STUDIES AND DEVELOPMENT OF A SMART STREET LIGHTING SYSTEM

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Submitted by

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I hereby declare that this thesis contains literature survey and original research work by the undersigned candidate, as part of her **M.Tech. in Illumination Technology and Design** studies during academic session 2019-2022.

All information in this document has been obtained and presented in accordance with academic rules and ethical conduct.

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ABSTRACT

Smart street lighting is a subject on intelligent illumination control of street lights to optimize the problem of power consumption and illumination of the streets in absence of the day light. Nowadays, the conventional street lights are replaced by high power Light Emitting Diodes (LEDs) street lighting system, which reduces the power consumption. By controlling the light output at night the energy consumption can be reduced and thus enhancing the life of the LED. This study proposes a model for modifying street light illumination by using sensors which result minimum electrical energy consumption. In this work, energy consumption is achieved by implementing a LED street lighting system using "Ambient light temperature sensor" and "Ultrasonic sensor". When surrounding lux becomes lower that the specified value, the street lights go on automatically and vice-versa. Additionally, when any moving element is detected (at night condition), then all street lights glow at their brightest mode, otherwise they stay in the dimming condition. In this work, the conventional SON (High pressure sodium vapour), SOX (Low pressure sodium vapour) and Mercury vapour lamps are replaced by LED which reduces heat emissions, power consumption, maintenance and replacement costs than a conventional street light and also becomes eco-friendlier. An attempt is made in this study to develop a smart street lighting system using sensors that can be applicable for real time applications involving very lesser running costs and easier maintenance.

Keywords: Conventional Street lights, Energy consumption, Modifying street lighting illumination, Ambient light temperature sensor, Ultrasonic sensor, Eco friendly, Real time application, Running costs, Easier maintenance

CHAPTER – 1

INTRODUCTION

1.1: The benefit of using LED as street light

Light is very essential in daily life. Previously different types of light sources such as Carbon Arc lamp, Ceramic metal-halide lamp, Hydrargyrum medium-arc iodide lamp, Mercury Vapour lamp, Metal Halide lamp, Sodium-vapor lamp, Sulphur lamp and Xenon Arc lamp etc. are used but those did not have good energy saving capability and longer life span. Nowadays, Light Emitting Diode (LED) is expected to be replaced these lamps. A LED is a two-lead semiconductor light source. It is a p–n junction diode, which emits light when activated. When a suitable voltage is applied to the leads, electrons are able to recombine with electron holes within the device, releasing energy in the form of photons. This effect is called electroluminescence, and the color of the light (corresponding to the energy of the photon) is determined by the energy band gap of the semiconductor. An LED is often small in area (less than $1mm^2$) and integrated optical components may be used to shape its radiation pattern.

LEDs are small in size, durable and need lesser power, so they are used in handy devices such as flashlights. This is especially useful in cameras on mobile phones, where space is at a premium and bulky voltage-raising circuitry is undesirable.

Earlier LEDs were used as indicator lamps for electronic devices, replacing small incandescent bulbs. They are also packaged into numeric readouts in the form of seven- segment displays, and were commonly seen in digital clocks. Comparing to the other light sources LED has longer lifespan, Energy Efficiency, Improved Environmental Performance, The Ability to Operate in Cold Conditions, No Heat or UV Emissions, Design Flexibility, Instant Lighting and the Ability to Withstand Frequent Switching and Low Voltage Operation.

The major uses of LED (Light Emitting Diodes) are in front lights and backlights. Moreover, they use microstructure optics technology to illuminate the light. Microstructure optics is a waveguide found in Liquid Crystal Display monitors, PDAs, cell phones, and other displays. Its application is everywhere due to its compactness in size, lesser energy consumption, extended lifetime, and flexibility.

LED technology has the potential to improve mine safety in several areas. Illumination from LEDs can potentially improve a miner's visual performance for the detection of mine hazards. LEDs can be used for visually communicating warnings and alert, also reduce glare and helps to increase illumination level, reducing the risk of the injury of labours.

LEDs are now used very commonly in different homebased applications as well as commercial applications like: commercial spaces such as offices, stores, institutions, hospitals and government buildings, LEDs can be used stage lighting, theatrical lighting, architectural lighting, and different Decorative lightings wherever artificial light is used.

The usage of LEDs differs in various shapes and sizes based on the different places of application and light output, such as DIP (Dual in Package), SMD (Surface Mounted Device) & COB (Chip On Board) etc.

1.2: Aims and Objectives of the study

Despite having all the above mentioned benefits of LEDs, these general LED street lights (conventional type) are having limitations over the proposed smart LED street lighting system (using various sensors and control unit) in various aspects like energy consumption, efficacy, light output and performance. Using various sensors and logical circuit we can control the general characteristics of a LED street lighting system to make it SMART thereby enhancing its energy efficiency, eco-friendliness which consists lesser maintenance cost also.

So, in this study the main objectives which are tried to be fulfilled that to build up a smart street lighting system which uses some kind of sensors which enables streetlight luminaires to be operated automatically (switching ON & OFF and to glow in brightest and also fully dimmed condition) based on the actual surroundings requirement.

The study also consists of some desirable outcomes to be fulfilled:

- **High Lamp Efficiency:** Try to get more lumens (or brightness) per watt of energy,
- **Cost-Effectiveness:** Try to get low running costs,
- **Life of the system:** Aiming more life than the conventional one,
- **Power Consumption:** Lesser power consumption is desirable.

Introducing sensors for Ambient lux checking and Occupancy checking can help more to achieve the desired outcomes of lesser energy consumption.

But comparing to the others conventional Gas discharge lamps, sometimes LED lights have the drawback of its high initial investments of purchase and installations and somewhere issues are also reported of the failure of LED.

This study describes an intelligent street lighting system using LED is used with its controlled light output depending of the presence and absence of sunlight. This features of switching ON the lights only when surrounding lux level is below certain level and switching OFF the lights automatically when the surrounding lux level goes above of the specified lux value.

CHAPTER – 2

LITERATURE SURVEY

Literature Survey

Street lighting systems are still designed according to the old standards reliability and they often do not offer the latest technological advancements. The use of new technological advancements for the light sources are made of combination of sensors. There are different areas to be concentrated to achieve the high efficiency in the street lighting if the efficiency in each stage can easily be achieved the maximum efficiency in overall system development. The first one in this case, is to choose light emitting diodes (LEDs), instead of sodium vapor lamps (LPSV, HPSV & MV) and compact fluorescent lamps (CFL) because these are the best solutions since they offer benefits like long life and power saving.

Smart Street lighting is an intelligent system which can control and monitor the status of the individual street lamp and lights are switched to ON/OFF automatically by LDR status which depends on surrounding lux value. Intensity of the LED street lights are controlled on the basis of availability of surrounding lux value (day time or night time). LED has been the best potential light source for the next-generation lighting as it has many advantages such as high efficiency, long life, high reliability, and low power consumption.

The idea of this smart street lighting was studied by B. K. Subramanyam1 et al. [1], worked on intelligent wireless street light control and monitoring system, which integrates new technologies, offering ease of maintenance and energy savings. Using the solar panel at the lamp post and by using LDR, it is possible to save some more power and energy, and also can monitored and controlled the street lights using GUI application, which shows the status of the lights in street or highway lighting systems. It became essential for people work during nights and returning back to homes late nights; and also to stop the increasing crime rate during night times. This can be best achieved by implementing proper solar based lighting system on streets. We will get lesser power consumption, saving money through solar panel. Also saving precious time, decrease the huge human power through from the LDR, IR kind of Sensors. The Street lights are controlled through a specially designed Graphical User Interface (GUI) in the PC. The ZigBee technology can be used for the street lights monitoring and controlling at the PC end. When it becomes dusk then the street lights automatically gets turned on by the decreasing daylight lux level sensed by LDR and vice versa happened at the time of dawn. The voltage, current, lux level, luminous flux, brightness, efficiency, color temperature and CRI etc. also monitored in the PC and all the data are uploading continuously in the server through ZigBee technology. The system consists of a group of measuring stations in the street. (One station located in each lamppost) and a base station located nearby. The system is designed as a modular system, easily extendable. The LDRs are used to observe street light conditions as the light intensity of daylight and depending on the conditions they activate or off the lamps. Other factors influencing the activation are: climatic conditions, seasons, geographical location, and many possible alternative factors. For these reasons every lamp is designed independent to decide about the activation of light. The Control unit controls all the lighting system through a graphical user interface (GUI) application window we can control all the lights and we can monitor and status of the lights. The sensors transfer the collected information to a PC. ZigBee wireless communication network has been implemented with the utilization of radio frequency modules. They operate within the ISM band at the frequency of 2.4 GHz. The receiver sensitivity is high and therefore the chance of receiving bad packets is low (about 1%). The modules ought to be provided by 3V DC supply, and then the power consumption is within the order of 50 mA. The module supports sleep mode where consumption is smaller than 10μA.

P. Nithya et al. [2], in their work on Design of Wireless Framework for Energy Efficient Street Light Automation suggested an Intelligent management of the lamp posts by sending data to a central station by ZigBee [3] [4] [5] wireless communication. With the suggested system, maintenance can be easily and efficiently planned from the central station, allowing additional savings. The Internet of Things (IoT) refers to the transmission of data from devices to a master controller using gateways and current network procedures. Unlicensed and licensed spectrums are vital in the IoT market, according to market developments and studies. IoT systems use field sensors and data analysis to communicate with one other through the internet, allowing them to share and transmit information using a unique identifier provided to each item. In today's world, automation plays a key role, and IoT and LoRa [6] [7] can help to meet those needs. There is a considerable loss of electrical power in the street lighting and electrical systems due to the traditional on/off system, and studies are being conducted in the area to decrease he power loss using various technologies. IoT cloud server is utilized here for improved energy conservation and early resolution in case of any defect detection in mobile based surveillance with web. At this subject. a lot of research is being done to reduce energy loss in remote sites by introducing user-friendly applications. The major goal of this study is to create an automated and regulated street light that meets the needs of roadways, pedestrians, and vehicles. [8] Utilizing existing networks and unlicensed radio frequencies, a user-friendly control system to monitor and manage lighting systems from remote places using IoT and LoRa can meet the needs with low infrastructure expense. P. Nithya also works on Integration of Digital Addressable Lighting Interface (DALI) [9] [10] [11] devices in wireless sensor networks. Since different manufacturers usually deal with one aspect of building automation - e.g. heating ventilation and air conditioning, lighting control, different kinds of alarms, etc. - final building automation system has different subsystems which are finally taken to an integrated building management system. The main purpose is to provide the end consumer with an economical fully centralized system in which home appliances are managed by an [12] IEEE 802.15.4-based wireless sensor network. Not only is it necessary to focus on the initial investment, but maintenance and energy consumption costs must also be considered.

Srikanth M et al. [13], in their work on ZigBee Based Remote Control Automatic Street Light System. This streetlight control system helps in energy savings, detection of faulty lights and maintenance time and increase in life span of system. There are three areas to be concentrated to achieve the high efficiency in the street lighting if the efficiency in each stage can easily achieve the maximum efficiency in overall system development. The first one in this area, is to choose light emitting diode (LED) technology, instead of sodium vapor lamp and compact fluorescent lamp (CFL), because it is the best solution since it offers benefits like power saving and long life. The second solution is the most revolutionary, it uses a sensor combination to control and guarantee the desired system parameters; the information is transferred point by point using ZigBee transmitters and receivers and is sent to a control terminal used to check the state of the street lamps and to take appropriate measures in case of failure. Finally, the third possibility would be the use of renewable energy sources rather than conventional power sources with a positive effect on the all environment issues. The Solar energy is the most important resource in this field to achieve the maximum efficiency. Street light control system is a centralized system which control and monitor status of the individual street lamp. Lights are switched to ON/OFF automatically based on PIR and LDR status. Status information stored in the PIC controller and also monitored over all status in control base station via ZigBee communication channel, LED has been the best potential light source for the next-generation lighting as it has many advantages such as high efficiency, long life, high reliability, and low power consumption. The smart system is developed using Arduino Uno microcontroller kit. Arduino is an open-source hardware kit with 8-bit Atmel AVR pre-programmed on-board microcontroller kit, with boot loader that uploads programs into microcontroller memory. They are different type of Arduino based on their features it is being categorized some of them are Arduino Deicimila, Arduino UNO, Arduino Leonardo, Arduino Mega, Arduino Nano, Arduino Due, Arduino LilyPad and many more Development boards. Here for this study Arduino Uno R3 are used. The Arduino Uno R3 specification are ATmega328 microcontroller, operating voltage at 5v, input voltage 7 to 12v, input voltage limit up to 20v, digital I/O pins 14, analog pins 6, DC current 40mA, flash memory 32KB including 0.5KB used by boot loader. SRAM of 2KB, EEPROM of 1KB and clock speed of 16 MHz some of the Features of Arduino UNO are power: can be USB connection or external power supply, with 7 to 12 volts Recommended. The Arduino UNO provides power pins for other devices, the variants are 5v 3.3v and vin IOREF pin for optional power. Memory: It as 2KB of SRAM and 1KB of EEPROM. Input and Output pins: there are 14 digital pins with serial transfer and external interrupts and PWM pins as well and 6 analog pins. Communication: the ATmega 328 provides UART TTL serial communication which is available on 0 and 1 digital pins, the 16U2 firmware uses the standard USB COM drivers, and no external driver is needed. A Software Serial library allows for serial communication on any of the Uno's digital pins. Automatic reset is provided using software running on computer with Arduino Uno board connected to that computer. This IDE is supported for every product of Arduino components. In this project two sensors are being used and wireless device module to accomplish the objective of the study.

Anila Devi Y et al.[14]worked on GSM Based Remote Control System of High Efficiency Intelligent Street Lighting System Using a Zigbee Network of Devices and Sensor. New intelligent and smart street light system is designed with wireless technology for maintenance and network of sensors for controlling. In which, they used high efficiency LED lamp which consumes less energy with high life time and which are supplied with renewable energy of solar panels. Street light controllers are smarter versions of the mechanical or electronic timers previously used for street light ON-OFF operation. They come with energy conservation options like twilight saving, staggering or dimming. Also many street light controllers come with an astronomical clock for a particular location or a Global Positioning System (GPS) connection to give the best ON- OFF time and energy saving. Automatic Street Light Control System is a simple and powerful concept, which uses transistor as a switch to switch ON and OFF the street light automatically. By using this system manual works are removed. It automatically switches ON lights when the sunlight goes below the visible region of our eyes. It automatically switches OFF lights under illumination by sunlight. This is done by a sensor called Light Dependent Resistor (LDR) which senses the light actually like our eyes. By using this system energy consumption is also reduced because now-a-days the manually operated street lights are not switched off properly even the sunlight comes and also not switched on earlier before sunset. In sunny and rainy days, ON time and OFF time differ significantly which is one of the major disadvantage of using timer circuits or manual. This study exploits the working of a transistor in saturation region and cutoff region to switch ON and switch OFF the lights at appropriate time with the help of an electromagnetically operated switch. A street light, lamppost, street lamp, light standard, or lamp standard is a raised source of light on the edge of a road or walkway, which is turned on or lit at a certain time every night. Modern lamps may also have light-sensitive photocells to turn them on at dusk, off at dawn, or activate automatically in dark weather. In older lighting this function would have been performed with the aid of a solar dial. It is not uncommon for street lights to be on poles which have wires strung between them, or mounted on utility poles.

