAL SETUP:

- **AUTO LIGHT INTENSITY CONTROL OF LED LAMPS:**

- **NORMAL VIEW:**

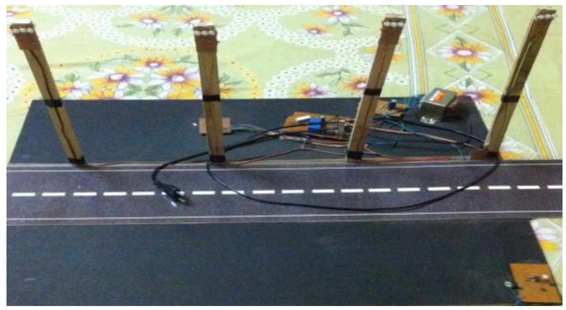


Figure 5.1: Hardware view of auto light intensity control of LED lamp

- **IN DIM MODE:** When there is no traffic on the road, the LED lamps work in DIM mode, which save energy during the night.

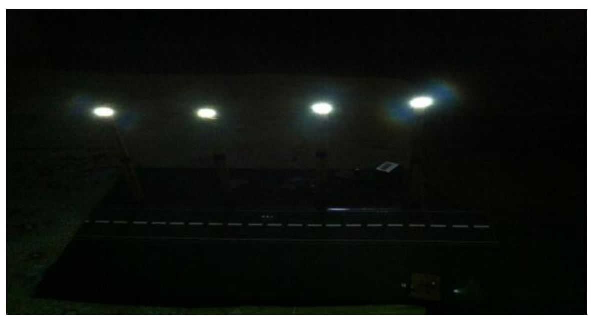


Figure 5.2: Hardware View in Dim mode

- **IN FULL MODE**: When any vehicle passes on the road, then the IR sensor placed opposite to transmitter detects it and increases LED lamp intensity for the few seconds that is depended upon timer IC output interval time.

