Energy Saving Smart Light Switching System

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***Abstract*—The main objective of this paper is to design a smart lighting system with the aim of energy saving and automatic operation. Smart energy saving light switching system can be used in a room where sun light is not uniformly distributed during the day time. In this paper, two light dependent resistor sensors which are used to detect the intensity of light falling on them and one passive infrared sensor used to detect the movement of human body. The switching algorithm is implemented on AT89S52 microcontroller. The hardware of the switching system is designed, fabricated and tested. It has been observed that the light energy switching system gave fairly good result at different locations.**

***Index Terms*—**Light dependent resistor, Passive infrared sensor, Switching system, Microcontroller, Intensity.

I. Introduction

THE work published by various authors to save energy using automatic lighting system is presented in the section.

The paper published by the author Aurele J. Maillet et al. [1] discussed energy efficient lighting technologies. In addition to this the author also addressed various guidelines and improved technologies for indoor and outdoor application that includes pulp and paper industries. The author Francis Rubinstein et al. [2] demonstrated the energy saving and demand reduction capabilities of lighting control system. A novel two-part control photocell strategy proposed by the authors was successfully implemented and demonstrated. After 9 months of operation the authors observed that energy saving of approximately 50% relative to previous usage. The paper presented by the authors Sheryl Nathan et al. [3] provides a new innovative idea to extend the feature of energy saving in lighting products using LEDs. They have experimentally demonstrated that by using LED bulbs in place of large consuming electrical energy components such as high power bulb, incandescent bulb, reflector lamp, gas discharge lamp, mercury vapour lamp etc. 1million kilowatt-hours (kWh) of energy can be saved. In paper [4] the automatic light switching system can be used as door sensor to save energy and also security purposes. This is eco-friendly, automatic sensing and controlling, energy saving system. This system is based on the principle of light switching "ON" or "OFF" with respect to individual present in room or not respectively. System gives the functionality to manual switching where light needed during the day time. This is basically used in restrooms. In this paper there is no clear idea of what type light system has been used.

The authors Sermin onayg et al [5] have demonstrated and analysed with one year of experimental data of energy saving by using a day light responsive lighting control system in comparison with conventional lighting system. The experimental data evaluated in different months, seasons and weather condition annually in accordance of days as clear, mixed or overcast. The result of this analysis refers that the energy can be saved up to 30%.

In this paper an energy saving smart switching system is developed, which is an application of energy efficient technology. The smart switch is one which automatically turn on and turn off array of LED light as per our requirement depending on the threshold limit of the intensity of the sun light and also depending on whether the person is

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present or absent inside the building. If the intensity is less than or equal to the threshold value and the person is inside the building then LED light will be in ON condition, otherwise it will be in OFF condition. The major contribution of this paper is to build: (i) Automatic light switching system (ii) LED array.

The principle of operation of smart energy saving lighting system based on sensing intensity of light by LDR and then movement of human body by PIR sensor in monitored area. This state will decide to either turn-on or turn-off the LED arrays.

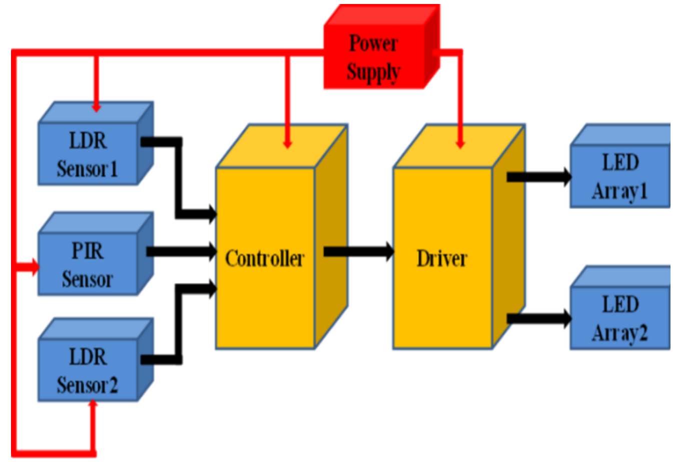


Fig. 1. Block diagram of smart energy saving lighting system.

