VOL. 10, NO. 22, DECEMBER 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

IMPLEMENTATION OF PASSIVE INFRARED SENSOR IN STREET LIGHTING AUTOMATION SYSTEM

N. L. Ramli[1], N. Mohd Yamin[1], S. Ab Ghani[1], N. Md. Saad[1] and S. A. Md Sharif[2]
[1]Sustainable Energy & Power Electronics Research Cluster (SuPER), Faculty of Electrical and Electronics, Universiti Malaysia Pahang, Pekan, Pahang, Malaysia
[2]Faculty of Computer Systems & Software Engineering, Universiti Malaysia Pahang, Lebuhraya Tun Razak, Gambang, Kuantan, Pahang, Malaysia
E-Mail: noorlina@ump.edu.my

ABSTRACT

This paper presents a smart street lighting system which provides a safe night time environment for all road users and pedestrian. The main objectives are to build an automation system of street lighting using a low-cost microcontroller which is Arduino and to achieve energy-saving. Light Emitting Diode (LED) is represented as the light module. This system is controlled according to the specific mode. These modes are controlled by two sensors which are Light Dependent Resistor (LDR) and Passive Infrared (PIR) sensor. This system can automatically turn on and off the lights according to traffic flow. This system operates during the night and the focus is only for the one-way road at a junction. Street light will be on when only there is road user otherwise, it will turn off. This design can save a great amount of electricity or energy consumption compared to conventional street lights that keep alight during nights. Moreover, the maintenance cost can be reduced and lifespan of the system will increase. As the result, the system has been successfully designed and implemented as a model system.

Keywords: arduino, PIR sensor, LDR sensor, light emitting diode, energy-saving.

INTRODUCTION

Nowadays, street lighting is essential for all areas whether urban or rural since people know that street light is an alternative during the day night in order to keep the safety of the road users. Street lights management control is quite simple, yet as the urbanization, the number of streets increased rapidly [1]. The traditional lighting street lamp on-off control is based on chronological time, which may inefficient and inflexible.

The existing street lighting control system used timer and photocell. The timer is set up to turn on the street light within 7.00 p.m. until 7.00 a.m. Meanwhile, photocell reacts based on the presence of light or electromagnetic energy. In a rainy day or when the light intensity is low, the photocell will energize the contact and automatically turn on the street lights. This system is quite inefficient since the condition of day and night is uncertain. Sometimes at 7.00 p.m. the day is still bright but the street light is already switched on. In contrast, at 7.00 a.m. the street light is already switched off although the day is still dark. Thus, this system is quite inflexible.

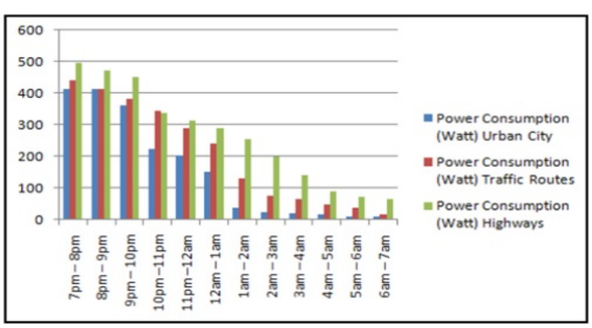

Figure-1. Power consumption for each hour at the urban city, traffic routes and highways [9].

The public lighting is designed to meet the needs of local communities, such as the rising number of road and sidewalk traffic safety [2]. In order to surge the efficiency, a modern street lighting control system must be able to adapt the light level intensity to determine the optimum energy consumption level. However, power wastage will happen if there is no user or vehicles use that road especially in rural areas at midnight. Figure-1 shows the power consumption in the urban city, traffic routes and highways from 7.00 p.m. till 7.00 a.m. The graph showing the use of road reduced beginning at 1.00 am until 7.00 am.

This Street Lighting Automation System is an intelligent system which provides the flexible and efficient system in order to control the street lighting autonomously. This system is controlled by two sensors which are PIR sensor and LDR sensor. LDR sensor is used in order to detect darkness to activate ON/OFF switch. In the previous study [3][4], the researchers have suggested the new technique to automate their system using both sensors. With the presence of these sensors that detect the intensity of light and used to detect the presence of humans or cars then, it turned on the system automatically. The main controller for this project is using an Arduino Uno.