Soyoung Hwang et al. [15], remote monitoring and controlling system based on ZigBee networks. Real-time remote monitoring is implemented with JMF [16] which is a multimedia extension API of Java. The system consists of a real-time home monitoring sub-system and a light control subsystem. A home server with a home camera caters for home status through video to client. It also works as a home gateway to provide interoperability between the heterogeneous ZigBee [17] [18] and Internet and local and remote control over the home’s light devices through the light control sub-system. A client can access the home server through a web service or smartphone. The client can monitor home status through a real-time monitoring sub-system and control the lights through the On/off control panel. It shows the operation process of the real-time monitoring sub-system. The server finds a video device and captures images. Then, it generates captured data and transforms the data format for RTP communication [19]. After that, it generates the session manager and streams media data to the client. A client using the web or a smartphone generates the session manager and connects to the server. Then, it receives media data and displays the video. In this way, the client can monitor the in-home status in real-time. Light control sub-system is composed of a server which works as a gateway, ZigBee coordinator, end-device, switch node and a light [20]. Recently, the home environment has seen a rapid introduction of networked digital technology. This technology offers new and exciting opportunities to increase the connectivity of devices within the home for the purpose of home automation. Moreover, with the rapid expansion of the Internet, there is the added potential for the remote control and monitoring of such networked devices [21]. ZigBee has become one of the most promising technologies for home networks. ZigBee is a specification for a suite of networking, security and application software layers using small, low-power, low data rate communication technology based on [22] IEEE 802.15.4 standard for personal area networks. Moreover, owing to the rapid growth of mobile technology, high performance smartphones are widespread and in increasing cases they are being utilized as a terminal device. This paper proposes design and implementation of a remote monitoring and controlling system based on ZigBee networks. The client program in a smartphone is implemented on the android platform [23]. Clients can monitor their homes and send light control commands using the web or a smartphone. This system can be applied in many areas such as elderly protecting systems, cultural heritage or forest fire monitoring systems, managing systems for agricultural cultivation and so on.

CHAPTER-3

THE FUNDAMENTALS OF SMART STREET LIGHTING

3.1: Smart Street Lighting

A smart streetlight is a kind of lighting fixture that incorporates technology, like installation of cameras, photocells and other sensors like occupancy sensor within itself in order to introduce real-time monitoring functionalities. These type of lighting also called as Adaptive Lighting as this type of lighting system is recognized as a significant step for the development of smart cities.

In addition to enable the cities with proper amount of street light for local conditions, installing smart street lighting will help to improve the citizen's satisfaction regarding security and safety at night time against theft, system fault analysis and rectification, significant power savings with very lesser power consumption and a very lesser lighting system maintenance.

As smart city transformation is going on everywhere, transformation in lighting technology from traditional lighting to light-emitting diodes (LEDs) are taking place. However, by a research forecast, on 2026, the central management system will connect to more than two-thirds of new LED streetlight installations.

3.2: How Smart street lighting system works

[24] The technology behind smart streetlights varies depending on its features and requirements. A typical smart street light depicted in Fig 1, involves a combination of sensors in it. Upon implementation on standard streetlights, these lighting systems can detect any moving object and enables dynamic lighting and dimming accordingly at night time. It also allows different neighboring fixtures to communicate with each other. If a pedestrian or car or any moving object is detected, all street lights will glow with its higher intensity level until keep glowing until the moving object stays and after it is gone all lights will automatically go to their dimming condition.

Additional capabilities of smart streetlights may also provide us technologies such as image sensors, seismic sensors, sound sensors, speakers, weather and water detection sensors, and wireless transmitter.

AHOY SYSTEMS is a manufacturer and supplier for LoRa based smart street light systems depicted in Fig 2, for municipalities, real-estate developers, residential colonies which offers solutions and products for street lights, street light feeder systems, street light dimmers on GSM, LoRa and LoRaWAN telemetry.

- Ultra-low energy consumption that saves up to 60% electricity and pays for itself in less than 4 years,
- Uniquely identifiable and addressable lights for real-time operation on individual lights and detection of faulty lights,
- Easy retro fitting in existing LED street lights to start savings immediately,
- Live monitoring/operation of entire street lighting system over cloud based software platform

3.3 Additional features of Smart Street Lighting Technology:

i. Additional capabilities of smart streetlights consist of detection of various weather conditions,

ii. Monitoring the traffic conditions,

iii. Count of pedestrian,

iv. Speed control technology or Speedometer installed in it for the measurement of speed of different types of vehicles (Heavily loaded or lightly loaded) and comparing the speed with the specified limit fixed by Union Ministry of Road Transport and Highways,

v. Host a public Wi-Fi module,

vi. Conduct surveillance of various activities by installing cameras in it,

vii. Integration with various intercom system to notify on various emergency conditions when fault occurs.

3.4 Benefits of Smart Street Lights

- Reduced energy cost with the usage flexible dimming controls,
- Increased pedestrian satisfaction through improved safety measures;
- Lowered repair and maintenance costs with the monitoring software;
- Reduced carbon emissions and light pollution,
- Increased lamp life and shorter response times to outages,
- Improved planning on real traffic patterns and insights,
- Increased revenue opportunities, such as leasing poles for digital signage.

3.5 Limitations of Smart Street Lights

Despite the long-term value in upgrading lighting networks, there are a few drawbacks. Although smart streetlights save money over time, the initial investment is a huge one. Smart Street lighting costs can account for more than 40% of a city's energy costs -- although converting from halogen to basic LED luminaires yields up to 80% in instant savings.

Another barrier is the lack of consumer knowledge surrounding the features and benefits of smart streetlights. Finally, implementation of smart streetlights require compliance with federal and utility regulations.

3.6 Some smart features of Smart Street Lighting technology:

- Dynamic lighting controls (variation of Light intensity) based on movement detection,
- Environmental condition and weather monitoring,
- Digital signage that can update as needed, such as parking regulations or accident alerts and can control parking management, such as alerting officials of illegally parked vehicles or availability of open spaces to the drivers;

- Extended cellular and wireless communications,
- Traffic condition management (Road congestion monitoring system) through real-time data analysis,
- Automatic emergency response in the event of a car crash or crime.

3.7 Examples of adapting Smart Street lighting technologies in cities:

i. In While Los Angeles received a revenue boost from Smart Poles, which offer Long-Term Evolution (LTE) reception and save energy, Chicago could save $10 million a year in energy costs, thanks to a four-year initiative to replace 270,000 city lights with LEDs and intelligent controls,

ii. Cities in Spain have invested in green street lighting with the development of the wind-powered turbine operated lamppost,

ii. In San Diego, sensor-based smart streetlights have been installed to help direct drivers to vacant parking spaces and alert traffic enforcement officers to illegally parked cars. These intelligent fixtures can connect to systems to help determine which locations are the most dangerous and need to be redesigned. Systems such as these could help municipalities adjust traffic signals by monitoring intersections and noting when traffic backs up, and sensors connected to the streetlights could also detect sounds such as gunfire, broken glass or a car crash.

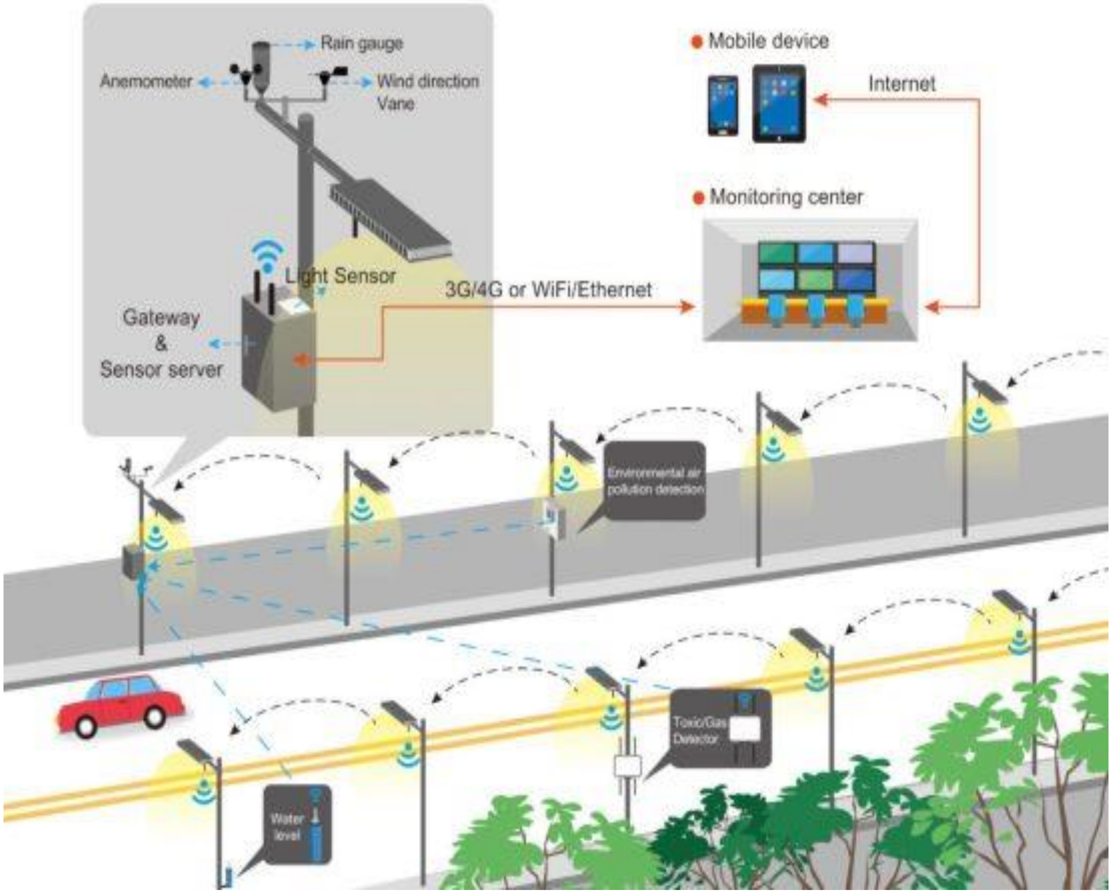

Fig. 1: Smart Street Lighting Technology in Cities

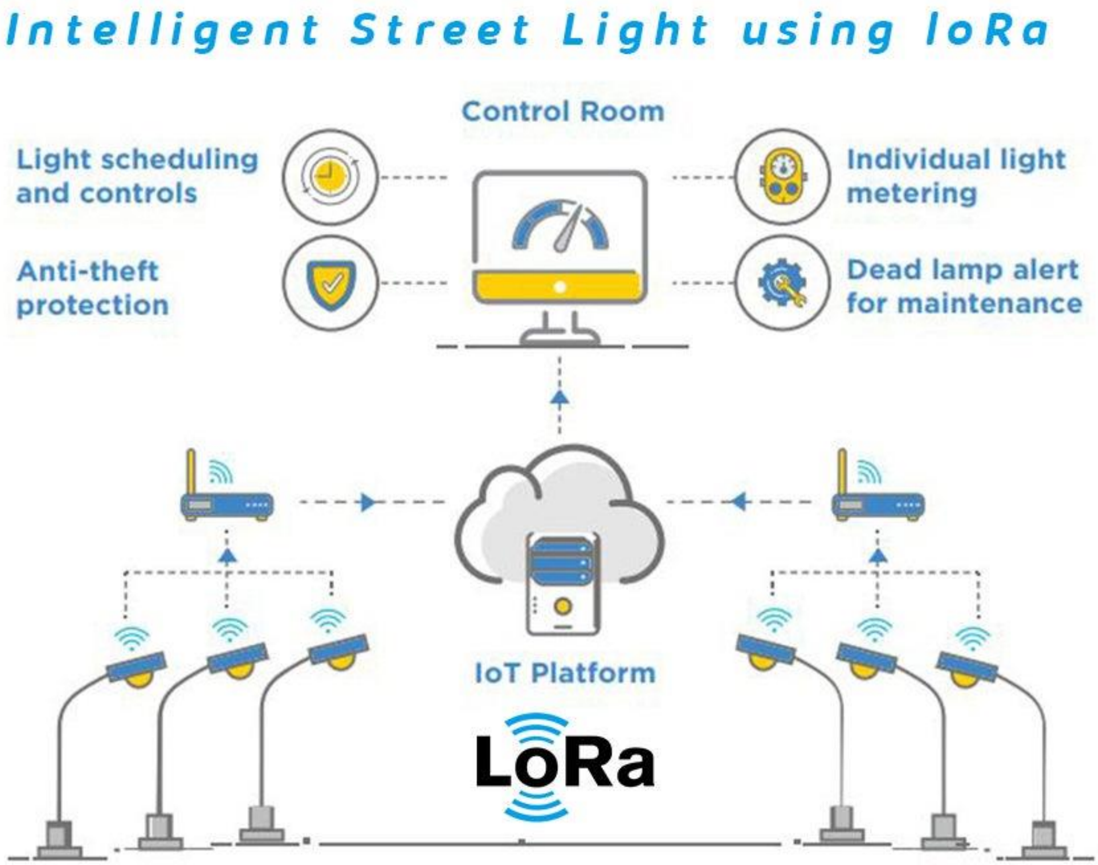

Fig. 2: Intelligent Street Lighting Technology using LoRa (IoT Platform)

CHAPTER –4

METHODOLOGY AND STEPS OF DEVELOPMENT

4.1 Techniques which are used in this development process:

i. The street and outdoor lighting installations provide citizens with safe roads, stylish and inviting public areas and enhance the security in their homes, businesses and different places in the city. They are very important elements of infrastructure in cities around the world. Unfortunately, according to different reports, the street lighting is one of the biggest electrical energy consumers, accounting for about 40 % of the total energy consumption in cities (The European PPP Expertise Centre (EPEC) 2010; European Commission 2013; Mohamed 2013). This shows that they are costly and contribute considerably to environment pollution. The production of electricity needed to power the street lighting systems significantly adds to carbon dioxide emissions (CO_2, greenhouse gas) and nuclear dust. The costs of the electrical energy together with the environmental factors encourage municipalities to implement solutions to measure, analyze and reduce energy consumption in order to reduce spending and decrease maintenance costs.

ii. Technical parameters and functions of an experimental street lighting system are presented in this paper. Their analysis and verification have included in the research works. A research installation of intelligent public space lighting is located at one of the car parks of a university campus. Besides the standard functionalities of classic street lighting systems, associated with lighting a particular space, the experimental installation has advanced monitoring and control ones.

iii. Arduino Nano is used here (Process flowchart is depicted in Fig 3) as the controller of the entire system. We have used a LDR here and with the value of which we have done the scaling with lux value of daylight. We have done it as value 81= 70 Lux. So, at the time of dusk when the lux level becomes <70 lux the LED lights automatically go on and continue its glowing with 100% intensity.

iv. There is a time lapse given in the initial period of starting of LED street lights. The LED will continue its glowing with 100% intensity for 3 hours irrespective of the absence of any kinds of objects within 3 meters of its operational region. This actually provides a non-dimmable constant glow of LED street light in the peak busy hours.

v. We can monitor the system voltage, current through LED and the LED lux level in the LCD display.

vi. After the completion of the time lapse period, the LED Street light continue its glowing with 90% of its intensity. We can also monitor the system voltage, current through the LED and the lux level of the LED.

vii. At that time the sensors like Ambient Light intensity measuring sensor GY30 BH1750FVI and Ultrasonic sensor HC SR04 come into the action. Whenever no any object is detected within the 3km of the experimental region the intensity of the LED light goes decreasing and will be dimmed up to its 10% intensity level in order to reduce the power consumption and energy efficient. At the time of decreasing or even after the full dimming of the LED, if any object comes within the experimental region of 3km, the intensity level of the LED starts to rise up until and unless it gets reached to its 90% intensity level. The LEDs will continue its 90% intensity level until the object stays within the experimental region. After the object is gone it again starts decreasing its intensity value and dimmed completely. Second and multiple millisecond delays are used in order to make the glowing and dimming fully recognizable.