II. Block Diagram And Description

The block diagram of smart energy lighting system is briefly described in this section:

A. *Power supply*

The power supply consists of transformer, rectifier, filter, voltage regulator. The transformers are used to convert high ac voltage to low ac voltage with little power loss. Bridge rectifier is used in place of full wave rectifier due to its low cost. It converts low ac voltage to pulsating dc voltage. Filter is used to obtain dc level with ripple of < 1%. Regulator (IC 7805, IC7812 and IC7815) is used as voltage regulator with fixed voltage (5V, 12V & 15V).

B. *Light Dependant Resistor*

LDR is light dependent resistor which consist of light sensing component called cadmium sulphide (CdS) cell. The resistance of LDR is inversely proportional to the intensity of light and also electrical conductivity. If intensity of the light is very high the resistance of LDR become very low and conducts electricity and vice versa. This high and low intensity is only responsible for energizing electromagnet inside the relay.

C. *Passive Infra Red Sensor*

Passive infrared sensor (PIR) which senses the infrared radiation generated by body producing heats include animal and human body whose radiation is strongest at a wavelength of 9.4µm. Fresnel lens is integrated in PIR sensor which is Plano convex lens. We are using FL65 Fresnel lens having infrared transmitting range of 8 to 14µm that is most sensitive to human body radiation. Source current up to 23mA @5V is applied to PIR sensor. Its sensitivity affected by the size and thermal properties of nearby object. It's operating temperature range 0 to 50^0C or 32 to 122^0F.

D. *Relay*

A relay is on-off switching electromechanical device made up of coil. When current flows through it, produces magnetic field and accordingly changes its state from on-state to off-state and vice versa. The main advantage of using relay is that it allows a low dc voltage circuit and control high power circuit. Here we are using 5V and 12V relay to run driver circuit and microcontroller respectively.

E. *Microcontroller*

In our circuit AT89S52 microcontroller which is a 8-bit controller with 8K bytes of in system programmable flash-memory, 256 bytes of RAM, 32 I/O lines, watchdog timer two data pointer, a full duplex serial port UART, on-chip oscillator with clock cycle frequency of 33MHz, eight interrupt source, power of flag, three 16-bit timer/counter. A power supply of 12V is used to power up microcontroller. The output of LDR1, LDR2 and PIR sensors are connected to input port pins p3.0, p3.1 and p3.2 of microcontroller respectively. The output port pins p1.0 and p1.1 are connected to two relays which drives LED array. The software architecture of smart energy saving lighting system is shown in Fig. 2.

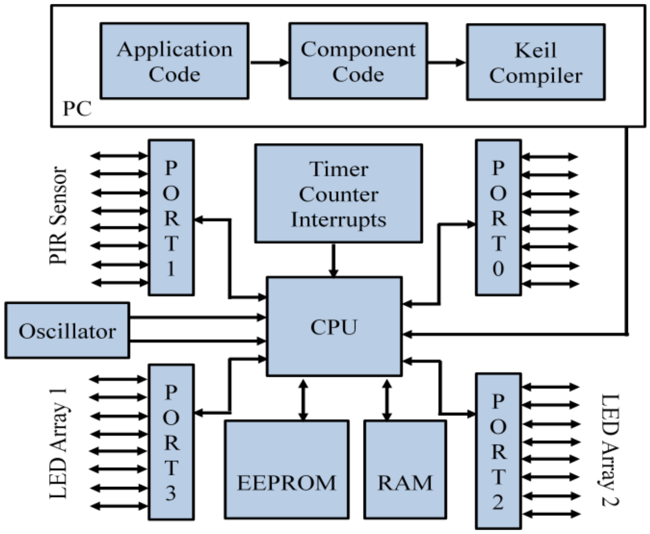


Fig. 2. Software architecture of smart energy saving lighting system.