The main reason LED was chosen is to reduce the energy consumption as it were very effective in lighting and low light decay in the lifetime. The LEDs have about 110° light emission angle. Meanwhile, the conventional lamps usually have 360° and need a reflector to direct the light beam to the target [5]. Table-1 shows the comparison between LED and another type of lamps used in existing street lighting.

VOL. 10, NO. 22, DECEMBER 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

Table-1. Comparison energy consumption between LED and other types of lamps [5].

Type of lamp	Luminous Efficiency in m/W	Color-Rendering Properties	Lamp life in hrs	Remarks
High Pressure Mercury Vapor (MV)	35-651	Fair	10,000-15,000	High energy use, poor lamp life
Metal Halide (MH)	70-1301	Excellent	8,000-12,000	High luminous efficiency, poor lamp life.
High Pressure Sodium Vapor (HPSV)	50-1501	Fair	15,000-24,000	Energy-efficient, poor color rendering.
Low Pressure Sodium Vapor	100-1901	Very Poor	18,000-24,000	Energy-efficient, very poor color rendering.
Low Pressure Mercury Fluorescent Tubular Lamp (T12 & T8)	30-901	Good	5,000-10,000	Poor lamp life, medium energy usage, only available in low wattage.
Energy-efficient Fluorescent Tubular Lamp (T5)	100-1201	Very Good	15,000-20,000	Energy-efficient, long lamp life, only available in low wattage.
Light Emitting Diode (LED)	70-1601	Good	40,000-90,000	High energy savings, low maintenance, long life, no mercury. High investment cost, nascent technology.

METHODOLOGY

Design architecture

The system development starts with the design architecture of the proposed system. The block diagram of this system is as shown in Figure-2. The components for this project have been classified based on the components group consists of input, output and controller. Sensors are used to control the desired system parameters. Next, the sensors will transfer the gathered information into the controller which runs the software in order to analyse the system. Meanwhile, the purpose of the microcontroller is to gather the data from the street light and transfer it as the output of the system.

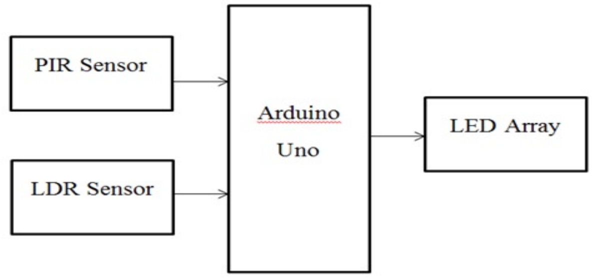

Figure-2. Block diagram of street lighting of automation system.

Hardware specification

In hardware specification, Arduino Uno has been selected as the controller for this system due to its low cost, compact size, compatibility, easy interfacing over several other type of controller including Programmable Integrated Circuit (PIC), Programmable Logic Controller (PLC) and others. Arduino is an open-source hardware kit with 8-bit Atmel AVR pre-programmed on-board microcontroller kit. It comes with boot loader which uploads programs into microcontroller memory. Figure-3 shows the diagram of Arduino Uno.

Figure-3. Diagram of Arduino uno [6].

Two types of sensor used in this system which are Light Dependent Resistor (LDR) and Passive Infrared (PIR) sensor. LDR sensor is an electronic component that has a variable resistance that changes with the light intensity fall upon it. The resistance will drop with increasing incident light intensity. In other words, when there is dark, it has high electrical resistance yet when there is light, it has low electrical resistance. Normally, LDR often used in sensing circuit [7].

In the meantime, PIR sensor is a passive electronic device that detects motion by sensing infrared fluctuations. It is made up of crystalline material which generates surface electric charge when exposing to heat in the form of infrared [8]. PIR sensor allowed to sense motion, either vehicle or human in or out of the sensor range. This sensor is quite small, inexpensive, easy to use, low power and easy to interface with. Figure-4 and Figure-5 show the diagram of LDR sensor and PIR sensor respectively.

ARPN Journal of Engineering and Applied Sciences

Figure-4. Diagram of LDR sensor [8].