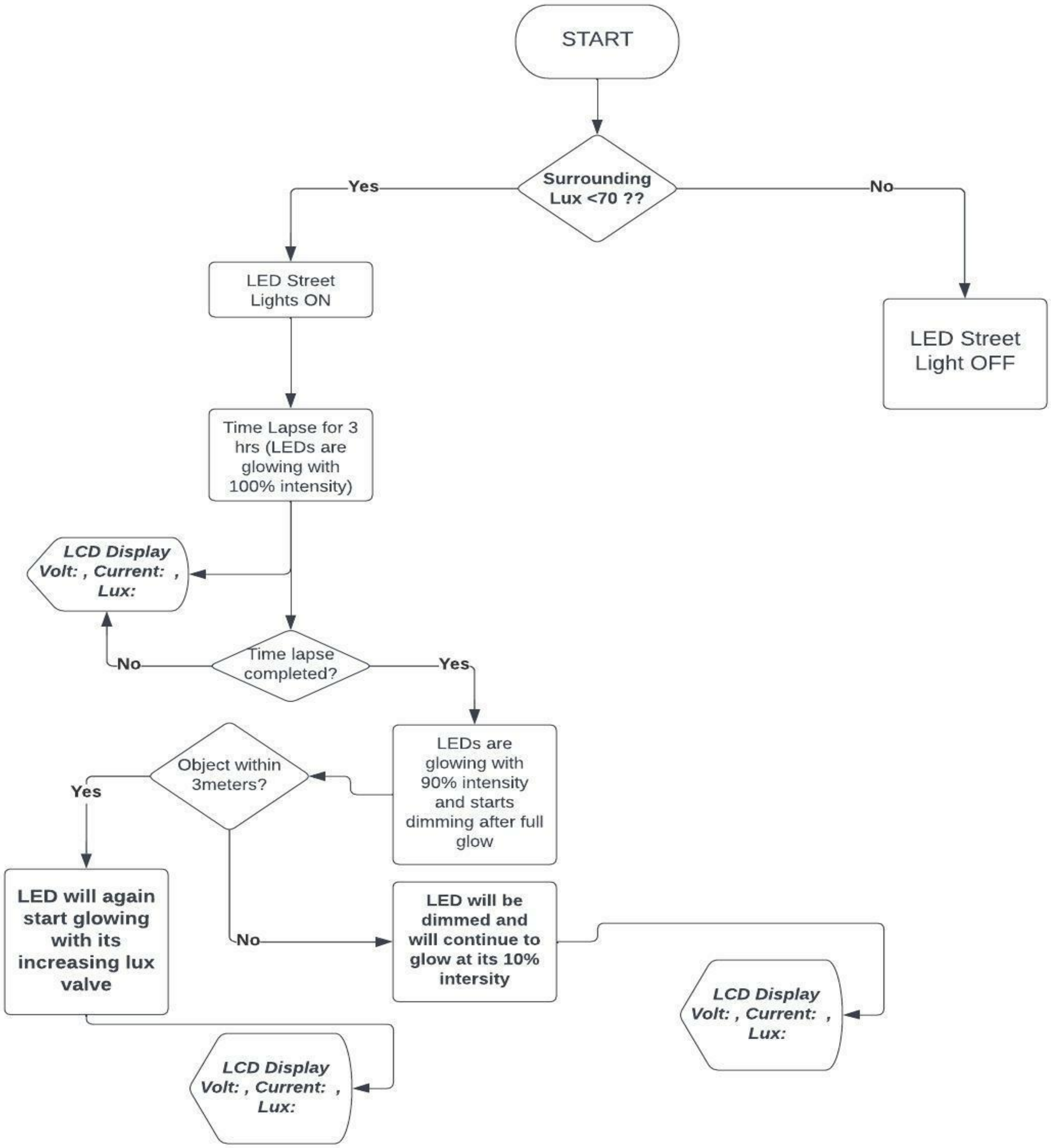

Fig. 3: Flowchart of the developed street lighting system

viii. In the total research work we have used-

- For firing of MOSFET or any other power electronic switching device a very high switching frequency is needed, for MOSFET it'll be about a few kHz to a few 100 kHz.

Arduino simply isn't capable of delivering such high frequency PWM. The TTL family made of BC 337 (NPN Transistor having max gain 630 and can switch upto 45Volt 800mA) and BC 327 (PNP Transistor having max gain 630 and can switch upto 45Volt 500mA) is used here which can provide the required frequency for switching. TTL family works on voltage 0 to 5V, where the high level is 5V and the low level is 0V. TTL logic circuits take very less power. Generally, a TTL logic circuit takes 10 mW power. The propagation delay of the TTL circuits is very low, it few nanoseconds.

- The Opamp made comparator circuit is used here in order to compare the initial LDR values with the set reference (LDR value 81).
- A 10K POT is used to set the contrast of the 16X2 LCD Display.
- The output signal is of the Opamp circuit is a voltage signal varying from 0 Volt to 2.5 Volt from its varying intensity level from 10% to 90% which in turn shows the corresponding current value (0-260) mA.
- A DC filter circuit is used in the voltage and current sensing circuit to make the signal ripple and noise free.
- In the main circuit board we have used 516ACO- Multilayer capacitor to filter out the small noises.
- We have connected current and voltage sensor output to the Analog pins of Arduino Nano in order to see the voltage output by Multi meter connecting with respect to the analog pin and the ground.
- A voltage regulator is a component of the power supply unit that ensures a steady constant voltage supply through all operational conditions. It regulates voltage during power fluctuations and variations in loads. It can regulate AC as well as DC voltages The 7805 Voltage Regulator IC is a commonly used voltage regulator that finds its application in this research work also. It provides a constant +5V output voltage for a variable input voltage supply

- This circuit is a prototype only where an automatic intensity controller is developed using smaller range of component value. If we use MOSFET with the heat sink mount in it we can make the circuit capable to deal with higher load value or like, it can drive 1.5 Amp LED loads.

4.2 Cost effectiveness and easy availability of choosing the sensors:

AMIS74980x ambient light sensor from AMI Semiconductor's is used within both automotive as well as consumer applications. The main feature of this sensor is, allowing the display controller to regulate the intensity in less dark current.
Likewise, the ambient light sensor like ALS-SFH5711 from OSRAM hypes human eye characteristics intended for mobile & automotive applications. These devices are used to replicate the sensitivity arc of the person's eye, allowing mobile displays and the levels of its brightness to be attuned more accurately. These sensors are used in automotive applications like headlight control & cockpit dimming.
The APDS-9004 ambient light sensor from Avago Technologies is used for backlighting control in DVD players, consumer LCD displays, mobile phones, notebook PCs, digital cameras, etc. The main feature of this sensor is an automatic alteration to save power & to increase the LCD screens life in handy display devices. Additionally, these sensors control the backlighting based on the program set by the maker.
But comparing all these sensors **GY 30 BH 1750 FVI Ambient light sensor** is less costly and easy available in the market and it has various application ranges from very least to moderate voltage level. That's why I have chosen this sensor.

HFS-DC06 5.8G DC 5V Microwave Motion sensor module for LED lighting Doppler effect can be used for distance sensing of application. But this sensor requires complex circuitry while being used in various application.

RCWL-0516 Microwave Radar sensor (PIR) can be used for distance sensing purpose. But due to having lesser operational range it's applications are limited.

Here in this research work **HC SR04 Ultrasonic motion sensor** is used which is less costly, easy available and has sufficient operational ranges required in small to moderate project work.

The street lighting system with the mentioned devices with their functions in this research work can also be used in real development process. Broader research works are aimed by analyzing the ranges of various components used which in turn finally resulting the desired lesser energy consumption in the outdoor lighting installation.

CHAPTER – 5

RESULTS WITH DETAILED ANALYSIS

5.1 Apparatus used in this developed system

i. 1 No. of Arduino Nano shown in Fig 4, having specifications like **Microcontroller**-ATmega328P, **Architecture**-AVR, **Operating Voltage- 5** Volts, **Flash Memory**-32 KB of which 2 KB used by Bootloader, **SRAM**- 2KB, **Clock Speed-**16 MHz, **Analog I/O Pins**-8 Nos, **EEPROM-**1 KB, **DC Current per I/O Pins**- 40 milli Amps, **Input Voltage**- (7-12) Volts,

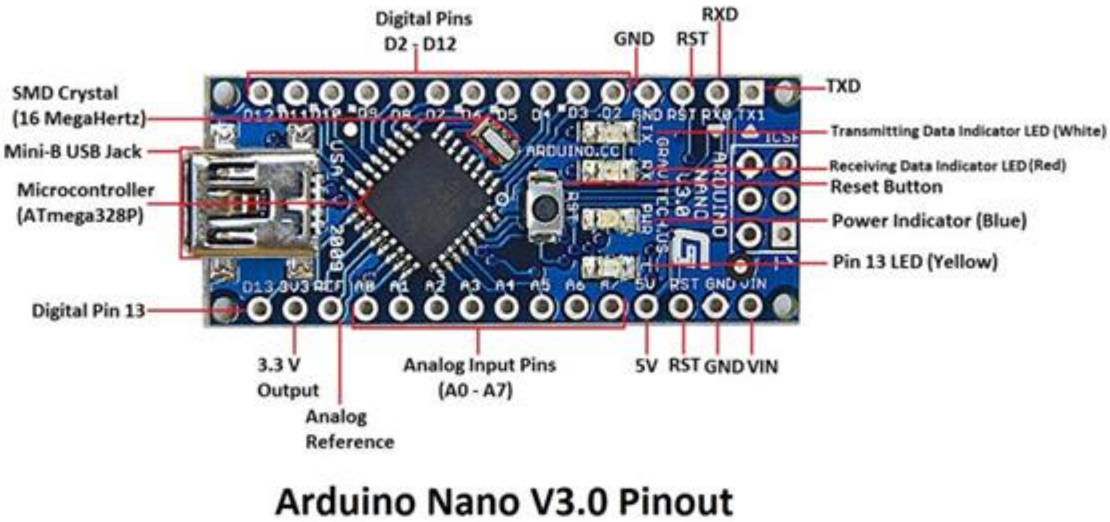

Fig. 4: Arduino Nano Pinout

ii. 3 Nos. of Line Vero boards, out of three, the main circuit board having dimension (30cm X 15 cm) is used for Arduino circuit, and another two circuit boards having dimensions (3cm X 2.3 cm) and (8.8 cm X 6.5 cm) are used in LED voltage and current measurement circuit,

iii. 3 Nos. of 3Volt LED lights (used as street light),

iv. 1 No of (15cm X 6.5cm) Heat sink,

v. 12 volt SMPS (DC supply) to start up the Arduino Nano board,

vi. 1 No of RG1602A, 16X2 LCD Display,

vii. 1 No of P1036160CO- 10K POT,

viii. 1 No of TRFZ44N301K- N Channel Power MOSFET,

ix. 17 Nos. of 90º- Male to female bus strips,

x. Small wires for connecting purpose and Copper wires for shorting purpose in the Veroboard,

xi. 1 No. of LM358P (82MHOCEF3),

xii. 1 No. of (834TO) W103,

xiii. 1 No. of L7805CV

xiv. 1 No. of (134T) W103,

xv. 1 No. of Zener Diode,

xvi. 513ACO- (Yellow colored) Multi-Layer capacitor,

xvii. 1 No. of LDR,

xviii. 1 No. of GY30 BH1750FVI- Digital Light Intensity sensor,

xix. 1 No. of HC-SR04- Ultrasonic sensor,

xx. 1 No. of KA7805,

xxi. 19 Nos. of Male type bus strips,

xxii. 1 No. of CTBC 337-40LS (BC 337 is a NPN transistor with max gain of 630. It can switch load up to 45V, 800mA),

xxiii. 1 No. of CTBC 327-40LS (BC 327 is a PNP transistor with max gain of 630. It can switch load up to 45V, 500mA),

xxiv. List of Resistances- 10 kΩ (3 Nos.), 1 kΩ (4 Nos.), 10Ω (1 No.), 1Ω (2Nos.), 47E=47Ω (1 No.)

xxv. List of Capacitances- 10µF, 63 Volt (2 Nos.), 100µF, 50 Volt (1 No.)

5.1.1 Use of Line Vero Boards-

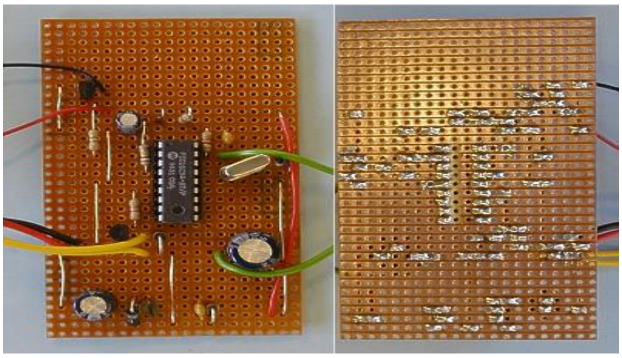

Fig.5: Circuit using Line Vero boards

This type of wiring board shown in Fig 5 may be used for initial electronic circuit development, to construct prototypes for bench testing or in the production of complete electronic units in small quantity. Vero board was first used for prototype construction within Vero Electronics Department in 1961.

5.1.2: Use of Daylight or Artificial Lighting-

The experiment requires the presence of sunlight. The automatic intensity control and turning on and off of the smart street lights is done based with respect of the lux level of sunlight. The lux value of the direct sunlight is 32000 lux to 100000 lux. Actually there is no requirement of street lights in the daytime. But the parameters of the experiment is set up like decreasing lux value in dusk is measured in a competitive manner in order to make the street lights start to glow. But this experiment can also be done in absence of the sunlight. Here in this prototype study Artificial Lighting is used as the source of light.

5.1.3 Use of Different Apparatus

Fig 6, 7, 8 & 9 shows sources used like 3 phase of AC supply (AC variac), 12 Volt DC supply (SMPS) which is used as the main power supply in the Arduino Nano circuit. CRO is also used here to find the frequency and waveform of pulse width modulation (10% or 90%) of the output PWM signal from the Arduino Nano pin and which is main driven signal. Multi meter is also used in the experiment in order to observe circuit continuity of the board and the voltage and current of the LED street light when it is glowing.

Fig. 6: AC Variac

Fig. 7: 12V SMPS

Fig. 8: Oscilloscope

Fig. 9: Multi meter

5.1.4 Use of the controller Arduino Nano Board:

The Arduino Nano shown in Fig 10, is a small, complete, and breadboard-friendly board based on the ATmega328P released in 2008. It offers the same connectivity and specs of the Arduino Uno board in a smaller form factor. The Arduino Nano is equipped with 30 male I/O headers, in a DIP-30-like configuration, which can be programmed using the Arduino Software integrated development environment (IDE), which is common to all Arduino boards and running both online and offline. The board can be powered through a type-B mini-USB cable or from a 9 V battery. In 2019, Arduino released the Arduino Nano Every, a pin-equivalent evolution of the Nano. It features a more powerful ATmega 4809 processor and twice the RAM.

<u>TECHNICAL SPECIFICATIONS-</u>

- Microcontroller: Microchip ATmega328P
- Operating voltage: 5 volts

- Input voltage: 6 to 20 volts
- Digital I/O pins: 14 (6 optional PWM outputs)
- Analog input pins: 8
- DC per I/O pin: 40 mA
- DC for 3.3 V pin: 50 mA
- Flash memory: 32 KB, of which 0.5 KB is used by bootloader
- SRAM: 2 KB
- EEPROM: 1 KB
- Clock speed: 16 MHz
- Length: 45 mm
- Width: 18 mm
- Mass: 7 g
- USB: Mini-USB Type-B
- ICSP Header: Yes
- DC Power Jack: No

The Arduino Nano has a number of facilities for communicating with a computer, another Arduino, or other microcontrollers. The ATmega328 provide UART TTL (5V) serial communication, which is available on digital pins 0 (RX) and 1 (TX). An FTDI FT232RL on the board channels this serial communication over USB and the FTDI drivers (included with the Arduino software) provide a virtual com port to software on the computer. The Arduino software includes a serial monitor which allows simple textual data to be sent to and from the Arduino board. The RX and TX LEDs on the board will flash when data is being transmitted via the FTDI chip and USB connection to the computer (but not for serial communication on pins 0 and 1). A Software Serial library allows for serial communication on any of the Nano's digital pins. The ATmega328 also support I2C and SPI communication. The Arduino software includes a Wire library to simplify use of the I2C bus.