F. *LED Array*

Array of Light emitting diode is used as light source which is responsible for saving lots of electrical energy and give sufficient lighting. The one array of

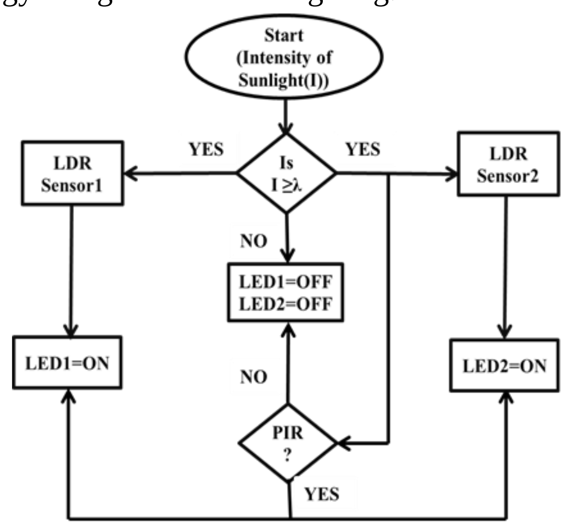


Fig. 3. Flow chart of smart energy saving lighting system.

LED consists of 12X8 LEDs and the total number of LEDs in two arrays are 96X2=192 LEDs which are soldered on printed circuit board.

III. IMPLEMENTATION

The flow chart and implementation shown in Fig. 3 explains the operation of smart energy lighting system. The flow chart steps are described in embedded C language, implemented, tested and compiled on Keil IDE compiler software version µVision3. The symbols and abbreviations used in flow chart are defined as follows:

I = Intensity of light (lux)

λ = certain value of light intensity after which LDR gets energized.

PIR = passive infrared sensor.

LDR = light dependent resistor

LED = light emitting diode

If light intensity is greater than threshold value of LDR it sends the signal to microcontroller i.e. $I \geq \lambda$ and microcontroller stores this state. Then it checks for PIR sensor status. If there is any movement in monitored area Fresnel lens gets energized and sends signal to microcontroller and it stores this state. This state defines OFF condition of the system. The state will be sending to relay which is connected to LED array and gets turned OFF.

If light intensity is greater than threshold value of LDR it sends the signal to microcontroller i.e. $I \geq \lambda$ and microcontroller stores this state. Then it checks for PIR sensor status. If there is no movement in monitored area Fresnel lens gets de-energized and sends signal to microcontroller and it stores this state. This state defines OFF condition of the system. The state will be sending to relay which is connected to LED array and gets turned OFF.

If light intensity is lower than threshold value of LDR it sends the signal to microcontroller i.e. $I \leq \lambda$ and microcontroller stores this state. Then it checks for PIR sensor status. If there is any movement in monitored area Fresnel lens gets energized and sends signal to microcontroller and it stores this state. This state defines ON condition of the system. The state will be sending to relay which is connected to LED array and gets turned ON.

If light intensity is lower than threshold value of LDR it sends the signal to microcontroller i.e. $I \leq \lambda$ and microcontroller stores this state. Then it checks for PIR sensor status. If there is no movement in monitored area Fresnel lens gets de-energized and sends signal to microcontroller and it stores this state. This state defines OFF condition of the system. The state will be sending to relay which is connected to LED array and gets turned OFF.

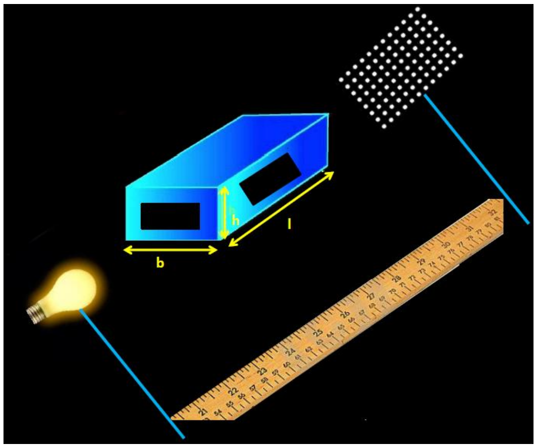


Fig. 4. Principle setup for light intensity measurement

We have calculated the intensity of LED array experimentally with respect to the intensity of incandescent bulb. The principle setup for light intensity measurement is shown in Fig. 4. We have used Jolly photometer method to measure the intensity of LED array is described below:-