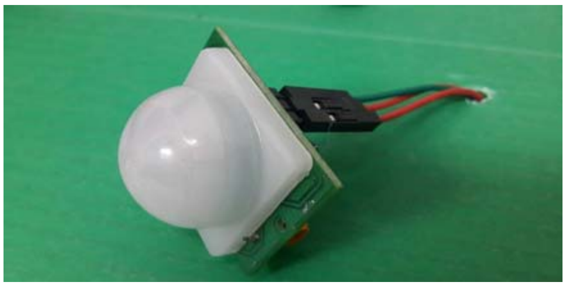

Figure-5. Diagram of PIR sensor.

Figure-6 shows the proposed design layout of the street lighting automation system. There are 12 LEDs used as the light module, 4 PIR sensors that locate about 5cm from the light pole and 1 LDR sensor at the junction of the road to detect light intensity.

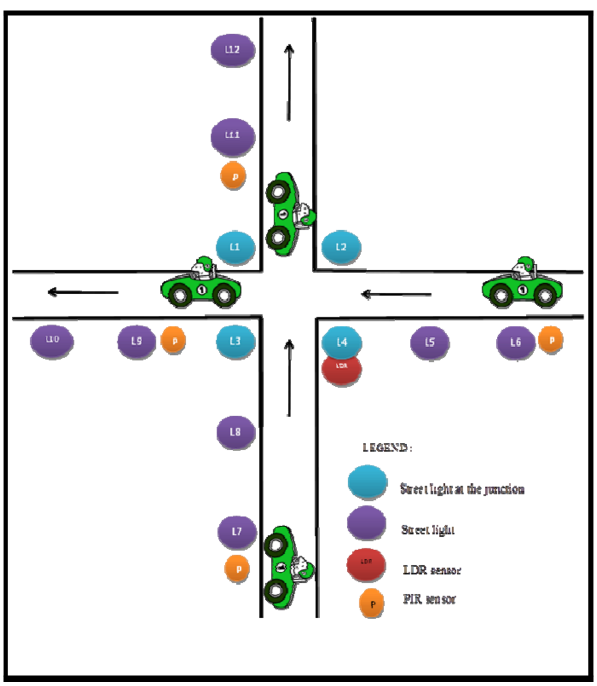

Figure-6. Design layout of street lighting.

Software development

The microcontroller required a program to operate and execute the process associated with the proposed design. Arduino software has been used as the interface between software and hardware of this project. This Arduino version 1.0.6 makes it is easy to write and upload the code to the board. It can be used in any Arduino board and written in Java. There is simple step to verify, compile and upload after writing the code and simply know either the code written contains error or not.

The complete flowchart which indicates the whole operation of the system and controlled by two modes is as shown in Figure-7. These modes are controlled by two sensors which are LDR and PIR sensor. The focus of this project is only a one-way road at a junction and it will detect any movement either vehicle or pedestrian.

Firstly, Mode 1 will be selected when LDR detect day or night. If it senses night, automatically the street lights at the junction of the road (L1, L2, L3 and L4) and all PIR sensors will be switched on. Next, Mode 2 will take over when each PIR sensor at any point senses the motion or any movement of the vehicle within 5 metres. Arduino microcontroller will switch on the street lights at the edge of the road. The street lights will turn on until the PIR sensor does not sense any movement within 10 seconds, therefore street lights will be turned off. When LDR sensor senses the intensity of light from the sun, the system will turn off both street lights and PIR sensor. Lastly, the system will loop to the initial condition.