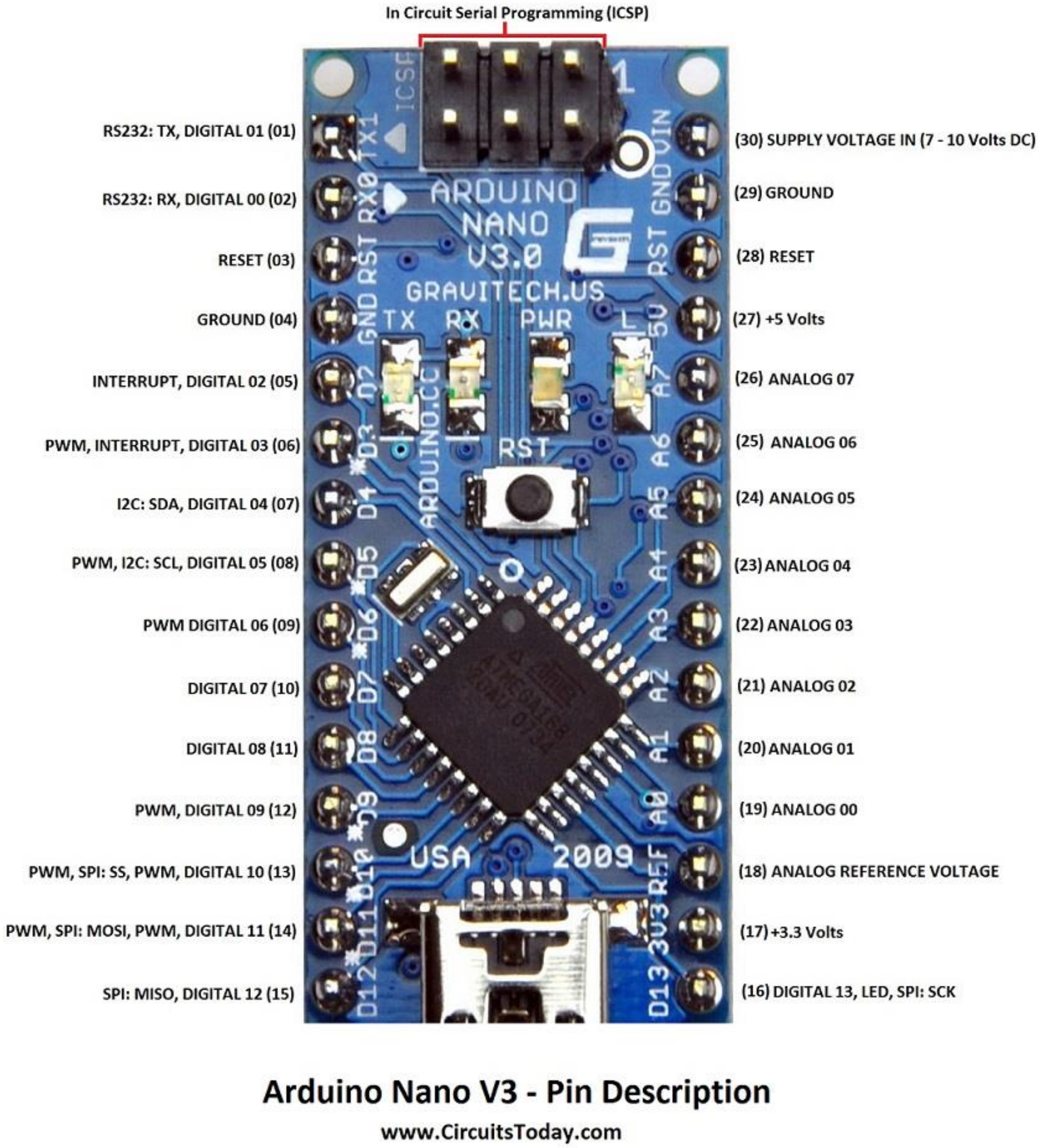

Fig. 10: Arduino Nano Pin Configuration

5.1.5. Stages of the development:

The below circuit diagrams of Smart Street light is designed in **"Express Sch" software** which are described below-

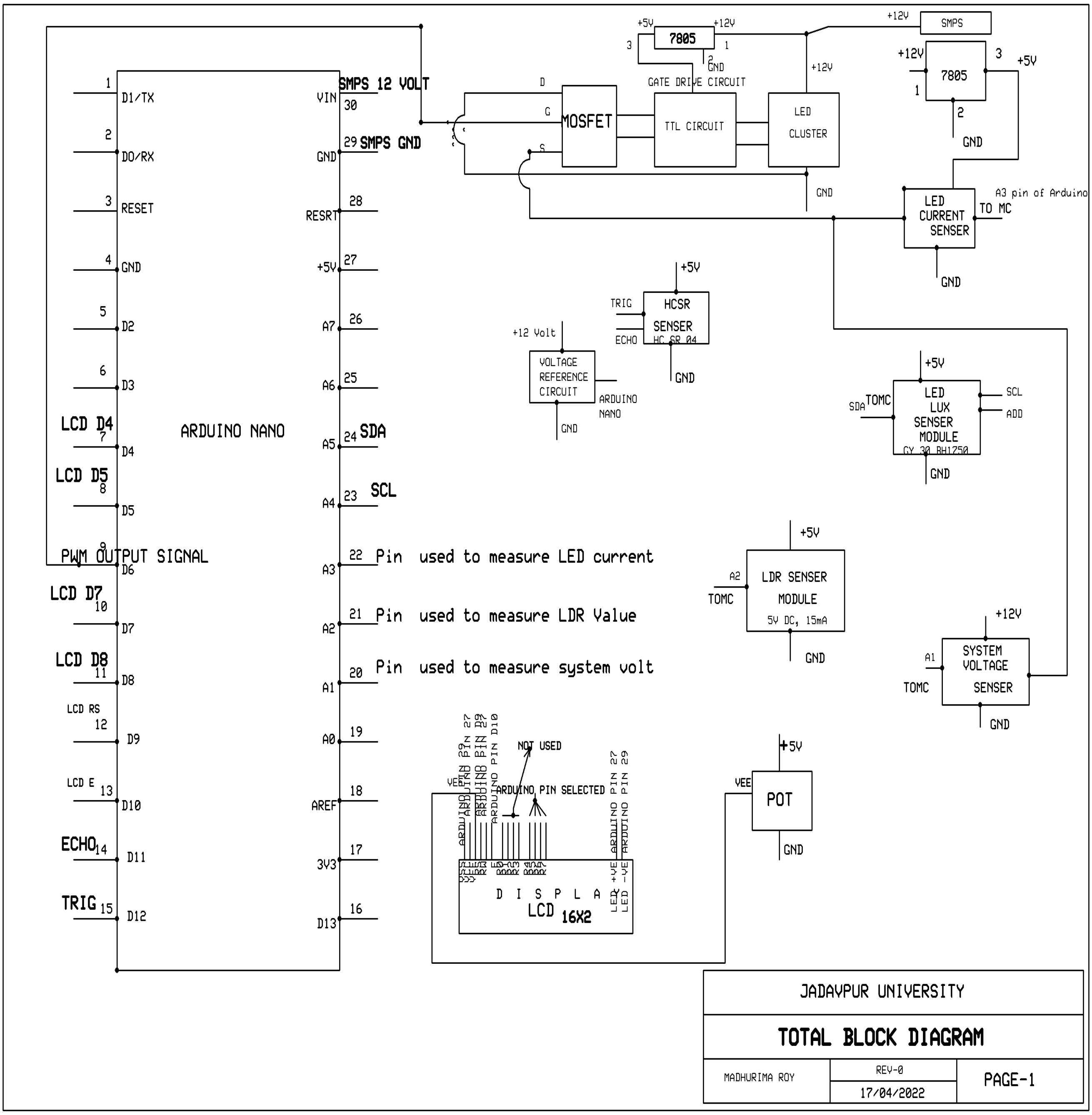

Fig. 11: Total Block Diagram of Smart Street Lighting

The Total Block diagram in Fig 11 consists of 12V SMPS, Arduino Nano Board, TTL Family, n channel MOSFET, LED cluster, LCD display, GY30 BH1750FVI sensor, HC SR04 sensor and System voltage, LED current and LED lux sensing circuit board. When surrounding LUX is > 70 LUX, PWM pulse output from Arduino Nano triggers the gate of the MOSFET which in turn glows the LED street lights ON. After becoming ON LEDs will go the "TIME LAPSE" condition which they will glow with 100% intensity irrespective of presence or absence of moving object. After time lapse condition ends the LEDs will start to glow with 90% intensity when it senses any moving object through HC SR04 Ultrasonic sensor and automatically go to dimming condition when moving object goes away. We can monition System Voltage, LED current and LED LUX level in LCD display in every condition.

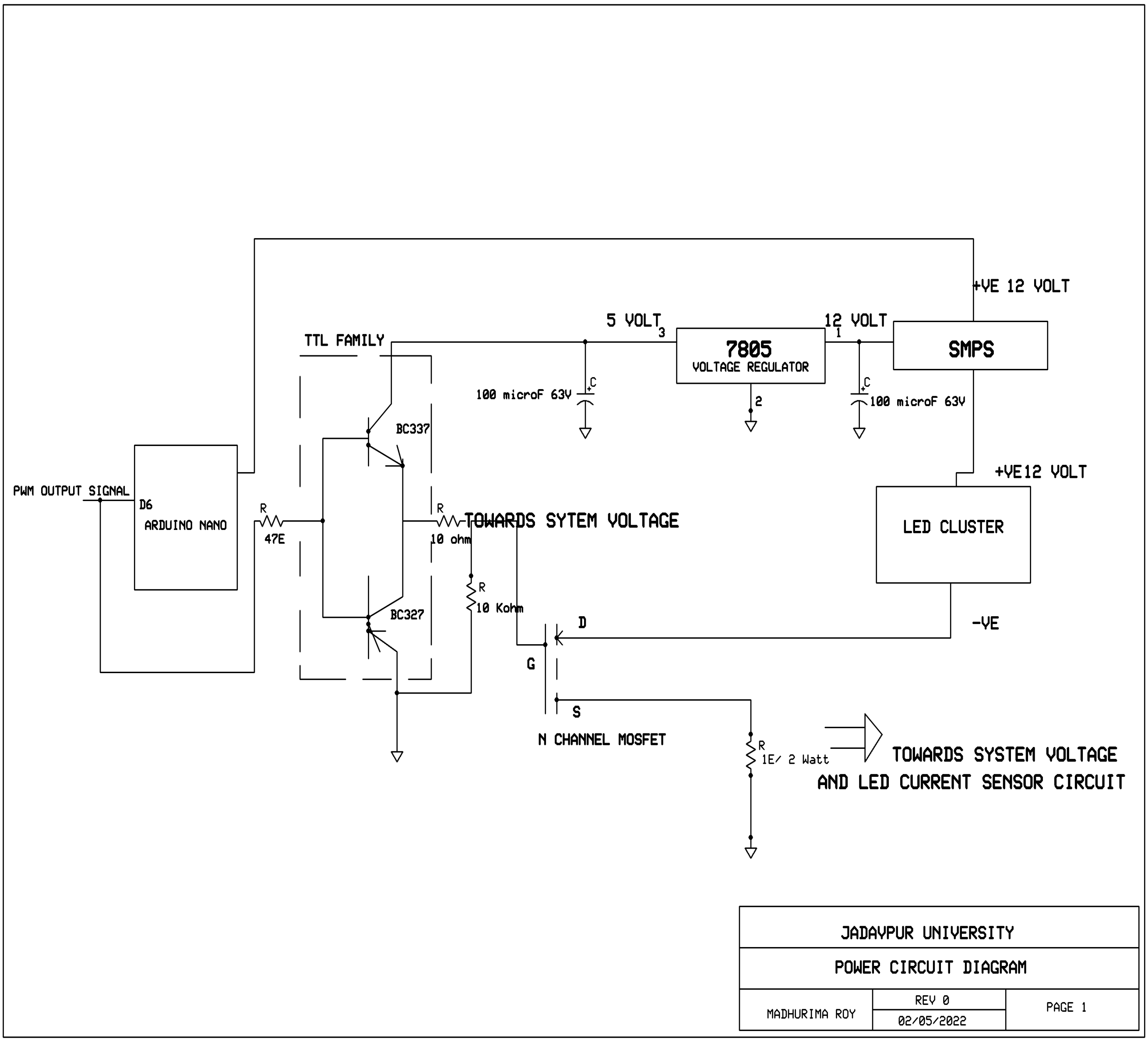

Fig. 12: Power Circuit Diagram of Smart Street Lighting

The total power circuit diagram in Fig 12 consists of the Arduino Board, TTL family,7805 regulator, 12 Volt SMPS and n channel MOSFET showing the gate triggering of MOSFET with high frequency switching. The TTL family consists of BC 337 and BC 327 and these are used here to provide the required frequency for switching. TTL family works on voltage 0 to 5V, where the high level is 5V and the low level is 0V. TTL logic circuits take very less power. Generally, a TTL logic circuit takes 10 mW power. The propagation delay of the TTL circuits is very low, it few nanoseconds. The high frequency PWM signal then triggers the gate of the n channel MOSFET in order to drive the LEDs and make those ON. The voltage across the LED could not be measured as any virtual ground is not present here. So, we can only measure the system voltage and the crent through LED through proper circuitry.

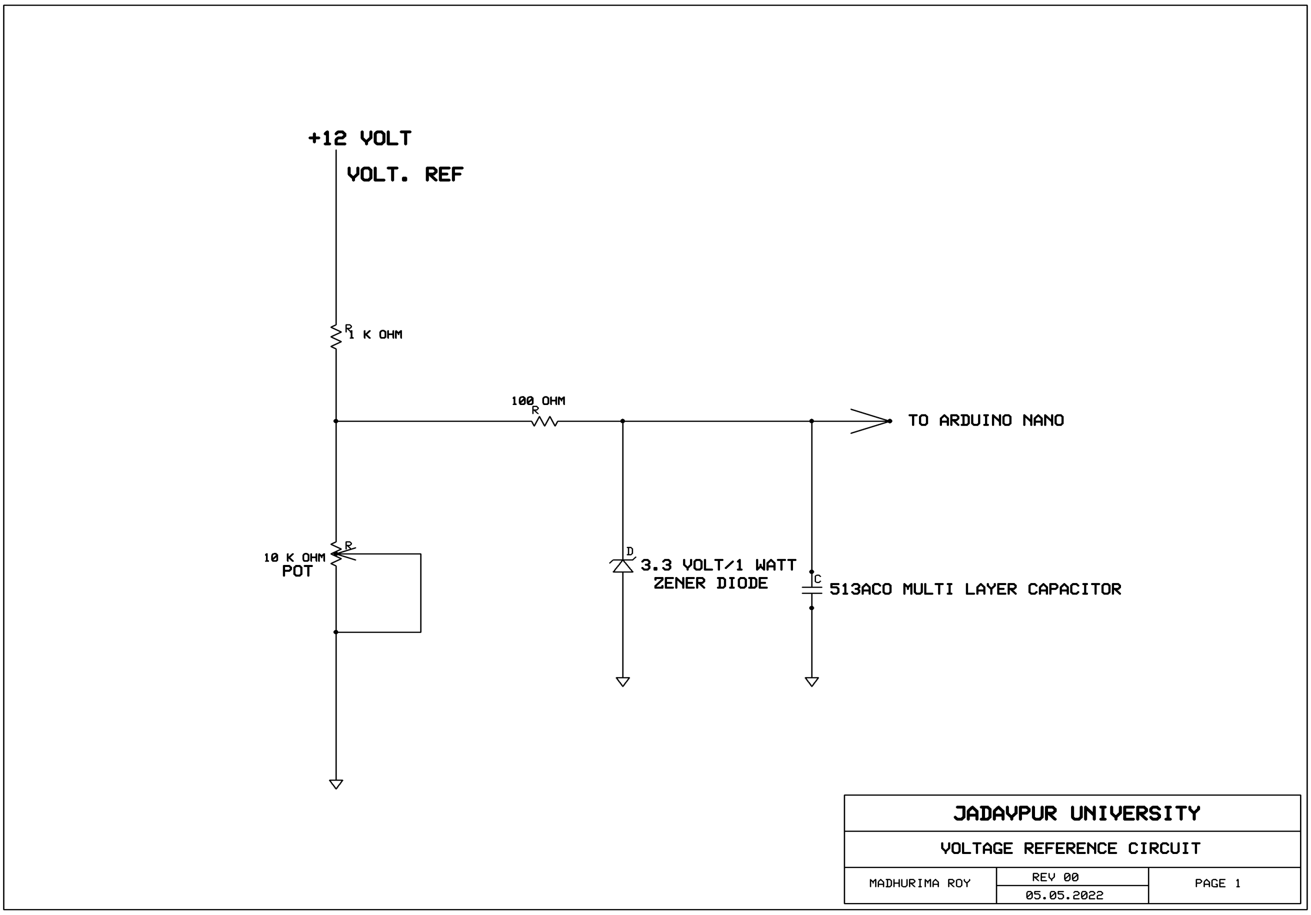

Fig. 13: Voltage reference circuit of Smart Street Lighting

The above Fig 13 describes the setting of the reference of 3.3 Volt using POT with respect of 12 volt supply (SMPS) to sense the controller 12 Volt Supply in order to make the LEDs on. The Zener diodes are used for voltage regulation, as reference elements, surge suppressors, and in switching applications and clipper circuits. When Zener is connected in parallel with a variable voltage source so that it is reverse biased, a Zener diode conducts when the voltage reaches the diode's reverse breakdown voltage.