1. Paraffin of 1/4th (0.55kg) was cut into equal halves.
2. Aluminium foil was cut as the same size as is of wax block.
3. Foil was placed between the wax blocks.
4. Windows were cut of size 7×5 cm into two sides of cuboid card box of dimensions 13×11×8. The 2 end windows should be the same size as each other, as these windows will allow light to hit the wax blocks when placed inside the box.
5. Block placed inside the box: A tape, small pieces of cardboard both were used to keep the wax blocks parallel with the opposing windowed sides and the foil between them.
6. We have chosen one of the test bulbs as a "reference bulb" to measure intensity of LED array. The reference bulb was assigned a comparative light intensity.
7. The photometer was placed between the two light sources. The photometer was kept at the same height as the two light sources so that the lights completely illuminate the wax blocks. Likewise, allow enough distance between the light sources initially so that the distance between them is significantly greater than the size of the wax blocks to allow even illumination.

   D_1= Distance between reference bulb to wax block.

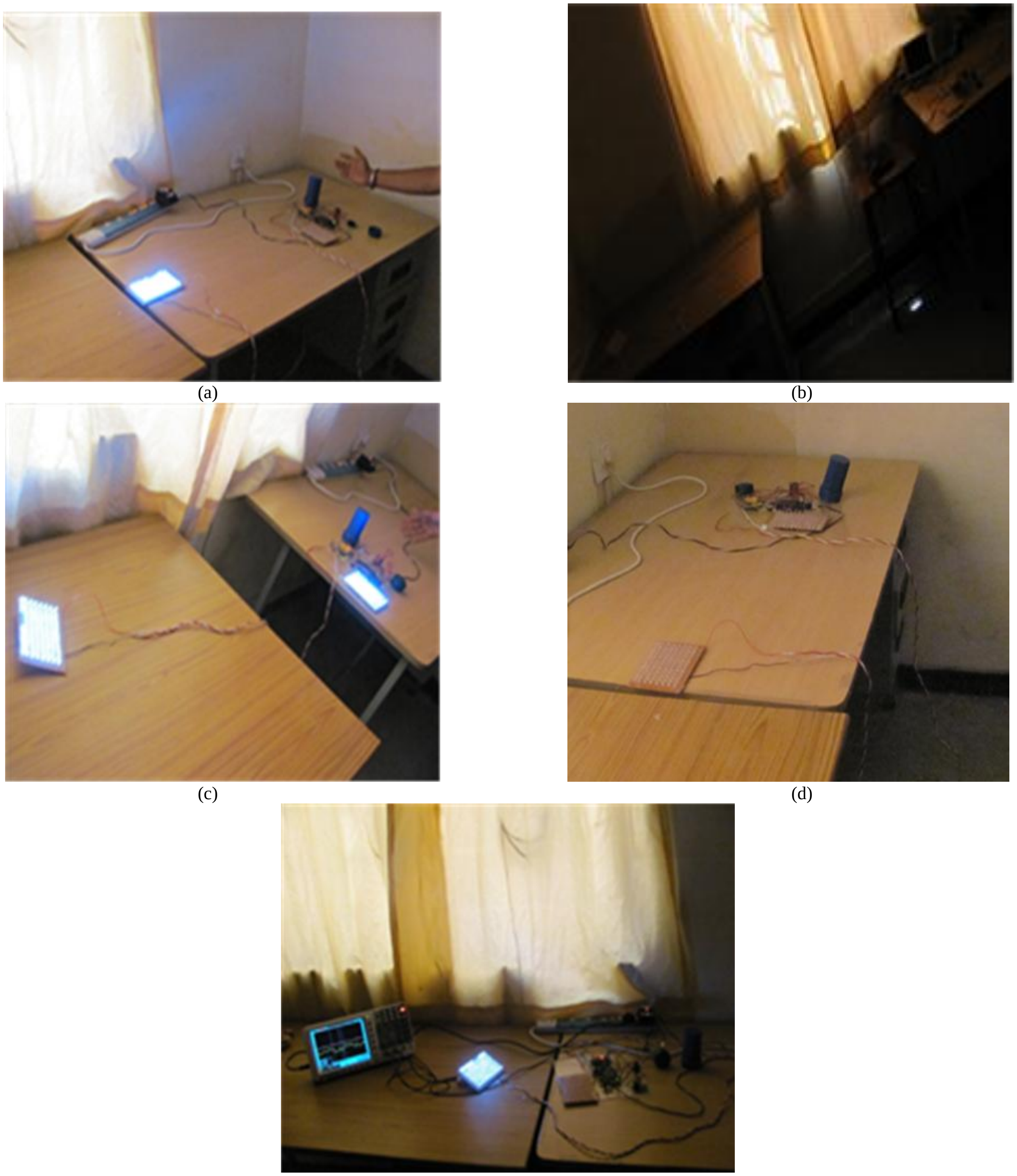
   I_1= Intensity of reference bulb.