Figure 5.3: Hardware View in full intensity mode

5.2 EXPERIMENTAL RESULT:

5.2.1 TRANSMITTER OUTPUT:

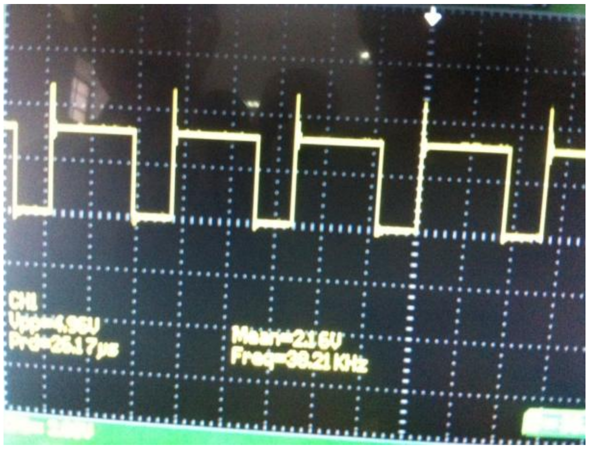


Figure 5.4: NE 555 Timer IC output waveform of transmitter circuit

Figure 5.5: Infrared white LED during dim mode waveform of transmitter circuit

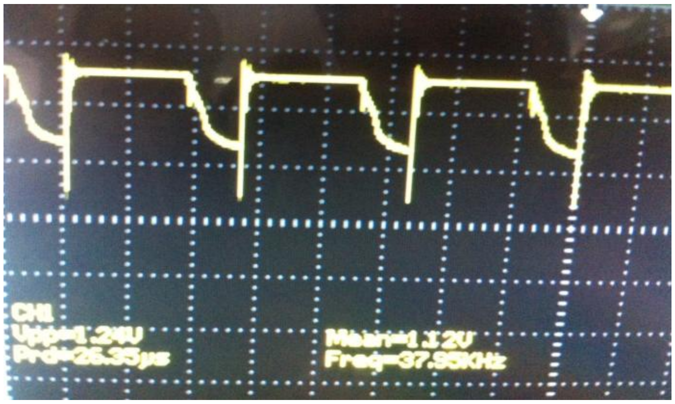


Figure 5.6: Infrared white LED during full mode waveform of transmitter circuit

5.2.2 TRANSFORMER OUTPUT:

Figure 5.7: Transformer output waveform

5.2.3 FULL WAVE RECTIFIER OUTPUT:

Figure 5.8: Full wave rectifier output waveform

5.2.4 IC 7805 OUTPUT:

Figure 5.9: output waveform of IC 7805

5.3 CONCLUSION:

In conventional system high intensity discharge lamps are used for street lighting system based on the principle of gas discharge. The system efficiency is very less. There are techniques present which control the light intensity of these Lamps so that energy wastage can be minimized during night when there is no traffic on road. But the proposed system has many advantages over the conventional one. It reduces the energy wastage so the efficiency of the system increases. The proposed system has less number of components. So, the system is less complex and more economical. The proposed system is modeled and a hardware prototype is developed in the lab. Sun tracking system is used to extract maximum solar energy .The solar energy is converted to DC power stored in a 12 volt, 2.5Ah battery with the help of solar panel. DC power serves as the standby supply in case of load shedding. The charging and discharging time and the voltage developed across the battery because of the solar panel connected at the source end are recorded at an interval of four and fifteen minutes respectively. The recorded data's are presented in tabular form as well as graph. The main supply is rectified and fed to the lighting loads. In case of obstacles near the lights the LED will glow with full intensity otherwise dim lighting will be there reducing the wastage of extra energy. The proposed system calculation shows 50% of energy saving compared to conventional system.

5.4 FUTURE SCOPE:

In the future, Mathematical and simulink model of the proposed system can be developed. Stability analysis can be done.

REFERENCES

1. Ali M., Orabi M., Abdelkarim E., Qahouq J.A.A., Aroudi A.E., "Design and development of energy-free solar street LED light system," *IEEE PES Conference on Innovative Smart Grid Technologies - Middle East (ISGT Middle East), Saudi Arabia*, pp. 1- 7, 17-20 Dec. 2011.
2. Adaime Pinto, R., Roncalio J.G., do Prado R.N., "Street lighting system using light emitting diode supplied by the mains and by batteries," *International Conference on New Concepts in Smart Cities: Fostering Public and Private Alliances (Smart MILE), Spain*, pp.1-7, 11-13 Dec. 2013.
3. Ahmed Sanjana," Solar Powered traffic sensitive automated LED street lighting system", *B.E Thesis submitted at BRAC University*, Dec 2012.
4. Amin Chaitanya and Kaul Rahul," GSM based Autonomous Street Illumination System for Efficient Power Management", *International Journal of Engineering Trends and Technology*, Vol. 4 Issue 1, 2013.
5. Castro M., Jara A.J., Skarmeta A.F.G., "Smart Lighting Solutions for Smart Cities," *27th International Conference on Advanced Information Networking and Applications Workshops (WAINA), Spain*, pp. 1374-1379, 25-28 March 2013.
6. Davis Wesley," Intelligent street lighting application for electric power distribution systems", *MS Thesis submitted at B.S., North Carolina Agricultural & Technical State University*, 2011.
7. Ereu G.M., Mantilla J.O., "A Methodology to Determine Electrical Energy Consumption in Street Lighting Systems," *IEEE/PES on Transmission & Distribution Conference and Exposition: Latin America,* pp. 1-5, 15-18 Aug. 2006.
8. Lee J.D., Nam K.Y., Jeong S.H., Choi S.B., Ryoo H.S., Kim D.K., "Development of Zigbee based Street Light Control System," *IEEE PES Conference on Power Systems and Exposition*, pp. 2236- 2240, Oct. 29-Nov. 1 2006.
9. Li Lian, Li Li "Wireless dimming system for LED Street lamp based on Zigbee and GPRS," *3rd International Conference on System Science, Engineering Design and Manufacturing Informatization, China*, vol. no. 2, pp. 100-102, 20-21 Oct. 2012.