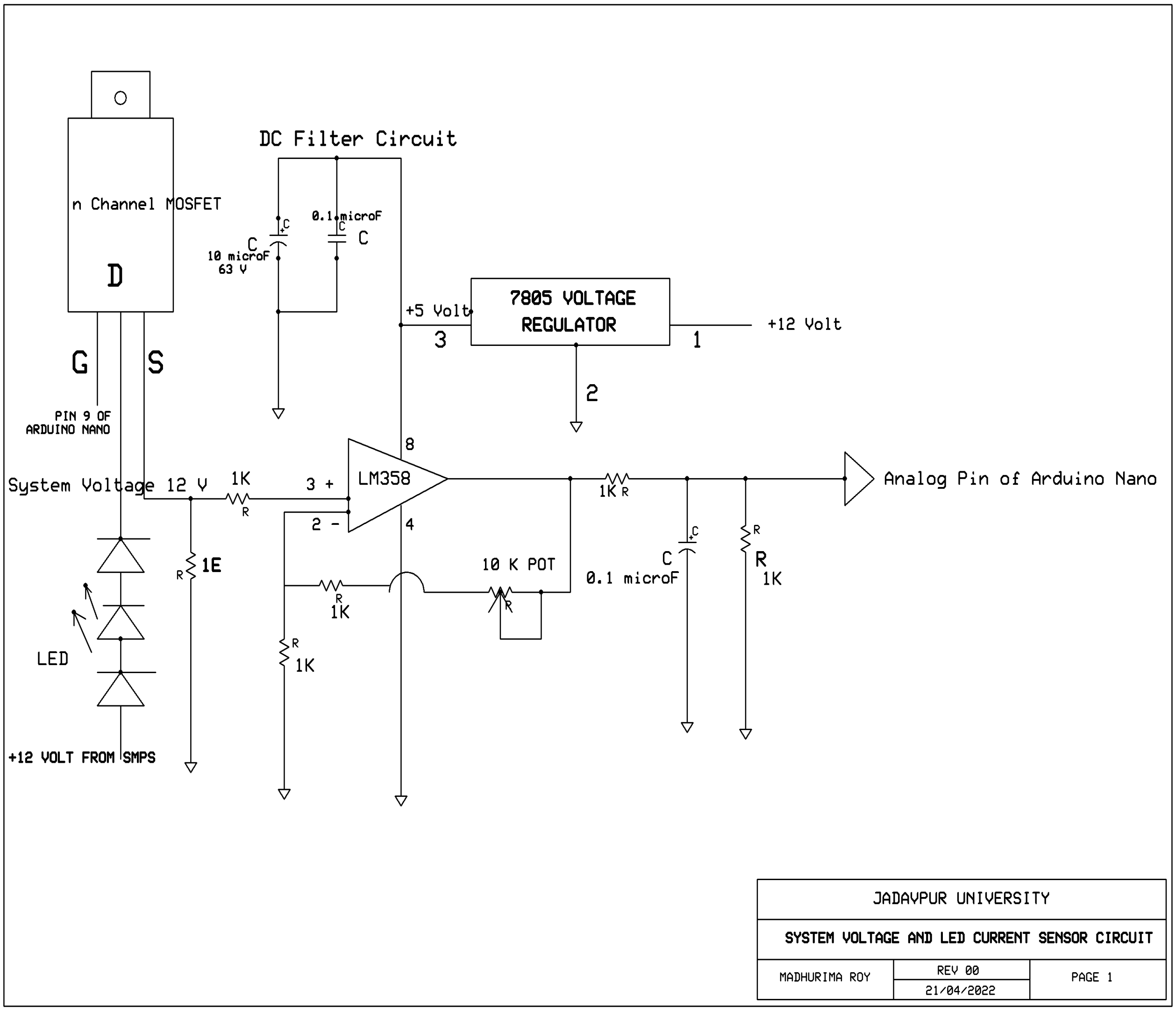

Fig. 14: System Voltage and LED Current sensor circuit of Smart Street Lighting System

The above circuit of Fig 14 diagram is a OPAMP based comparator circuit which gives us a voltage signal as output. The voltage signal is corresponding to the current flows through the LED cluster at system ON condition.

Three numbers of LED lights are mounted in the Heat sink (considered as a LED street light). A positive 12-volt DC is fed to ARDUINO NANO board from a 12Volt SMPS. A PWM signal of varying pulse with is generated from D6 pin (PWM, DIGITAL) of the Arduino Nano board and which is fed at the gate (as GATE PULSE) of the N channel MOSFET (IRFZ44N301K) through

TTL (Transistor-transistor logic) circuit. I have used two kinds of sensors- GY30 BH1750FVI- Ambient Light Intensity measurement sensor and HC SR04- Ultrasonic Sensor and one LDR in the circuit, details of which are as described below in Fig 15 & Fig 16-

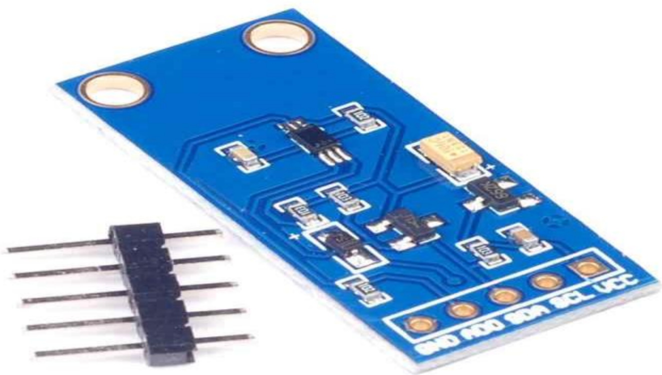

Fig. 15: GY30 BH1750FVI (Ambient Light Intensity Sensor)

- High precision determination accurate to 1 Lu for different lights
- Operating Voltage: 3-5VDC
- Built-in 16bit A/D converter
- I2C interface

Fig. 16: Ultrasonic Distance Sensor - HC-SR04

This is the HC-SR04 ultrasonic distance sensor. This economical sensor provides 2cm to 400cm of non-contact measurement functionality with a ranging accuracy that can reach up to 3mm. Each HC-SR04 module includes an ultrasonic transmitter, a receiver and a control circuit.

There are only four pins on the HC-SR04: VCC (Power), Trig (Trigger), Echo (Receive), and GND (Ground). This sensor has additional control circuitry that can prevent inconsistent "bouncy" data depending on the application.

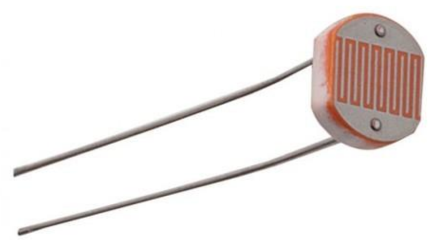

Fig 17: LDR (Light Emitting Diode)

A photo resistor or light-dependent resistor (LDR) or a photocell depicted in above Fig 17 is a light-controlled variable resistor. The resistance of a photo resistor decreases with increasing incident light intensity. In other words, it exhibits photoconductivity.

The scaling of the analog value of LDR with the surrounding lux level is done at the time of daylight exists (LDR valve: 81 is corresponding to the surrounding lux value 70). So, when the lux level falls below 70 at the time of dusk LEDs starts glowing. A time lapse of 3 hours (given by delay) is given at the beginning and when the LEDs start glowing, it will continue glowing with its 100 % intensity for 3 hours irrespective of sensing of any object within 3 meters (working plane taken, at it can be adjusted up to 4 meters based on the application). After ending of the time lapse, the LED will start glowing at its 90% intensity and after the full glow it will start dimming with decreasing intensity. The lux level of the street lights (LED) is measured by GY30 BH1750FVI sensor and which is displayed in a 16X2 LCD display in Fig 18.

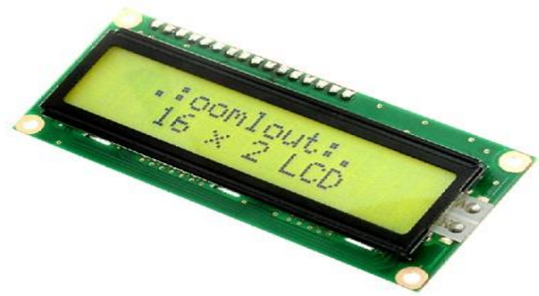

Fig. 18: 16X2 LCD Display

LCD 16×2 Pin Diagram:

The 16×2 LCD pinout is shown below.

- Pin1 (Ground/Source Pin): This is a GND pin of display, used to connect the GND terminal of the microcontroller unit or power source.
- Pin2 (VCC/Source Pin): This is the voltage supply pin of the display, used to connect the supply pin of the power source.
- Pin3 (V0/VEE/Control Pin): This pin regulates the difference of the display, used to connect a changeable POT that can supply 0 to 5V.
- Pin4 (Register Select/Control Pin): This pin toggles among command or data register, used to connect a microcontroller unit pin and obtains either 0 or 1(0 = data mode, and 1 = command mode).
- Pin5 (Read/Write/Control Pin): This pin toggles the display among the read or writes operation, and it is connected to a microcontroller unit pin to get either 0 or 1 (0 = Write Operation, and 1 = Read Operation).
- Pin 6 (Enable/Control Pin): This pin should be held high to execute Read/Write process, and it is connected to the microcontroller unit & constantly held high.

- Pins 7-14 (Data Pins): These pins are used to send data to the display. These pins are connected in two-wire modes like 4-wire mode and 8-wire mode. In 4-wire mode, only four pins are connected to the microcontroller unit like 0 to 3, whereas in 8-wire mode, 8-pins are connected to microcontroller unit like 0 to 7.

- Pin15 (+ve pin of the LED): This pin is connected to +5V
- Pin 16 (-ve pin of the LED): This pin is connected to GND.

Now, at the time of dimming if any object is detected by HC SR04, Ultrasonic sensor, (within the working plane of 3 meters taken in the experiment) the intensity of LED street lights again starts increasing (up to the 90% valve in maximum limit) till the object persists. When, finally the object is gone the LED street lights again starts decreasing its lux level and continue glowing with 10% (lowest) intensity level. During the experiment the detailed of LED lux value, system voltage and LED current is displayed by the 16X2 LCD display. Thus energy saving and longevity of the LED street light can be maintained very smoothly.

5.2 Demonstration of Circuits-

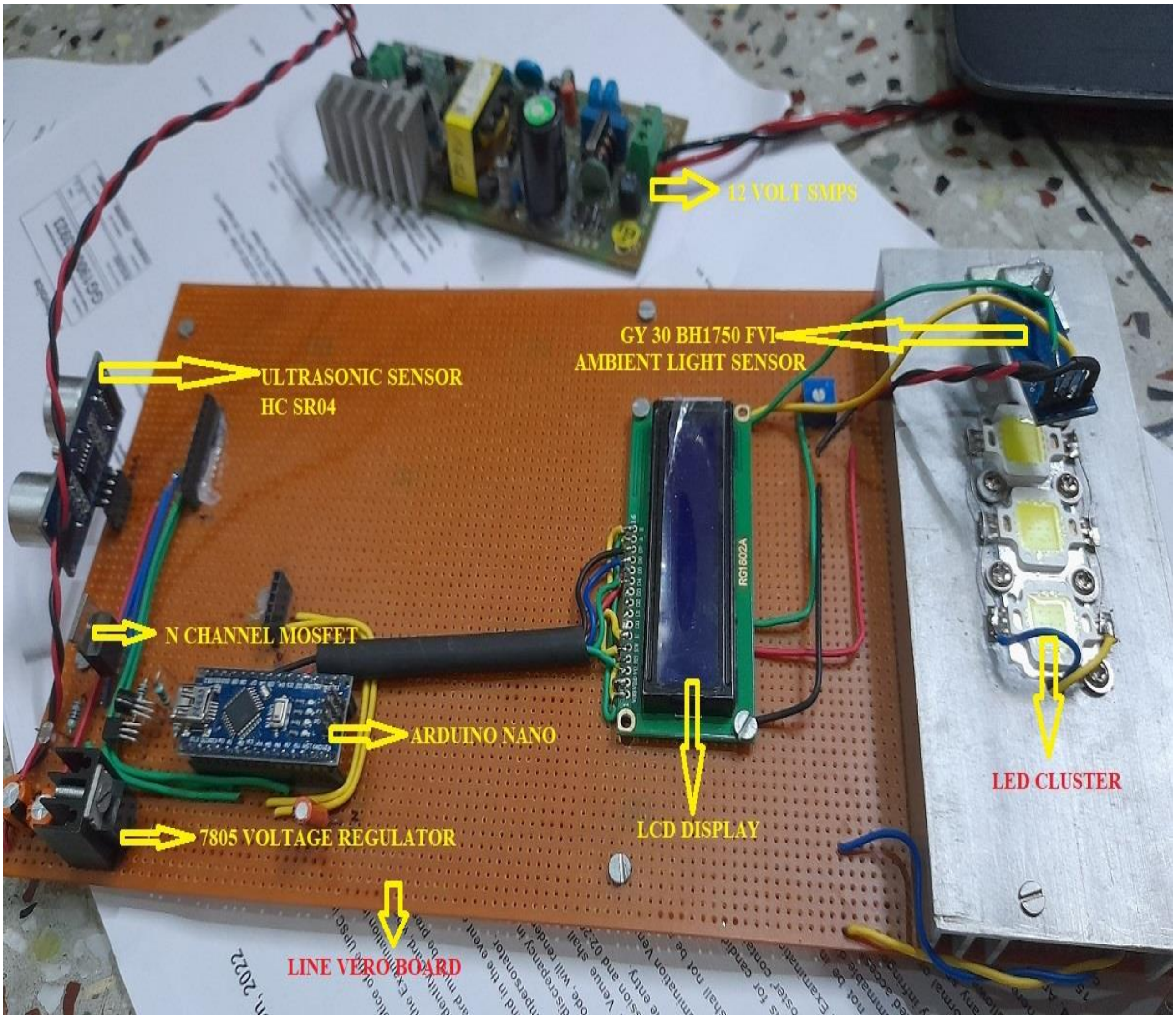

Fig. 19: Main Circuit Board (In OFF Condition)

The above Fig 19 describes the total circuit diagram of the system. 12V SMPS, Arduino Nano Board, TTL Family, n channel MOSFET, LED cluster, LCD display, GY30 BH1750FVI sensor and HC SR04 sensor.