   D_2= Distance between LED array to wax block.

   I_2 = intensity of LED array.
8. All other lights were turned off in the room**.** Close any window, shades, or blinds so that only light from the test light source is heating the block. Photometer moved toward or away from the bulbs until both wax blocks appear equally bright**.**
9. Distance was measured between the photometer and each of the sources. Measure from the bulb to the aluminium foil sandwiched between the wax blocks, including the thickness of the block facing the bulb.
10. Light intensity of LED array has been calculated by using the equation of square of the distance between the light source and the receiving device (the comparative photometer). At the point where each of the wax blocks in the photometer is illuminated equally, the intensity of the reference bulb divided by the square of its distance from the photometer is equal to the intensity of the LED array divided by the square of its distance.

$$\frac{I_1}{D^2{}_1} = \frac{I_2}{D^2{}_2} \quad (1)$$

11. The distance between the LED Array and the photometer was 19cm and the distance from the standard candle bulb is 10cm, the relative intensity of the LED Array to the standard incandescent bulb is 19 squared, or 361, divided by 10 squared, or 100, multiplied by the standard incandescent bulb's relative intensity which is shown in Eq.(1).
12. We knew the actual light intensity of the standard incandescent bulb; we have used that value instead of 1 to find the actual light



(a) (b) (c) (d) (e)

Fig. 5. Experimental setup (a) Only one LDR is covered with movement (b) None of LDRs are covered (c) Both LDRs are covered with movement (d) Both LDRs are covered without movement (e) Practical setup with CRO

intensity of the LED array. Light intensity as measured by the comparative photometer is measured using a unit called the lumens, defined as a measure total amount of visible light emitted by a light source. Standard incandescent bulb has an intensity of 250 lumens; the LED array in the example would have a light intensity of 760 lumens.

We have figured the LED array’s efficiency by dividing its intensity by its wattage.

The pseudo code for the smart light switching system is described below:

1. #include <reg52.h>
2. #define ON 0
3. #define OFF 1
4. #define adcport P0

```
5. #define rd P2_0
6. #define wr P2_1
7. #define cs P2_2
8. #define intr P2_3
9. sbit LEDARRAY1 = P3^0;
10. sbit LDR1 = P3^1;
11. sbit LEDARRAY2 = P2^0;
12. sbit LDR1 = P2^1;
13. sbit PIR = P1^0;
14. int detectmotion= 0;
    int switchmotion = 0;
    void DelayMs(unsigned int msec);
15. void DelayMs(unsigned int msec)
16. { unsigned int x,y;
17. for(x=0; x<=msec;x++)
18. {
19. for(y=0;y<=10;y++);
20. }
21. }
22. void main(void)
23. {
24. if (switchmotion == HIGH)
    {
    void conv();
25. void read();
26. unsigned char adc_val;
27. void main() {
28. while (1) {
29. conv();
30. read();
31. P0 = adc_val;
32. }
33. }
34. void conv() {
35. CS = 0;
36. WR = 0;
37. WR = 1;
38. CS = 1;
39. while (intr);
40. }
41. void read() {
42. CS = 0;
43. RD = 0;
44. adc_val = adc_port;
45. RD = 1;
46. CS = 1;
47. }
48. detectmotion = adc_val;
49. if (detectmotion == LOW) && (LDR1 ==
    HIGH) && (LDR2 == HIGH) {
    {LEDARRAY1 = OFF;
50. LEDARRAY2 = OFF;
51. DelayMs(50);
52. else {
53. LEDARRAY1 = ON;
54. LEDARRAY2 = ON;
55. DelayMs(50);
56. }
57. }
```