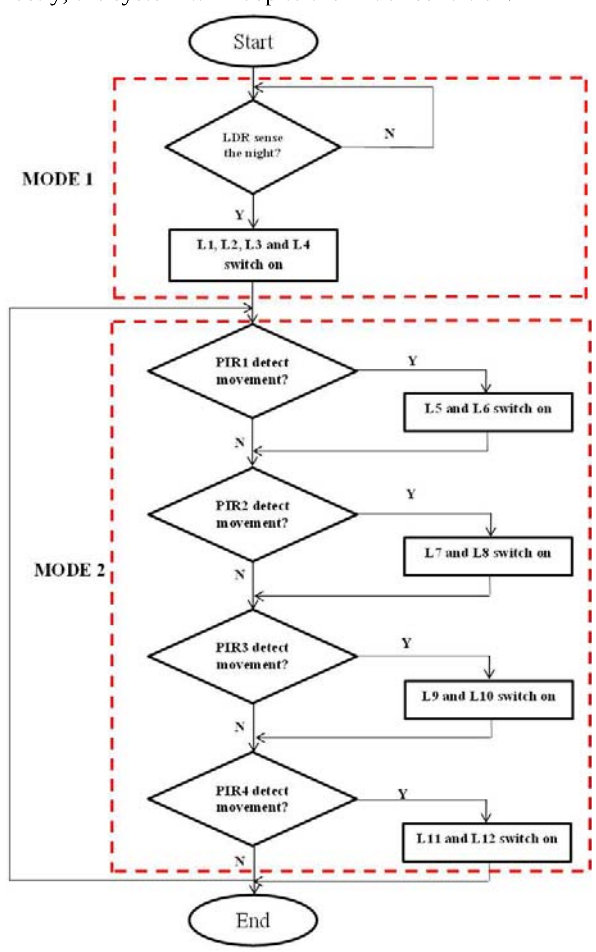

Figure-7. Flowchart of the system.

ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

The complete schematic diagram of proposed design system is as shown in Figure-8.

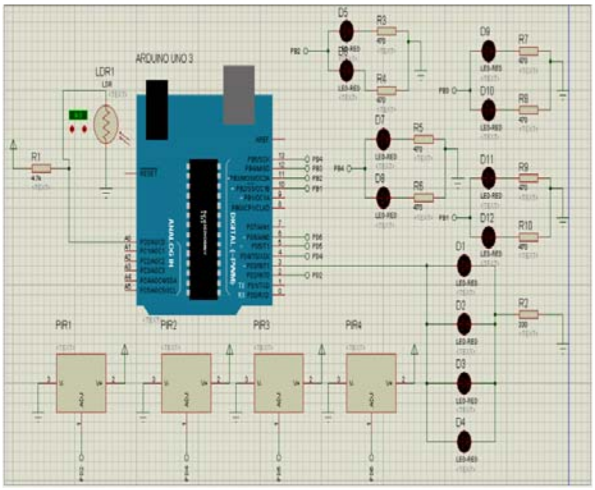

Figure-8. Complete schematic diagram of the system.

RESULT AND DISCUSSION

Hardware testing

A prototype of the street lighting automation system is developed and the whole prototype design is as shown in Figure-9. The design of the whole project was done with 12 LEDs, 4 PIR sensors and 1 LDR sensor. All the wiring and connection are connected to Arduino board. This was done by calibrating part by part which is started with LDR sensor, then PIR sensor and lastly LED as the light module. During a day, all LEDs and PIR sensor is turned off. This condition is shown in Figure-10.

Figure-9. Prototype of proposed design project.

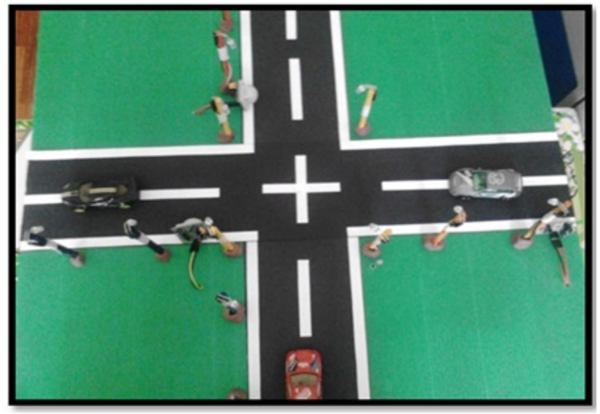

Figure-10. Condition during day.

Meanwhile during the night, whereby LDR sensor detects light intensity, 4 LEDs at the junction be turned on. This condition is on Mode 1. Figure-11 shows the condition of LEDs turned on during the night.