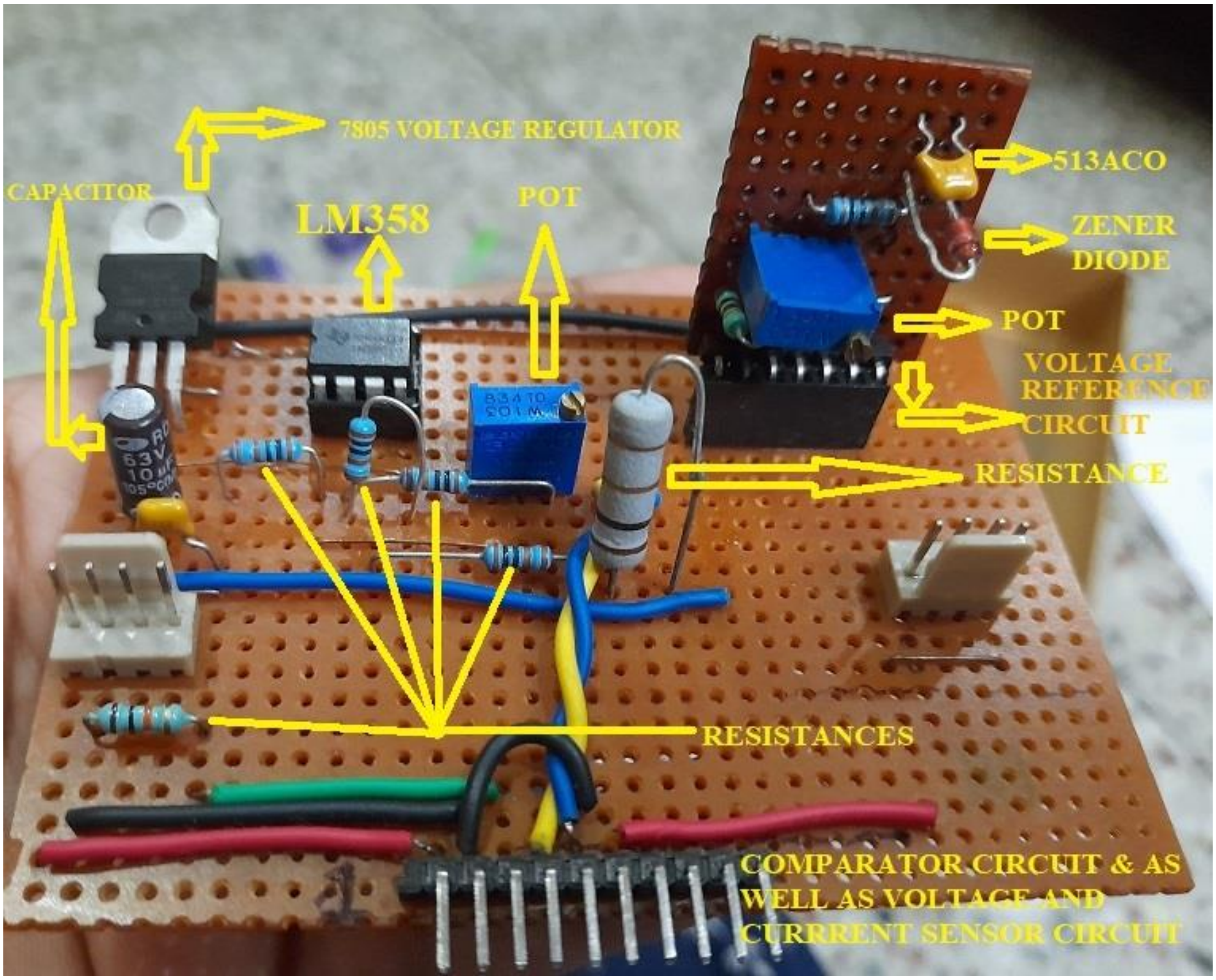

Fig. 20: System Voltage and LED current sensor circuit

The above circuit of Fig 20 diagram is a OPAMP LM 358 based comparator circuit which gives us a voltage signal as output. The voltage signal is corresponding to the current flows through the LED cluster when the system in ON condition. We can monitor the System Voltage, LED current (on the basis of some approximate calculation done in programming) and LUX value of LED (measured by the GY 30 mounted in parallel of the LEDs) in the LCD display in every stages of LEDs give the output. The small vero board consists the circuit which describes the setting of the reference of 3.3 Volt using POT with respect of 12 volt supply (SMPS) to sense the controller 12 Volt Supply in order to make the LEDs on.

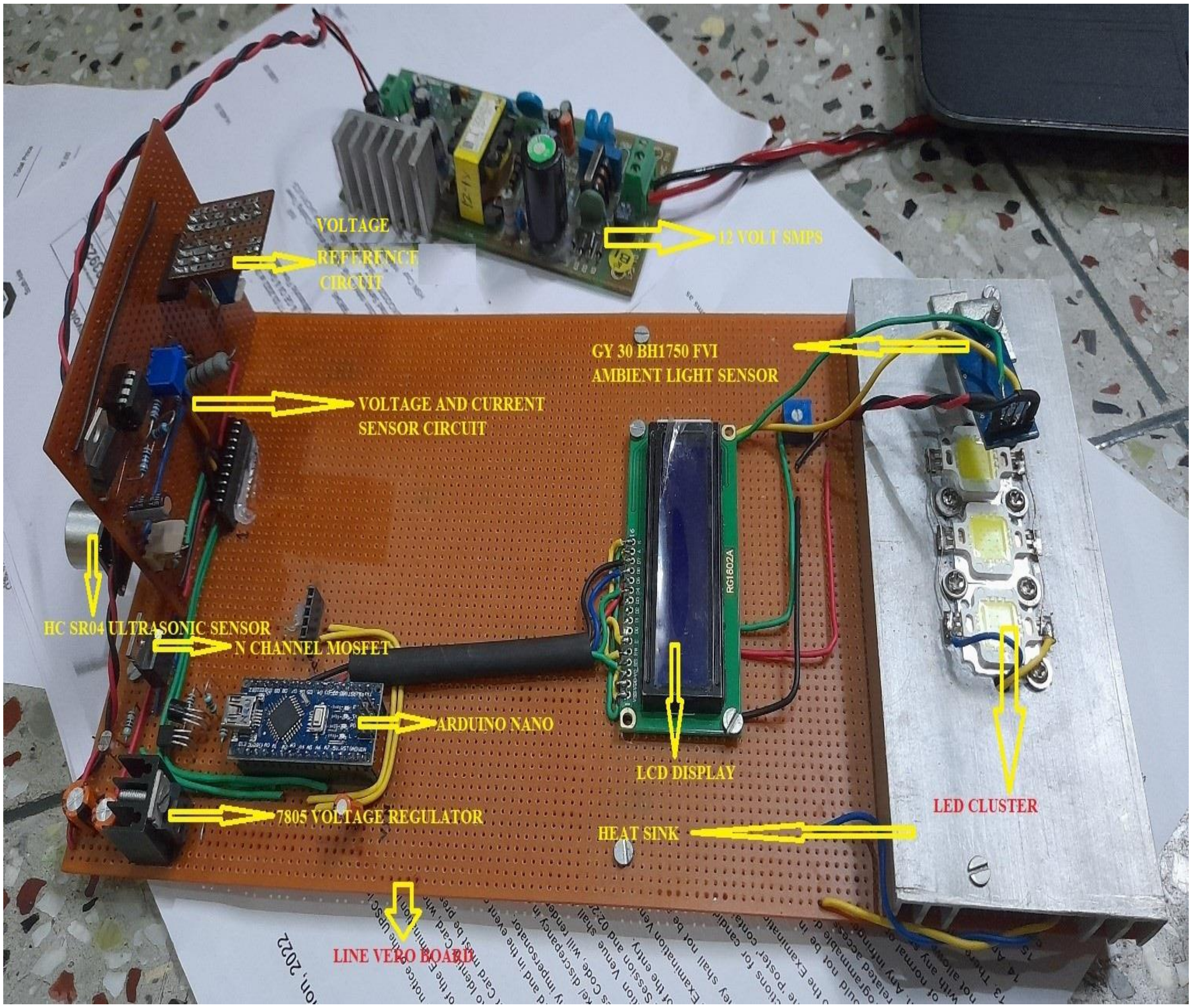

Fig. 21: Main Circuit Board + System voltage and LED Current sensor circuit board (In OFF condition)

In the above Fig 21, the main circuit board, system voltage and LED current sensing circuit are kept in system OFF condition. System OFF condition determines the daytime condition where the LED street lights not actually required to be operated. Here in this study, daytime condition determines when the surrounding LUX level is greater than 70 LUX. The scaling of the LDR is done in such a way when light level sensed by the LDR up to 70 (decreasing order) it will not make the total circuit ON. Just after the surrounding LUX falls below 70, the micro controller in Arduino board senses the value 81 which in results turning on the LED street lights and similarly when the LUX level increases and becomes more that 70, the LED street lights will automatically turn off.

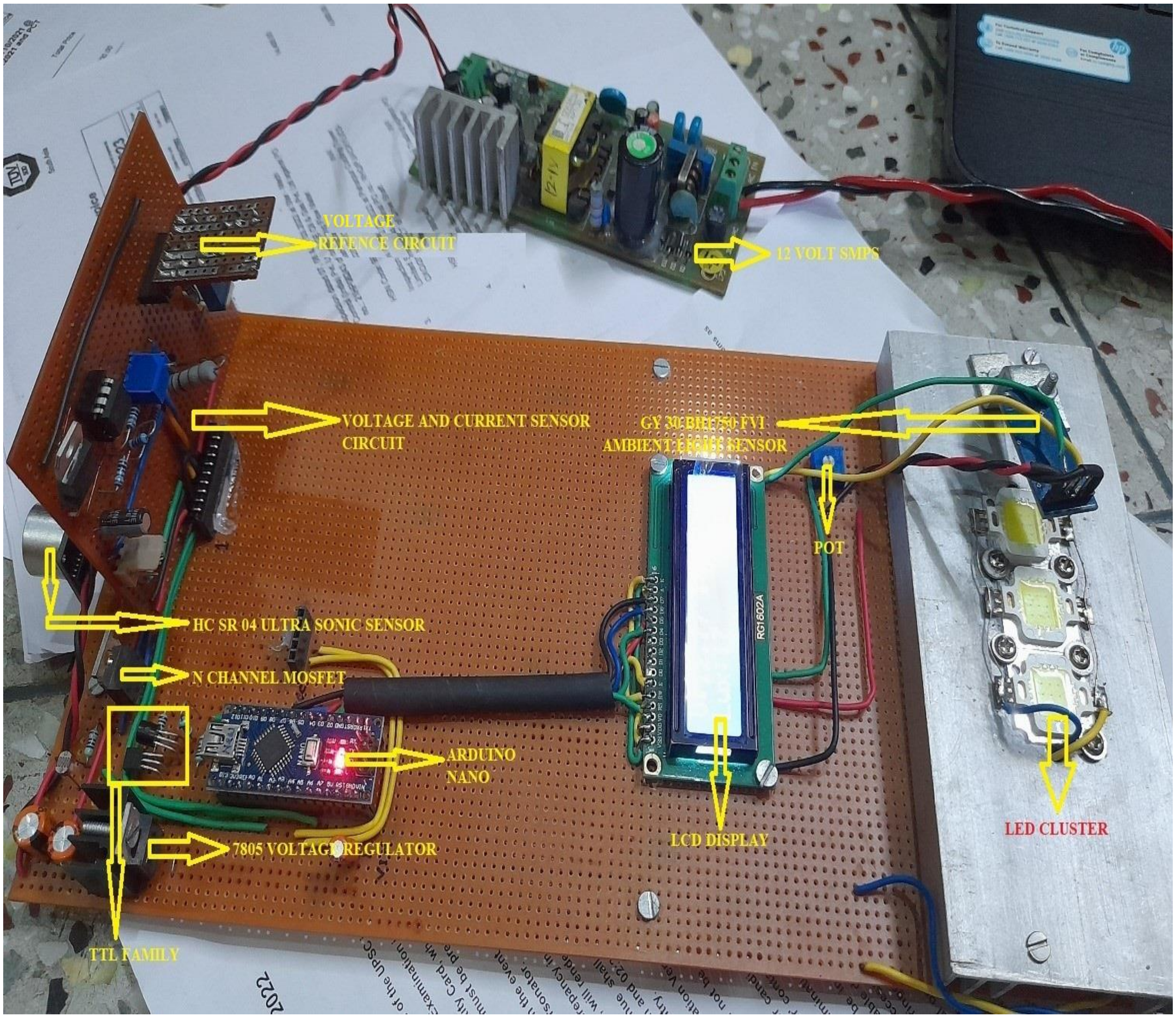

Fig. 22: Main Circuit Board (In ON condition and Daytime is created by Artificial Lighting) When Surrounding LUX is > 70 LUX (Daytime)

When Surrounding LUX is > 70 LUX (Daytime) shown in the above Fig 22, the LEDs will be in off condition. Here in this figure we can see the daylight is created artificially in a room and LDR does not sense the value of surrounding LUX lesser than 70. LCD display is showing the data of system voltage, current through LEDs and LUX value (reflected LUX because LEDs are not turned on) of the LEDs. All the sensors implemented in the circuit are not at all activated. But the function of the microcontroller within the Arduino Nano board are already started from the beginning of the starting of the system.

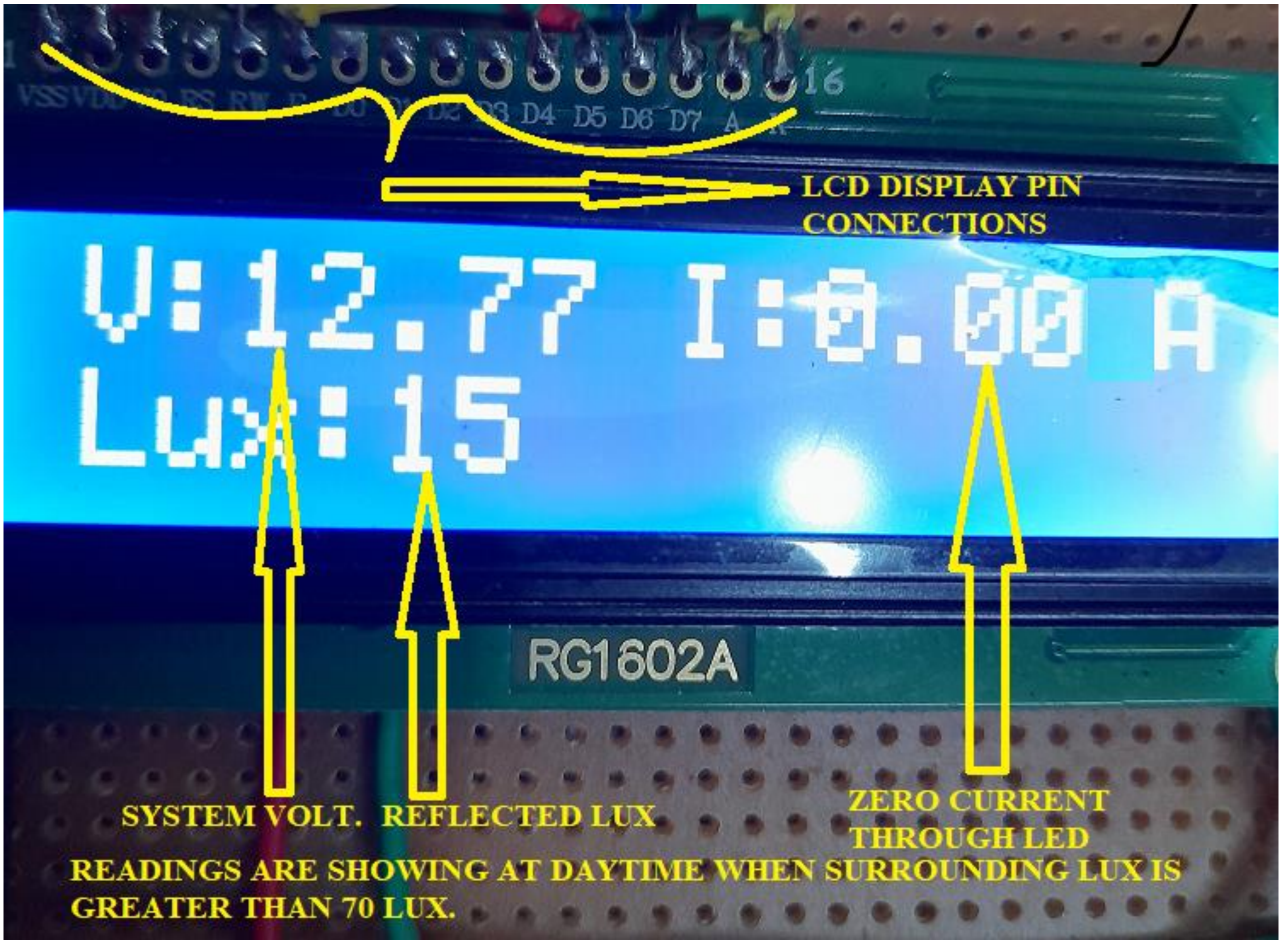

Fig. 23: LCD Display shows readings at day condition

When Surrounding LUX shows in the above Fig 23 is > 70 LUX (DAYTIME) LCD Display reading shows System voltage, Zero Current & very lesser reflected Lux value at the daytime condition. The current is showing zero because there is no current flowing through the LEDs as because of that they are not turned on till. When the LUX level decreases from 70 LUX, automatically all the LED street lights get turned ON and then we can see the current data in the LCD display and which means the LEDs are already activated and in operation.