IV. RESULTS AND DISCUSSION

The all four condition of switching "ON and OFF" of LED array as sensed by sensor LDR, PIR as mentioned above is experimentally verified and implemented as shown in fig. 4.From all four conditions in only one condition the LED array is in ON mode which implies we can save maximum power as possible. In Fig. 6 experimental waveform of LED array and LDR to get the precise ON and OFF timing is shown. In Table 1 ON and OFF time, differences and frequencies of LED array and both LDR's are tabulated. The intensity of light through LED array and incandescent bulb is compared and measured by jolly photometer method as explained above and practical setup for intensity measurement shown in Fig. 6. LED array's advantages over incandescent bulb and CFL are discussed in Fig. 7 where efficiency, heat, electric power, average life are parameters on which bar chart is made and the precise values of these parameters are shown in Table 2. we have taken 60 watt standard

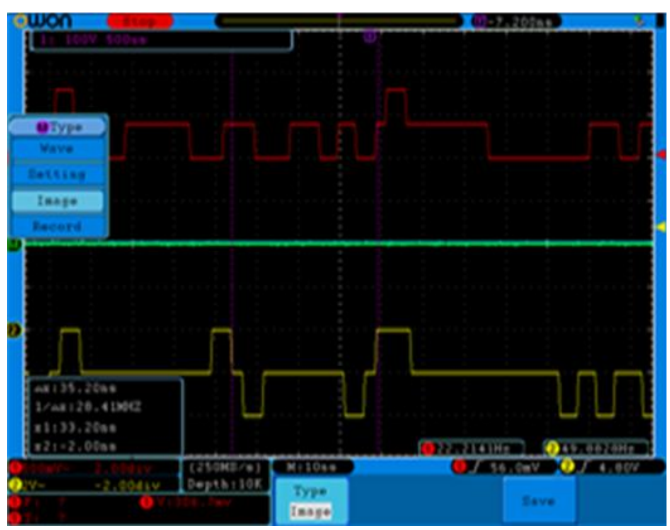


Fig. 6. Switching pulses across LDR1 (Red) and LED array1 (Yellow)

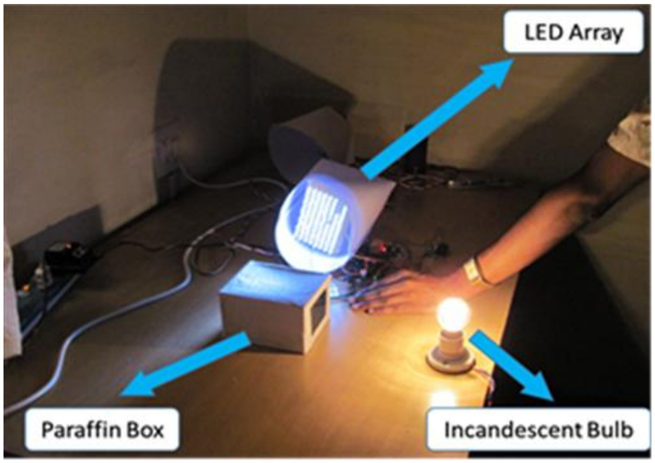


Fig. 7. Experimental setup for light intensity measurement

incandescent bulb, 15watt compact fluorescent lamp (CFL) and 9 watt LED array. All three gives almost equal amount of light intensity so these are used to compare about other parameters. LEDs are highly directional unlike incandescent and CFLs, they only emit light in one direction even standard incandescent bulbs emit light in all directions. So LEDs act as spot lights and, in a certain area may be brighter than our expectation while everywhere else tends to be dimmer than our expectation which makes it good for task lighting. LEDs are point sources not diffuse sources like the other light bulb types. LEDs gives shimmer effect which sun makes in water. In standard incandescent bulb up to 90% of the electricity going into heat instead of light whereas our system takes very less approximately