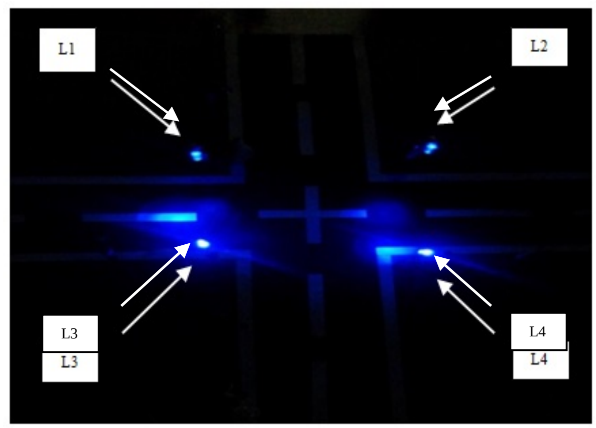

Figure-11. Condition during night, 4 LEDs at the junction turn on.

For Mode 2, PIR sensor will detect any movement of vehicles or pedestrians, then, LEDs will turn on. When PIR sensor 1 detects movement, LED 5 and LED 6 is turned on. This condition is as shown in Figure-12. Figure-13 shows the LED 7 and LED 8 turned on when PIR sensor 2 detect movement. Figure-14 however, shows the LED 9 and LED 10 turned on when PIR sensor 3 detect movement. And lastly Figure-15 shows both LED 11 and LED 12 turned on when PIR sensor 4 detect movement. The system then will loop to the initial condition.

VOL. 10, NO. 22, DECEMBER 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

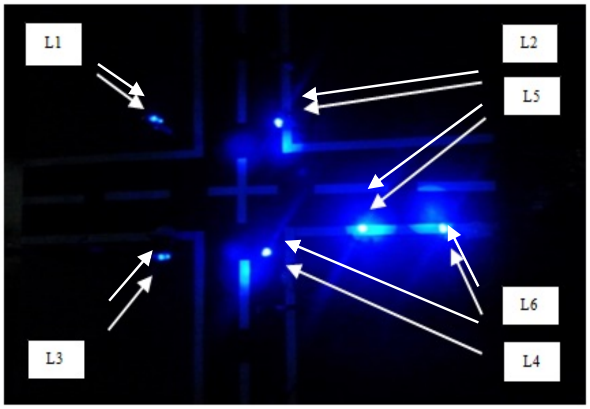

Figure-12. LED 5 and LED 6 turned on when PIR sensor 1 detect movement.

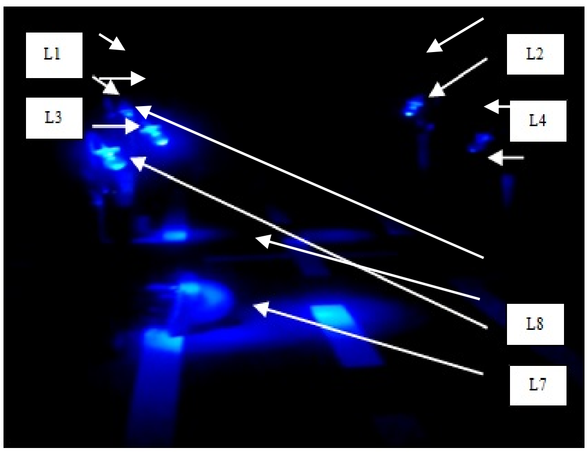

Figure-13. LED 7 and LED 8 turned on when PIR sensor 2 detect movement.

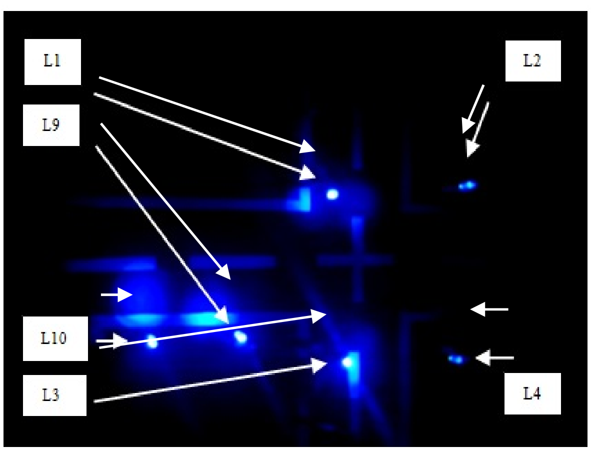

Figure-14. LED 9 and LED 10 turned on when PIR sensor 3 detect movement.