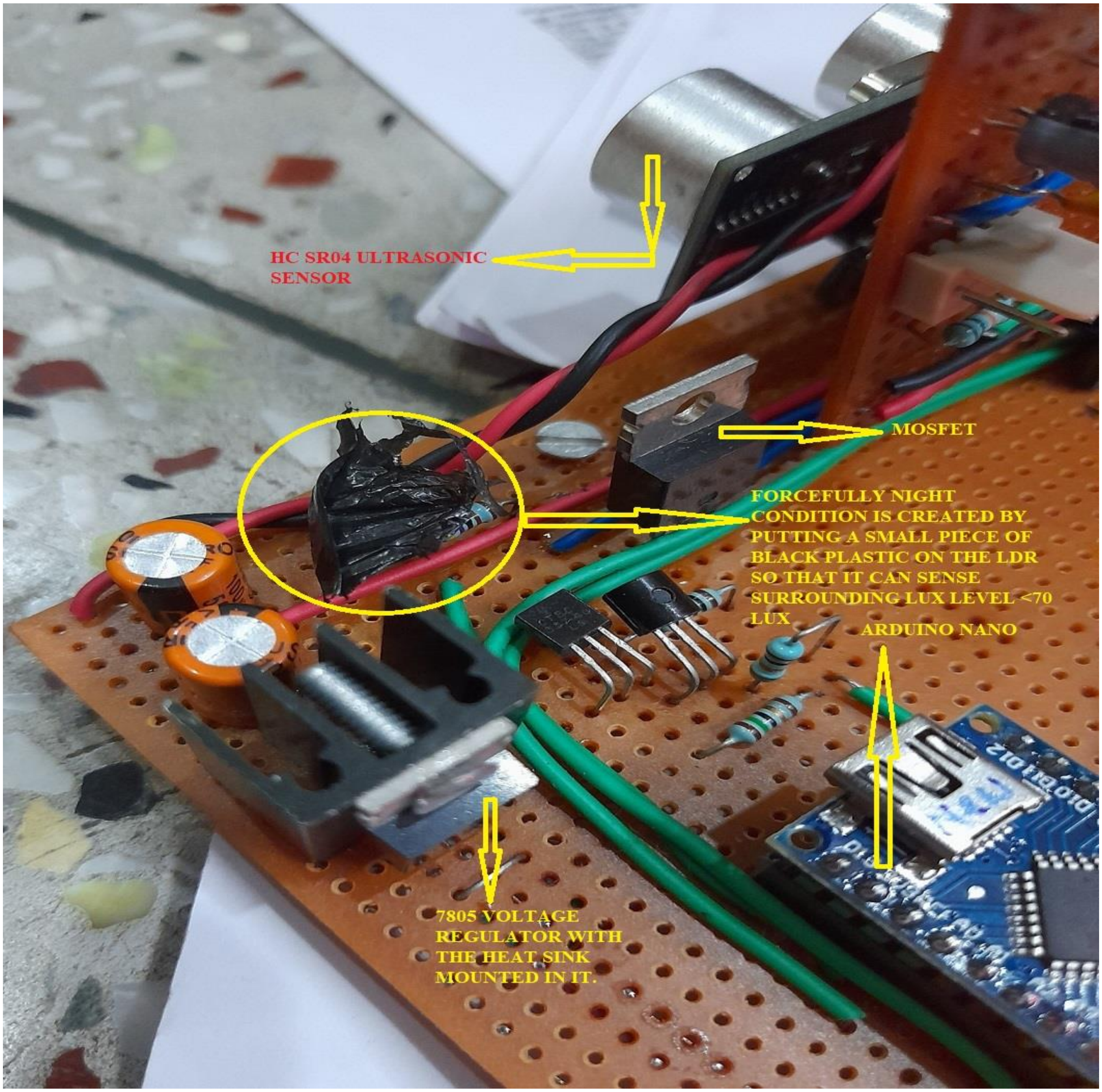

Fig. 24: Forceful Night condition (Covering LDR)

In the above picture Fig 24, night condition is created by putting a small piece of black plastic in the LDR or Light dependant resistance. It means a forceful night condition is created by forcefully decreases the value of the surrounding LUX less than 70. All the LED street lights will turn on in this stage and will continue to glow at their brightest mode (TIME LAPSE condition) up to a specified value of time. The LEDs are in brightest mode irrespective of sensing any presence and absence of any moving object.

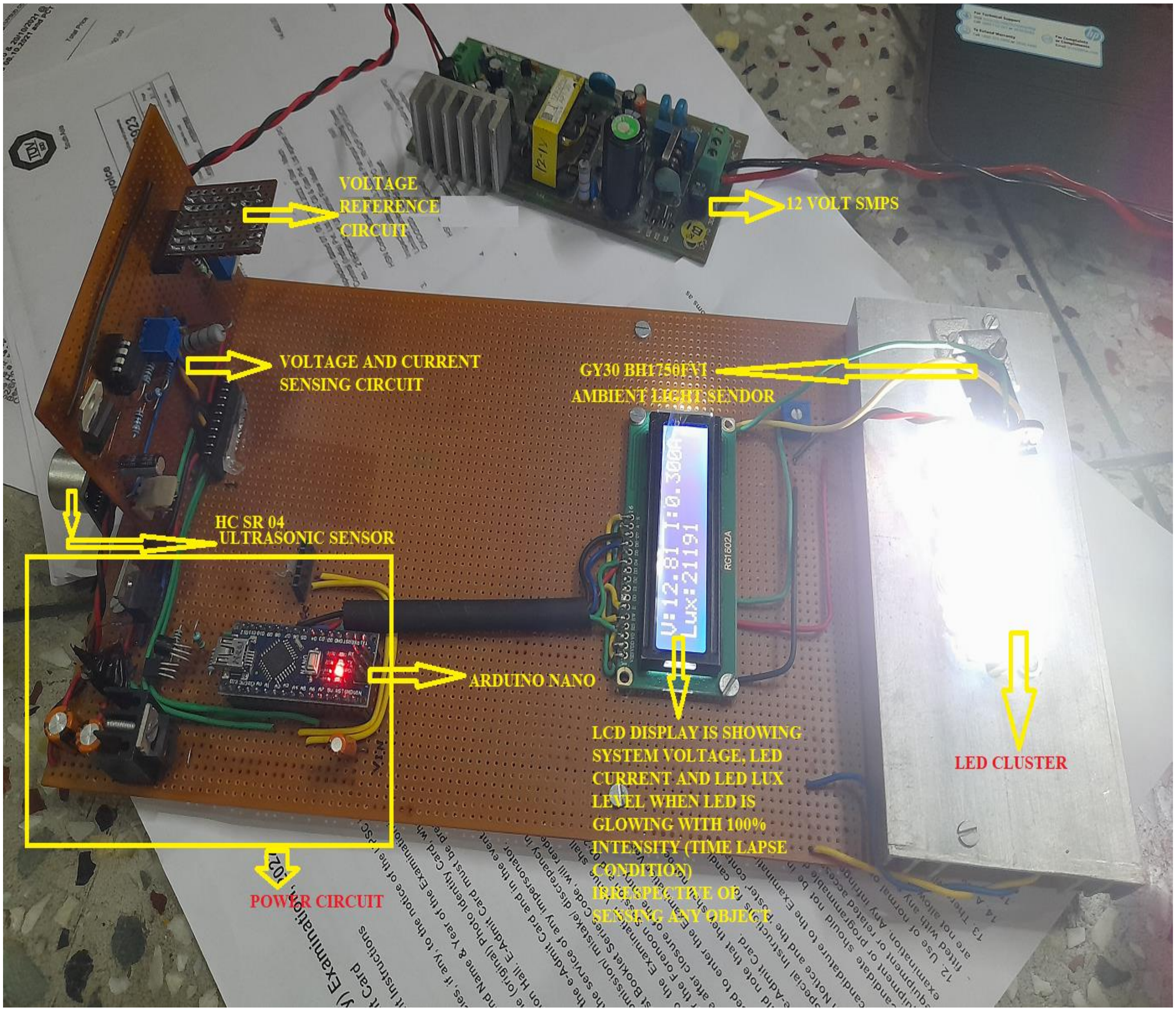

Fig. 25: Main Circuit Board (At night condition and Time lapse started)

In the above Fig: 25 when Surrounding LUX is < 70 LUX (At night condition) LCD Display reading showing System voltage, Full load Current & Lux value for 100% intensity (System in **TIME LAPSE** Condition). All the LEDs will glow with 100% intensity irrespective of presence and absence of moving object. LCD display is showing values of system voltage, LED current and LED

LUX level at this stage. In this stage the light output from the LED is highest and which stays up to a certain period of time. The time lapse condition should be presented in any smart LED street lighting in order to glow the fullest at the busy hours in a day.

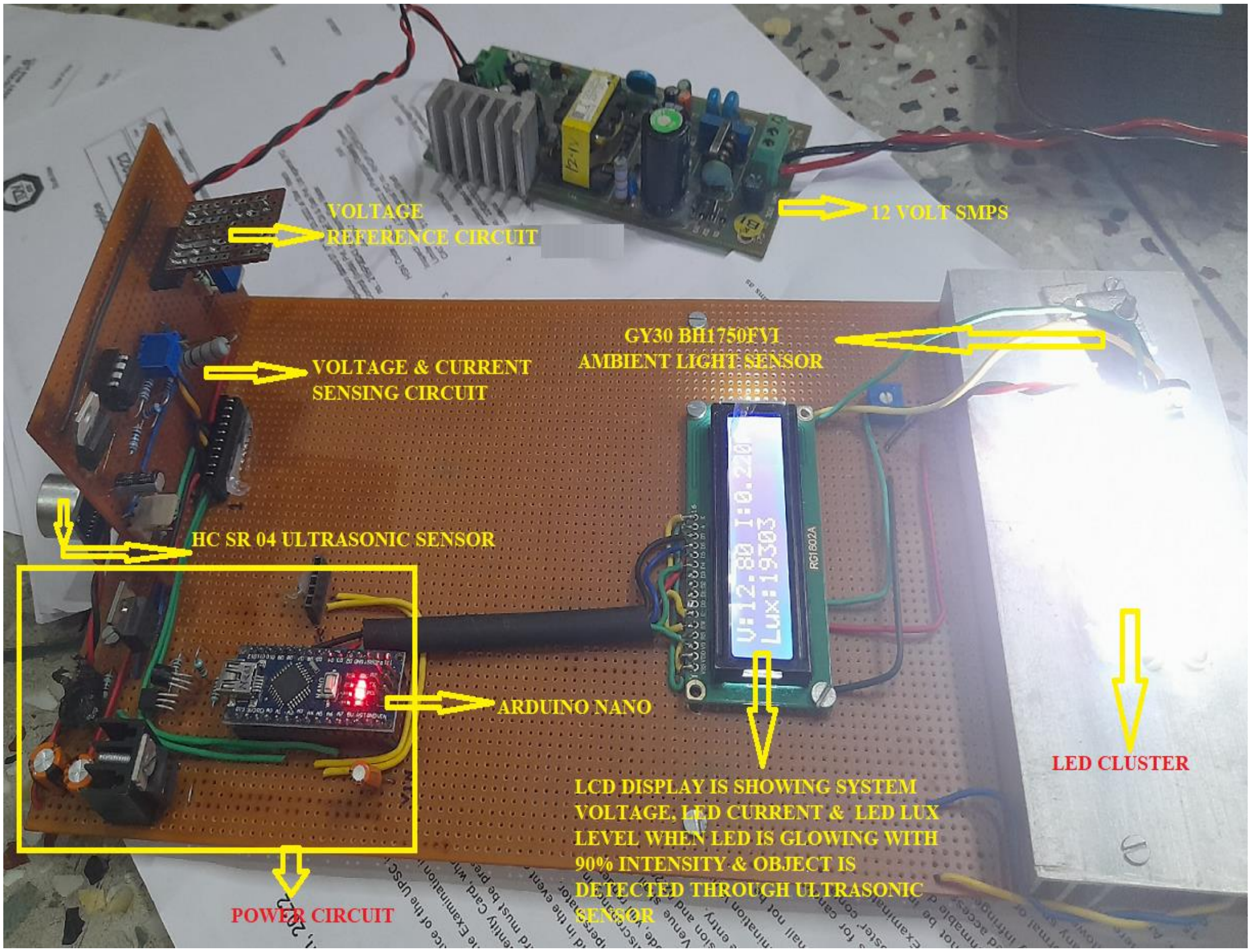

Fig. 26: Main Circuit Board (At night condition and moving object detected)

The above Fig: 26 describes when Surrounding LUX is < 70 LUX (NIGHT TIME) LCD Display reading showing System voltage, LED Current & Lux value for 90% intensity (After the completion of System's TIME LAPSE Condition and Object detected within 3 meters of operational region sensed by the Ultrasonic sensor). The use of high range Ultra sonic sensors in practical will result increasing range of operational area of the sensor in practical life.

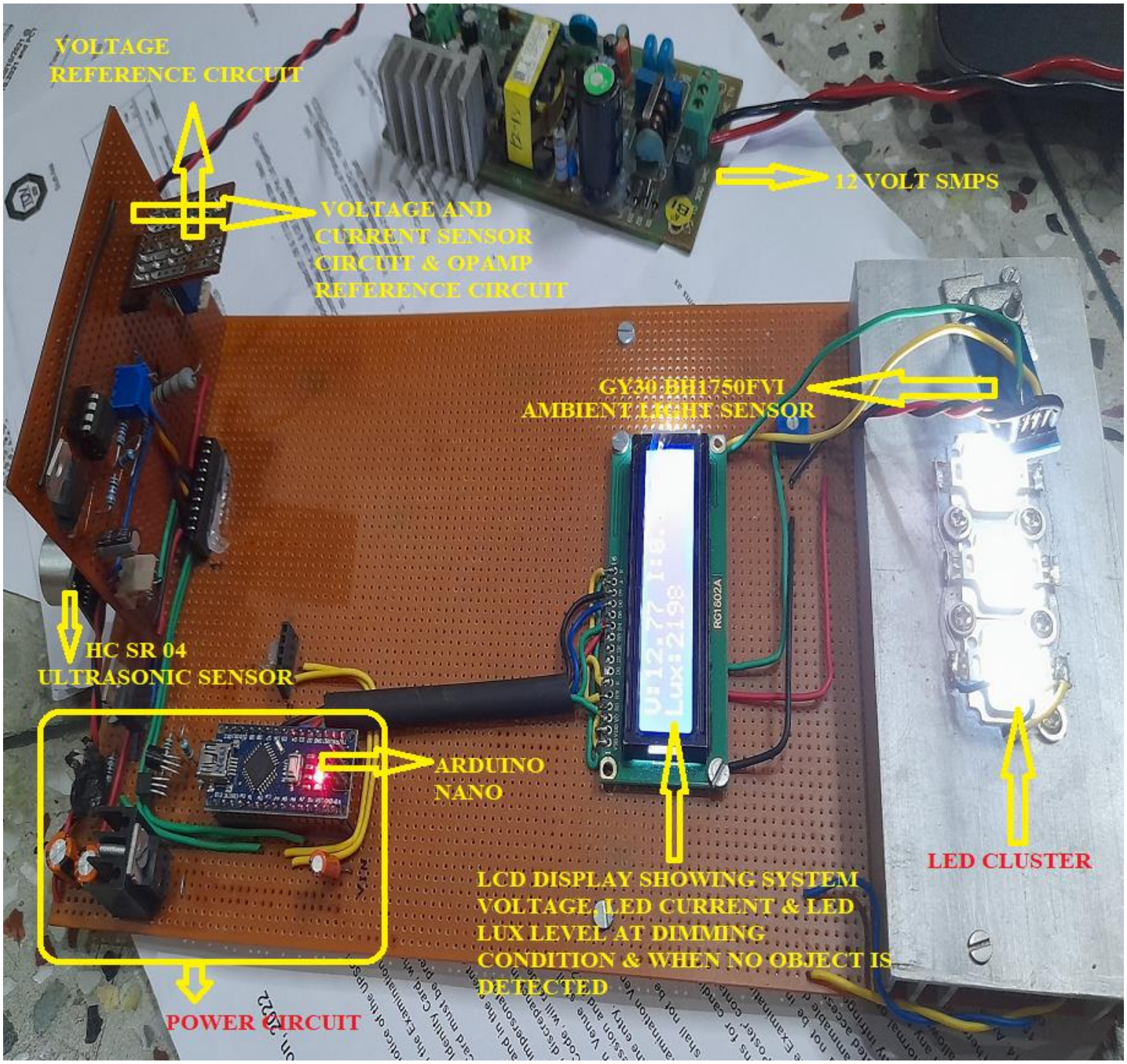

Fig. 27: Main Circuit Board (At night and fully dimmed condition and moving object not detected)

In the above Fig 27 when surrounding LUX is < 70 LUX (NIGHT TIME) LCD Display reading showing System voltage, least LED Current Value & Lux value for 10% intensity (Full dimming condition). In the stage no moving object is detected. If any moving object is detected at the time of value decreasing of LUX level, the LED will automatically start to glow with increasing value of

LUX level right from that time being otherwise it will continue to stay at its dimming condition throughout the night time.