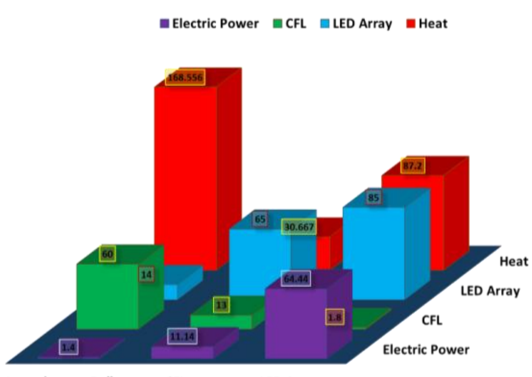


Fig. 8. Bar chart comparison of different light sources

5-10% whereas in CFL it is almost negligible. In case of initial turn-on time standard incandescent bulb and LED lamps normally rise rapidly to full luminosity, although LED lamps are faster than incandescent bulbs. CFL lamps typically have a stepped start-up with an initial time delay with no

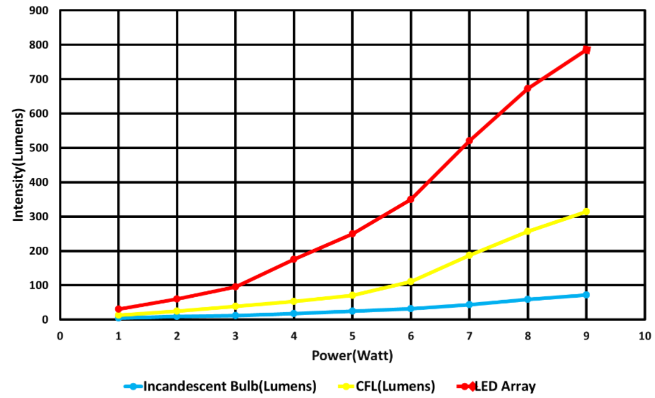


Fig. 9. Comparison of different light sources

light output, then a rapid rise to low level luminosity, followed by a gradual increment in luminosity.

To discuss power saving in our proposed system over standard incandescent bulb and CFL we can take up a drawing room of 10×10 where 5 60-Watt incandescent bulbs providing light; 8 hours used per day. That's

1)5×60-Watts = 300 Watts

- 8 hours = 2400 Watt hours per day = 2.4 kilowatt hours per day.
- 365 days = 876 kilowatt hours per year
- $0.10 per kWh = $80.76 per year in electricity for that drawing room.

Table 1. Experimental values LDR and LED Array

Channels	***On-time (ns)*** ***(X1)***	***Off-time (ns)*** ***(X1)***	**Difference (ns)** (ΔX)	**Frequency (Mhz)** ***(1/ΔX)***
Channel1 (LED array)	0.200	0.700	0.500	2000.00
Channel2(LDR1)	0.200	0.900	0.700	1428.60

2)We replaced those 6 standard incandescent bulbs with CFLs. We need

5×13W bulbs = 65W

- 8 hours = 520Wh = 0.52 kWh per day
- 365 days = 189.8kWh per year
- $0.10 per kWh = $18.98 per year

3)Now we replaced those 6 standard incandescent bulbs with LED arrays. That's

5×9W bulbs = 45W

- 8 hours = 360Wh = 0.36 kWh per day
- 365 days = 131.4kWh per year
- $0.10 per kWh = $13.14 per year

Almost $62 per year in electricity savings can be done by using CFL's in place of standard incandescent bulb whereas $67 per year in electricity savings can be done by using our proposed system.

In Indian context five 60-Watt incandescent bulbs providing light; 8 hours used per day is given below:

4)5×60-Watts = 300 Watts

- 8 hours = 2400 Watt hours per day = 2.4 kilowatt hours per day.
- 365 days = 876 kilowatt hours per year
- Rs. 1.45 per kWh up to 50 units and Rs. 2.6 from 50 to 73 units = Rs. 1587.76 per year in electricity for that drawing room.