10. Latha D. V. Pushpa," Simulation of PLC based Smart Street Lighting Control using LDR', *International Journal of Latest Trends in Engineering and Technology (ICSEM)*, Vol. 2 Issue 4, July 2013.
11. License F., "Remote-Control System of High Efficiency and Intelligent Street Lighting Using a Zigbee Network of Devices and Sensors," *IEEE Transactions on Power Delivery*, Vol. 28, Issue 1, pp. 21-28, Jan. 2013.
12. Mullner Reinhard and Reiner Andreas," An energy efficient pedestrian aware Smart Street Lighting system", *International Journal of Pervasive Computing and Communications",* Vol. 7, Issue 2, pp 147-161, 2011.
13. Natu Omkar," GSM Based Smart Street Light Monitoring and Control System", *International Journal on Computer Science and Engineering*", Vol. 5, Issue 03, Mar 2013.
14. Pantoni R.P., Brandao D., "A geocast routing algorithm intended for street lighting system based on wireless sensor networks," *9th IEEE/IAS International Conference on Industry Applications (INDUSCON), Brazil,* pp. 1-6, 8-10 Nov. 2010.
15. Po-Yen Chen;, Yi-Hua Liu, Yeu-Torng Yau, Hung-Chun Lee, ,"Development of an energy efficient street light driving system," *IEEE International Conference on Sustainable Energy Technologies, ICSET, Singapore*, pp.761-764, 24-27 Nov. 2008.
16. Popa M and Marcu A," A Solution for Street Lighting in Smart Cities", *Carpathian Journal of Electronics and Computer Engineering*, Vol. 5, pp. 91-96, 2012.
17. Priyasree Radhi, Kauser Rafiya," Automatic Street Light Intensity Control and Road Safety Module Using Embedded System", *International Conference on Computing and Control Engineering, Chennai*, 12-13 April, 2012.
18. Rajput K.Y and Yadav Priyanka," Intelligent Street Lighting System Using Gsm", *International Journal of Engineering Science Invention*, Vol. 2 Issue 3, PP. 60-69, March 2013.
19. Sarimin Nuraishah and Mohamad Najmiah Radiah," Zigbee based Smart Street Lighting System", *International Journal of Computer Trends and Technology*, vol. 4 issue 4, 2013.

20. Siddiqui A.A., Ahmad A.W., Hee Kwon Yang, Chankil Lee, "ZigBee based energy efficient outdoor lighting control system," *14th International Conference on Advanced Communication Technology (ICACT), Korea*, pp. 916-919, 19-22 Feb. 2012.

21. Srivastava Sakshee," Automatic Street Lights", *Advance in Electronic and Electrical Engineering*, ISSN 2231-1297, Vol. 3, Issue 5, pp. 539-542, 2013.

22. Singh Jasvir and Ganguli Souvik,'' Study and Design of Grid Connected Solar photovoltaic system at Patiala, Punjab", *M.E Thesis submitted at Thapar University*, July 2010.

23. Srivatsa D.K., Preethi B., Parinitha R., Sumana G., Kumar A, "Smart Street Lights," *Texas Instruments Conference on India Educators (TIIEC), India* , pp.103-106, 4-6 April 2013.

24. Thoreseth Anders," Characterization, Modelling and optimization of light emitting diode systems", *Ph.D Thesis submitted at Technical University of Denmark*, 31 March 2011.

25. Vitta P, Tuzikas A and Zukauskas A," Concept of Intelligent Solid – State Street Lighting Technology", *ELEKTRONIKA IR ELEKTROTRCHNIKA, ISSN* 1392-1215, VOL. 18, Issue 10, 2012.

26. Wu Yue, Shi Changhong, Zhang Xianghong, Yang Wei, "Design of new intelligent street light control system," *8th IEEE International Conference on Control and Automation (ICCA), China*, pp. 1423-1427, 9-11 June 2010.

27. Wei Liu Chee," Modular Intelligent Control System", *B.E Thesis submitted at Tunku Abdul Rahman University*, May 2011.