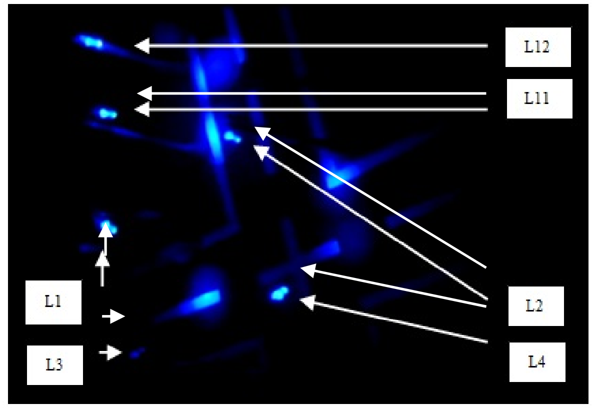

Figure-15. LED 11 and LED 12 turned on when PIR sensor 4 detect movement.

Energy utilization

For this street lighting automation system, the usage of energy or power can be less than the normal power consumption that have been analysed in existing street lighting since this system is using smart street lighting which only light up if there is vehicle or pedestrian. Regardless it is during peak hour on the night such as from 7.00 p.m. until 12.00 a.m. in the midnight. Plus, this system is using LED as the light module which is better in saving energy compared to the existing lamps. Assuming the street lighting functioning completely 12 hours within 7.00 p.m. until 7.00 a.m. Assuming 12 nodes are used to be working power consumed and is given as below.

Using High Pressure Sodium (HPS)
Total power consumed by 1 HPS = 400W
Number of nodes = 12
Number of working hours per day = 12
Power consumed per day = 12 x 12 x 400
= 57.6 kWh
= 57.6 units
57.6 x 30 = 1728 units per month = 1728 kWh/month

Using LED
Total power consumed by 1 LED = 200w
Number of nodes = 12
Number of working hours per day = 12
Power consumed per day = 12 x 12 x 200
= 28.8 kWh
= 28.8 units
28.8 x 30 = 864 units per month = 864 kWh/month

Using LED (for street lighting automation system)
Total power consumed by 1 LED = 200w
Number of nodes = 4 (fully light on for 12 hours)
8 (light on when sensor detect movement)

Number of working hours per day (for sensor):
Assume :7.00 p.m. – 1.00 a.m. (heavy traffic)

= 6 hours
:1.00 a.m. – 7.00 a.m.
= 3 hours (within 30 minutes vehicles pass through)
Total :9 hours

Power consumed per day = [(8 x 9) + (4 x 12)] x 200
= 24 kWh
= 24 units
24 x 30 = 720 units per month = 720 kWh/month

Energy saved between LED for automation system with HPS for public street lighting:
1728 – 720 = 1008

$$\frac{1008}{1728} x100\% = 58.33\%$$

Energy saved between LED for automation system with LED for public street lighting:
864 – 720 = 144

$$\frac{144}{864} x100\% = 16.67\%$$

Calculation for energy saving has been utilized using High Pressure Sodium (HPS) lamps and Light Emitting Diode (LED) [9]. Table-2 shows the estimated power saving after making the comparison between usage of HPS lamps and LED. From this calculation, the comparison in term of energy efficiency is obtained between High Pressure Sodium (HPS), type of lamps which is commonly used in public street lighting with Light Emitting Diode (LED) for automation system which operate according traffic flow by sensing the movement within certain time. Additionally, the comparison with another LED is also made, which used for public street lighting that operated within 12 hours from 7.00 p.m. until 7.00 a.m.

Table-2. Comparison of energy saving between LED and HPS.

Type of lamps used	Percentage of energy saving
LED for street light automation system VS HPS for public street lighting	58.33%
LED for street light automation system VS LED for public street lighting	16.67%

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

From this calculation, comparison of the energy saved between HPS lamps and LED lamp is obtained. About 16.67 % energy can be saved when compared LED for street lighting automation system with LED used for public street lighting. However, 58.33 % energy can be saved when compared LED for street lighting automation system with HPS used for public street lighting. The difference value between usages of HPS lamps quite high compared than the usage of LED. Consequently, usage of LED gives more energy saving compared than High Pressure Sodium (HPS) lamps.