5)We replaced those 6 standard incandescent bulbs with CFLs. We need

5×13W bulbs = 65W

- 8 hours = 520Wh = 0.52 kWh per day
- 365 days = 189.8kWh per year
- Rs. 1.45 per kWh up to 50 units = Rs. 275.21 per year in electricity for that drawing room.

6)Now we replaced those 6 standard incandescent bulbs with LED arrays.

5×9W bulbs = 45W

- 8 hours = 360Wh = 0.36 kWh per day
- 365 days = 131.4kWh per year
- Rs. 1.45 per kWh up to 50 units = Rs. 190.53 per year in electricity for that drawing room.

Almost Rs. 1400 per year in electricity savings can be done by using LED arrays in place of standard incandescent bulb whereas almost Rs. 85 per year in electricity savings can be done by using LED array in place of CFLs.

Light intensity comparison of incandescent bulb, CFL and our proposed system (LED Array) is discussed in Table 3 and graphically represented in Fig 9. In which we have taken input power 1-9 watts to show the advantage using LED Array in place of others. Intensity comparison between LED array and sunlight v/s time is graphically represented in Fig 10 and Fig 11. It is clear from the graph that the intensity of LED array at morning and evening time is maximum but the sunlight intensity is minimum. During midday LED array intensity is minimum as the intensity of sunlight is maximum.

Table 2. Comparison of different light sources

Light source	***Average life* (months)**	***Heat* (^{0}C)**	***Electric Power* (Watts)**	**Efficiency (lm/watt)**
LED array	64.44	87.2	9	85
Incandescent bulb	11.14	168.556	60	14
CFL	1.41	30.667	13	65

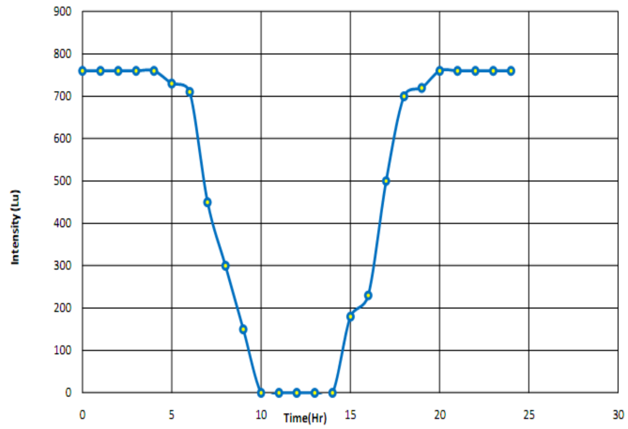


Fig. 10. Intensity of LED array v/s time

Table 3. Comparison of different light sources

Power(watt)	***Incandescent Bulb (lumens)***	***CFL (lumens)***	***LED Array (lumens)***
1	4.231	13	30
2	8.571	24	60
3	11	39	95
4	17	53	175
5	25	70	250
6	32	110	350
7	43	187	520
8	59	257	673
9	71.14	314	785

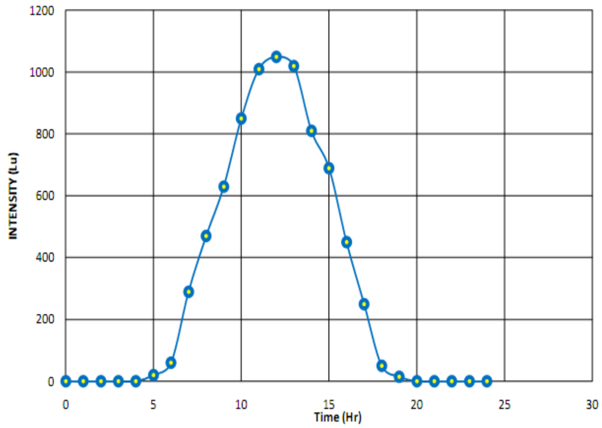


Fig. 11. Intensity of sunlight v/s time

V. Conclusion

The smart energy light switching system is implemented and verified experimentally. It has been observed that the method used in this paper gives better results than the methods proposed by various authors. Using smart energy light switching system the energy can be saved by utilizing light intensity effectively. In addition to this the environment can be protected from unnecessary emission of carbon dioxide.

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