28. Yun-gui Zhang, Li-na Zhao, Li-na Wang, Sheng-Yong Zhang, "A Web-Based Management System for Urban Road Lighting," *International Conference on Web Information Systems and Mining (WISM), Sanya*, vol. no. 2, pp. 279-282, 23-24 Oct. 2010.

29. Yusoff Yusnani Mohd," Towards Smart Street Lighting System in Malaysia", *IEEE Symposium on Wireless Technology and Applications (ISWTA), Malaysia*, Sep. 22-25, 2013.

30. Zotos N., Stergiopoulos C., Anastasopoulos K., Bogdos G., Pallis E., Skianis C., " Case study of a dimmable outdoor lighting system with intelligent management and remote

control," *International Conference on Telecommunications and Multimedia (TEMU), Greece*, pp. 43-48, July 30-Aug. 1 2012.

APPENDIX

A. REFERENCE LINKS:

1. www.instapower.com
2. www.grahlighting.eu
3. http://www.nofs.navy.mil/about_NOFS/staff/cbl/lumentab.html
4. http://www.designrecycleinc.com
5. http://www.gg-energy.com
6. http://megabrightsignsandlights.com
7. http://electricalnotes.wordpress.com
8. http://www.ti.com
9. http://pvshop.eu/offgrid
10. http://www.gelighting.com
11. http://www.energystar.gov
12. http://www.pveducation.org
13. http://www.solarchoice.net.au/
14. http://www.sustainableluminaires.com/savingscalculator.html

B. REFERENCES DATA SHEETS:

1. BC 547 Transistor data sheet
2. Infrared TSOP 382 data sheet
3. Light Emitting Diode data sheet
4. NE 555 timing IC data sheet
5. SPDT Relay data sheet
6. Transistor 7805 data sheet

C. PUBLICATIONS:

1. 'Review of an Energy Efficient Smart Street Lighting System'- Published in IJR (INTERNATIONAL JOURNAL OF RESEARCH), Vol. No. 1, Issue 5, pp.1018-1023, June 2014.

D. REQUIREMENT FOR PROPOSED WORK:

➢ AUTO LIGHT INTENSITY CONTROL OF LED LAMP

S. NO.	COMPONENTS	VALUE	TYPE	QUANTITY
1	TRANSFORMER	12012	Step down	1
2	DIODE	……....	IN4001	5
3	7805 TRANSISTOR	………	………	1
4	NE 555 TIMER	………	………	2
5	NPN TRANSISTOR	……....	BC 547	3
6	CAPACITOR	0.001,0.01uF,10nF	Ceramic	3
9	CAPACITOR	2200uF, 25V	Electrolyte	1
10	CAPACITOR	100uF, 25V	Electrolyte	1
11	RESISTANCE	10KΩ, 4.7 KΩ	………..	2
12	RESISTANCE	500KΩ	Variable resistance	1
14	IR LED	………..	White	1
15	IR RECEIVER TSOP- 382	……….	………	1
16	RELAY	12V	SPDT	2
17	LED LAMP	………..	……..	12
18	RIBBON WIRE	…….	……..	…….
19	GENERAL PURPOSE PCB	………	Small	5

➢ AUTO SWITCHING OF SMART STREET LIGHTING SYSTEM

S. NO.	COMPONENT	VALUE	TYPE	QUANTITY
1	TRANSISTOR 7805	……….	……….	1
2	LDR	....	……….	1
3	RESISTANCE	10KΩ	……….	1
4	NPN TRANSISTOR	……….	BC 547	1
5	DIODE	……….	……….	1
6	RELAY	6V	SPDT	1
8	GENERAL PURPOSE PCB	……….	……….	1