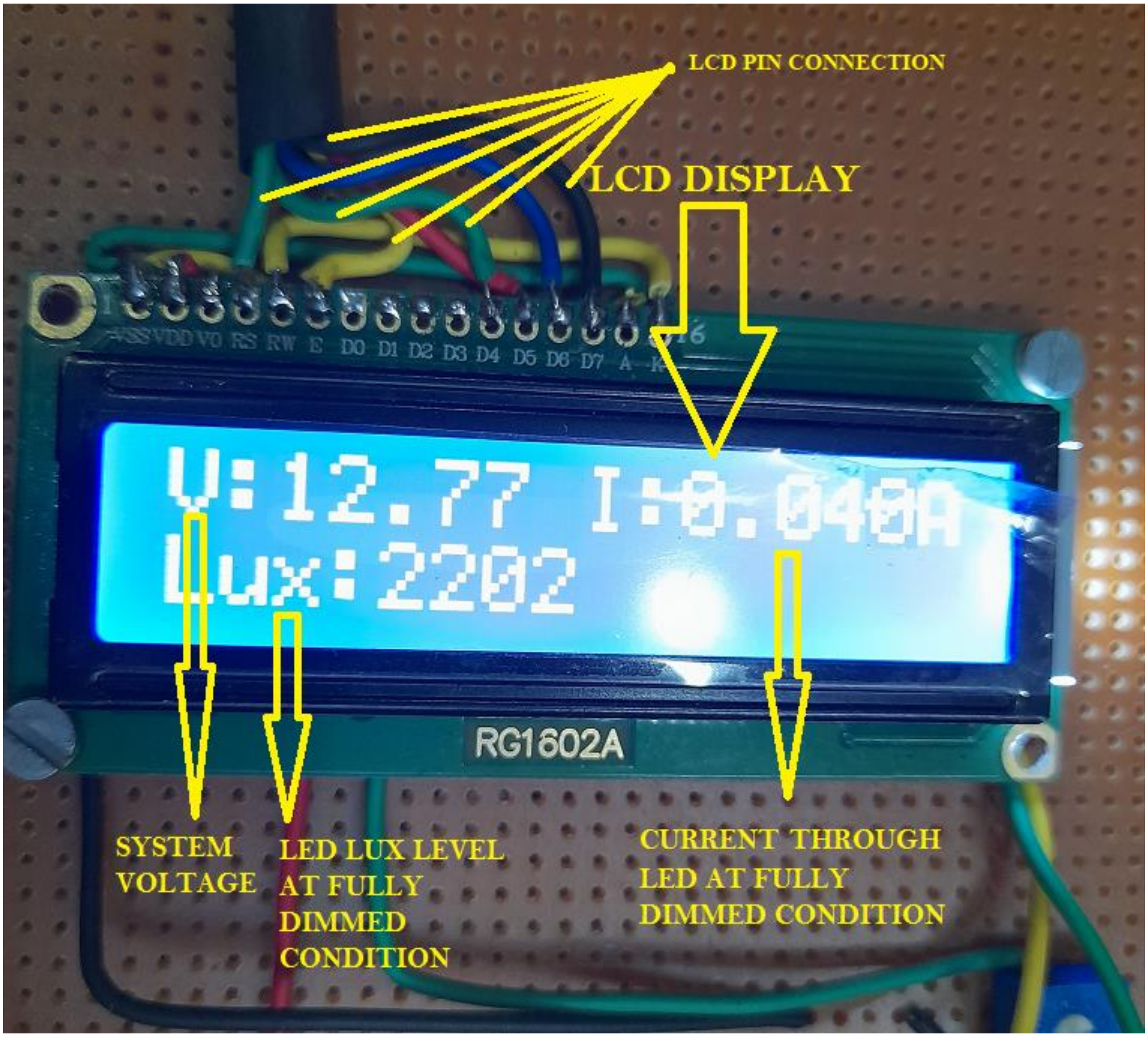

Fig. 28: LCD display showing results at night condition when no moving object is detected and LEDs are fully dimmed condition

In the above Fig 28 it is noted that when surrounding LUX is < 70 LUX (NIGHT TIME) LCD Display reading showing System voltage, Least LED Current & Lux value for 10% intensity level when no object detected within 3 meters of Experimental region. All LEDs are in fully dimmed condition thus saving the power consumption and achieving greater life span. The value of lux is showing the minimum for all the LEDs at the dimming condition.

5.3 Cost Analysis:

Costing of Conventional LED street light (Considering only one street light):

In India, for 1 km long two-lane road, with 40m pole distance and opposite arrangement using 100-watt LED street light. We have 50 street lighting columns taking the average cost of electrical energy as Rs. 10 per kW/h, the running cost for street light is (50x100x10)/1000 = Rs. 50/ hrs./km.

Like A 100 Watt LED street light installed on a highway road. Light pole is 30 feet long. Most of the time, street lights are used for 12 hours approx. a day. The average price in the India is Rs. 10/- per kilowatt-hour (Rs. 10/kWh).

Consumption for 12 hours is (12 hours*100 watt) = 1200 watt-hours = 1.2 kWh.

So daily Electricity cost is (1.2 kWh*Rs. 10) = Rs. 12. Monthly Electricity street light cost is (Rs.12*30) = Rs. 360. Or Rs. 4320 per year or Rs. 43,200 in 10 years. The power consumption and electricity cost can further reduce by using smart LED street lights described above.

Reduction in Costing in Smart street lighting system (Considering only one street light):

By using the smart street lighting technique described above A 100 Watt LED street light installed on a highway road. Light pole is 30 feet long. Most of this time, street lights are used for 5 hours approx. a day in brightest mode without dimming (like time lapse from 04:30pm to 09:30 pm), with dimming 3 hours (from 09:30pm to 12:30am next day) and almost with fully dimmed condition for 4 hours (from 12:30am to 04:30am). The average price in the India will be Rs. 10/- per kilowatt-hour (Rs. 10/kWh).

Consumption for 12 hours is (12 hours* 65 watt) = 780 watt-hours = 0.78 kWh.

So daily Electricity cost is (0.78 kWh*Rs. 10) = Rs. 7.8. Monthly Electricity street light cost is (Rs. 7.8*30) = Rs. 234. Or Rs. 2808 per year or Rs. 28,080 in 10 years.

So, the reduction is yearly bills (Rs. 4320- Rs. 2808)= Rs. 1512 per year and Rs. 15,120 in 10 years.

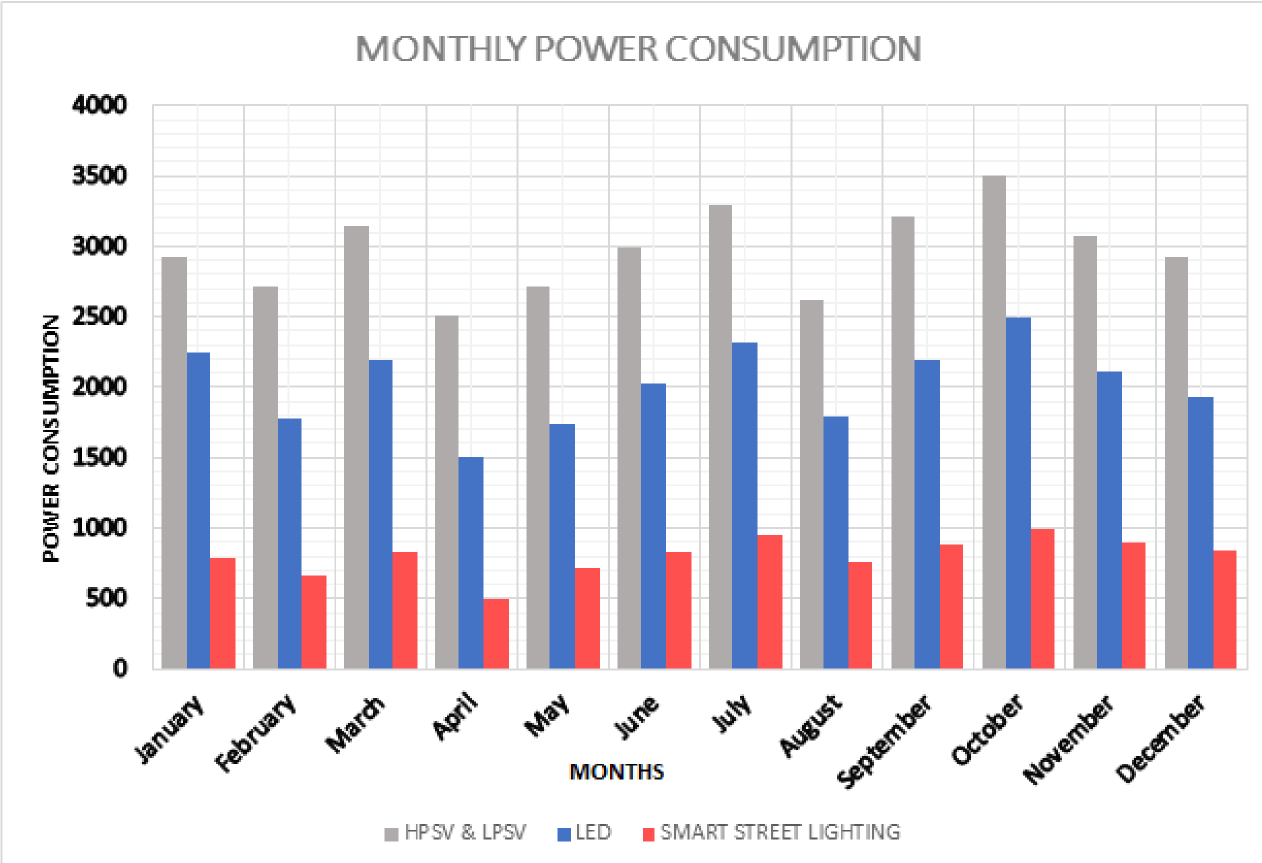

Fig. 29: Reduction in Monthly Billing (Power Consumption in kWh Vs. Months)

Finally, it can be concluded that using two light sensors- GY30 BH1750 FVI which is Ambient light temperature sensor and HC SR 04 which is Ultrasonic sensor in this study it is found that energy consumption is reducing in monthly billing (depicted in Fig 29). Conventional LED street lighting system has some limitations on its functionality thus resulting greater energy consumption, costlier maintenance, manual fault analysis and time taking replacement. Here in this study system voltage, current through LEDs and LED LUX level can be monitored through the LCD display. So, in any cases of faulty situation any LED street light malfunctions it can be clearly understood by visualizing the system output through LCD display.

Through the usage of ambient lux sensor, LEDs will automatically turn ON & OFF by sensing dawn and dusk conditions (here in the system LDR value 81 is scaled by programming with the minimum taken lux value 70 LUX). Hence the issue of un necessary glowing of LEDs at daylight time can be resolved so easily.

By the usage of the occupancy sensor HC SR04, LEDs will automatically get brightened and dimmed depending on the availability or absence of moving objects like pedestrian, vehicles etc at night condition. Busy schedules in the evening will receive a **TIME LAPSE** condition just after the LEDs get turned on and which means it will continue to glow with its fixed **100% intensity** for the specified time (mentioned in the program and can also be changed as per the actual requirement.

After ending the time lapse condition, those LED street lights started glowing with their **90% intensity** for rest of the time when the circuit senses any moving object otherwise LED street lights will automatically go to their fully dimming condition.

Thus, as per the Fig 29 monthly billing of smart LED street lights will be reduced significantly than using general LED street lights over the previous uses of HPSV & LPSV.

CHAPTER – 6
SUMMARY, CONCLUSION & FUTURE SCOPES

6.1 Summary

Traditional control and maintenance of street lamps is not enough more to modernization need. The main focus of proposed system is to optimize management and efficiency of street lighting systems and realize a kind of higher autoimmunization, more credible and efficient long-distance monitoring and control system. It uses a sensor combination to control and guarantee the desired system parameters and a suitable system output.

In the conventional street lighting system with HPSV, LPSV & MV problems can be found like greater energy consumption, lesser eco friendliness, greater operating cost, less reliability etc. These mentioned problems of HPSV & LPSV systems are reduced after using LEDs as the street lights but it also consists some limitation over various aspects like- Energy consumption, efficacy, reliability, maintenance and quick operation upon surrounding requirement. So, in this study, an attempt has been made in order to make the LED street light more smart which makes the system more energy efficient, eco-friendlier, having easier maintenance, more reliable and automatically operating upon the actual surrounding requirement with the help of control unit and installed sensors within itself.

In this work the whole process of the attempt to make a smart street lighting system is described vide six number of chapters. Like:

- In the first chapter the benefits of using a LED as street light is described aiming to make it smarter by using sensors and programming control which is elaborated as main objective of the study,
- In the second chapter similar development studies and research works are described which are done by the various researchers from where several guidance is achieved,
- In the third chapter the basic concept of Smart street light has been described with its benefits, smarter aspects and a few examples of implementation is also elaborated,
- In the fourth chapter the detailed methodology is described using which the attempt is planned to be executed in the proper manner in order to get the desired output. A flowchart is also prepared based on various steps involved in the methodology,
- In the fifth chapter the whole implementation process with detailed analysis of the developed system has been described and also the final observation is demonstrated

by the graphical representation. The matter of cost effectiveness is also described,

- Finally, in the sixth chapter the total summarization of the total study has been prepared in brief and from which the conclusion can be described so easily.

6.2 Conclusion:

Finally, a conclusion can be drawn based on the above summarization is:

A general LED street having benefits in its usage as street light over the conventional HPSV & LPSV street lighting system but the output is having some limitations in various aspects like energy efficiency, reliability, eco friendliness over various emissions and controlling activities upon the actual surrounding requirement. A smart LED street light is nothing but a LED street light with some sensors, controlling unit and monitoring system installed within itself and which in turns omits those limitations in activity of a conventional LED street light is having. In this study two types of sensors are used such as “Ambient light intensity sensor” and “Ultrasonic sensor” which make the LED street lights smarter by controlling its ON & OFF and Brightest and fully dimmed activities over dawn and dusk and presence or absence of any moving objects like vehicles, pedestrians at night respectively. The system voltage, LED current and illumination level of the smart LED street lights can also monitor by the LCD display implemented in the system by which easily detect any faulty condition and can opted for replacement very quickly and last but not the least the reduction in energy consumption is also observed finally by visualizing the monthly billing in a year.

6.3 Future scopes

This study describes an intelligent street lighting system using LED with a control system for efficient management. This features switching ON the lights only when necessary increasing the energy saving and Lamps lifetime. The intensity controlling nature offers very less maintenance and flexible, extendable and fully adaptable user needs in rural and urban areas. The simplicity and the reliability of electronic components enhances the feature of the sensor also and also successfully implement the smart concept of the street light.

[25] Adaptive, interoperable lighting solutions are needed to bring savings to the next level, facilitated by connecting LED bulbs with a central management system (CMS) over the internet. These networked street lighting systems allow operators to monitor and regulate light levels in unprecedented ways, resulting in increased energy savings and lower operational costs. The 50% energy savings that are realised by switching to LEDs increase to 80% when connectivity and a central management system (CMS) are added.

While the energy and cost saving benefits are driving adoption, cities are increasingly seeing infrastructure. With an even and widespread distribution across urban areas, readily available power and integrated connectivity, smart street lighting is being used to form the technology foundation of a city. Through the addition of data collection devices such as sensors and cameras, street lighting infrastructure is being used as a platform to host a variety of applications in the areas of environmental monitoring, traffic optimization, smart parking and public safety. Furthermore, street lighting infrastructure is being used to host charging points for electric vehicles, and as a base for public Wi-Fi and communication networks.

The Internet of Things Institute provides a useful metaphor: “Lamp posts may well follow a trajectory similar to that of mobile phones. It wasn’t so long ago that mobile phones were suited for one purpose only – making calls. Now, making a phone call has become almost secondary to all of a smart phone’s other capabilities. Similarly, while the lamp posts of yesteryear provided only illumination, modern-day lamp post can serve as multi-functional smart-city nodes, capable of monitoring everything from crime to parking to weather forecast”.

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