Estimated power saving calculation
Cost of controller = RM 182.10

Saving per month (RM):
= (kWh (not installing PIR sensor) – kWh (installing PIR sensor) x 0.192 sen
= (864 – 720) x 0.192
= RM 27.65

Operation cost per month (RM):
= kWh x 24 hours x 30 days x 0.192 x 4 PIR sensor
= 0.024 x 9 x 30 x 0.192 x 4
= RM 4.98
Saving per year (RM):
= (27.65 x 12) – (4.98 x 12)
= RM 272.04

Simple Payback Period (SPP)
SPP = Cost of controller / Savings per year
= 182.10 / 272.04
= 0.669 years

The calculation is based on Malaysian street lighting tariff that shows the calculation of energy saving for street lighting automation system and simple payback period (SPP) [10]. From the calculation, approximately 0.669 years are required to recover the initial investment through project savings. Therefore, the simple payback period of automation system will reduce for installation in the large area compared to the small area.

CONCLUSIONS

By referring all the results, it can be concluded that both hardware and software development of this project meet the objective of design. A working prototype of street lighting automation system was successfully built using Arduino Uno. Usage of PIR sensor as the input gives energy saving to the system since LED turn on only when there is movement from vehicles, thus, the usage of power consumption by LED decreases. About 16.67 % energy can be saved when compared LED for street lighting automation system with LED used for public street lighting. However, 58.33 % energy can be saved when compared LED for street lighting automation system with HPS used for public street lighting.

For future development, this system can be upgraded for two ways road especially in highways, traffic routes and urban areas.

REFERENCES

[1] Y. Wu, C. Shi, X. Zhang and W. Yang. 2010. Design of new intelligent street light control system. 8th IEEE International Conference Control Automation ICCA 2010, pp. 1423–1427.

[2] A. Lavric, V. Popa and I. Finis. 2012. The design of a street lighting monitoring and control system. EPE 2012 - Proc. 2012 International Conference Expo. Electrical Power Eng., pp. 314–317.

[3] R. S. Alex and R. N. Starbell. Energy Efficient Intelligent Street Lighting System Using ZIGBEE and Sensors. International Journal of Engineering and Advanced Technology (IJEAT). Vol. 3, No. 4, pp. 41–44.

[4] R. N. Shilpashree, H. O. Shruthi, S. Smitha, C. N. Veenashree, and A. S. S. I. GSM BASED AUTOMATION OF STREET LIGHT. International Journal of Innovative Science, Engineering & Technology (IJISET). Vol. 1, No. 3, pp. 296–298.

[5] S. Kumar. 2010. Energy Efficient Street Lighting: Guidelines. Available: <http://www.beeindia.in/schemes/documents/ecbc/eco3/DSM/Energy%20Efficient%20Street%20Lighting%20Guidelines.pdf>. (3 August 2015).

[6] M. Srikanth and K. N. Sudhakar. 2014. ZigBee Based Remote Control Automatic Street Light System. International Journal of Embedded and Software Computing (IJESC). pp. 639-643.

[7] K. Praveen, R. M. Nanda, A. B. Venkata, and H. Kadakol. 2014. Modular Weather and Environment Monitoring Systems using Raspberry Pi. International Journal of Engineering Research & Technology. Vol. 3, No. 9, pp.686–689.

[8] P. Chodon, D. M. Adhikari, R. Biswa, and S. Gyeltshen. 2013. Passive Infrared (PIR) Sensor Based Security System. International Journal of Electrical, Electronics and Computer Systems. Vol. 14, No. 2, pp. 2–6.

[9] C. A. Swathi, S. H. Kumar, A. R. Annappa. 2014. Smart Street Lighting System Based On Sensors Using Plc And Scada. International Journal Of Mechanical Engineering And Technology (IJMET). Vol. 5, No. 9, pp. 44–50.

[10] M. F. Abas, N. Saad, and N. L. Ramli. 2009. A Smart GUI Based Air-Conditioning and Lighting. Proceedings of the 8th WSEAS International Conference on Circuits, systems, electronics, control & signal processing. pp. 87-92.

[11] R. Husin, Z. Othman, M. F. Saari. 2005. Automatic Lighting System for Energy Efficiency based on Low Cost Microcontroller. International Journal of Simulation Systems, Science & Technology (IJSSST). pp. 43-48.