- SUN SEEKER

S. NO.	COMPONENT	VALUE	TYPE	QUANTITY
1	SOLAR PANEL	12W,12V	Monocrystalline	1
2	BATTERY	12V,2.5Ah		1
3	LDR	....	……….	1
4	DC MOTOR	12V	Car window motor	1
5	TRANSISTOR 7805	……….	……….	1
6	NPN TRANSISTOR	……….	BC 547	2
7	NE 555 TIMER	……….	……….	2
8	RELAY	12V	SPDT	2
9	RESISTANCE	200KΩ	……….	2
10	RESISTANCE	2Ω,15W	……….	1
11	CAPACITOR	100uF,25V	Electrolyte	1
12	WOODEN BASE	……….	……….	1
13	PANEL SUPPORT	……….	……….	1
14	GENERAL PURPOSE PCB	……….	……….	1

- BATTERY INTERFACE CIRCUIT WITH LOAD

S. NO.	COMPONENT	VALUE	TYPE	QUANTITY
1	SPDT RELAY	12V	………….	1
2	DIODE	………….	IN4001	1
3	CAPACITOR	1000uF, 25V	Electrolyte	1
4	+VE AND -VE TERMINAL WIRES	………….	Red and Black	2
5	+VE AND –VE CONNECTORS		Red and Black	2

E. HARDWARE SETUP:

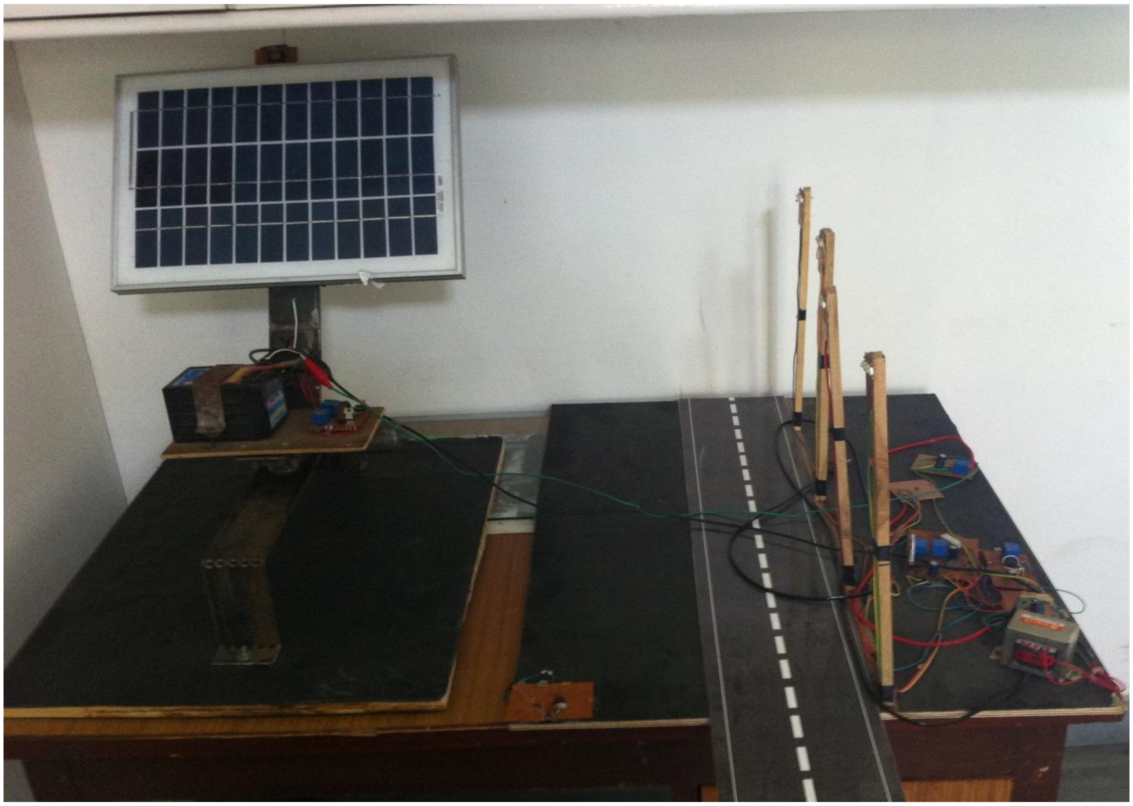


Figure: Complete Hardware Setup