EXPERIMENTAL COMPARISON OF LIGHTING PERFORMANCE OF LED WITH CFL

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ABSTRACT

Lighting has been identified as one of the areas where energy conservation can be achieved in the shortest possible time, when the right technology is deployed. This experiment compares the performance of Light Emitting Diodes (LEDs) with Compact Fluorescent Lamps (CFLs) to ascertain the energy efficiency of the lighting types. Five distinct brands of 3 W LED were purchased from the market, with the brand comprising a set of five (5) lamps each. With the aid of a light meter, the Illumination of the lamps was measured at the manufacturer's rated operating voltage to obtain the luminous efficacy of the lamps. The luminous efficacy of 5 W and 8 W compact fluorescent lamps (CFLs) and LEDs were compared at the same operating voltage to ascertain the best performance. The efficacy of the LED lamp was observed to be higher when compared to that of the CFLs under test. In the analysis that followed, a typical household which deployed ten (10) lamps each of LEDs, CFLs, and incandescent lamps revealed that, although the initial cost of purchasing LED was higher, the energy saving was quite significant when compared to CFLs and incandescent bulbs. It is concluded that if energy efficiency is considered a priority when lighting systems are being deployed in buildings, LED provides the technology that can help achieve the desired performance even though the initial cost of purchase is higher.

Keywords: Luminous Efficacy, Light Emitting Diodes, Energy Efficiency and Conservation, Compact Fluorescent Lamp

1.0 INTRODUCTION

Light is a form of electromagnetic radiation. It is similar in nature and behaviour to radio waves at one end of the frequency spectrum and X-rays at the other. Light is reflected from a polished surface at the same angle that strikes it [1]. Light source can be measured in terms of its Luminous intensity measured in candela (cd); Luminous flux (lm) is the measure of the visible light energy emitted. The luminance of a lamp is the visible light emitted per square meter. A Light Emitting Diode (LED) is a solid state device which is highly energy-efficient and very reliable source of luminosity [2]. A single LED is a DC low-voltage solid state device and cannot be directly operated on standard high-voltage AC power without circuitry to convert the voltage applied and the current flow through the lamp. In principle a series diode and resistor could be used to control the voltage polarity and to limit the current, but this would be very inefficient since most of the applied power would be dissipated by the resistor.

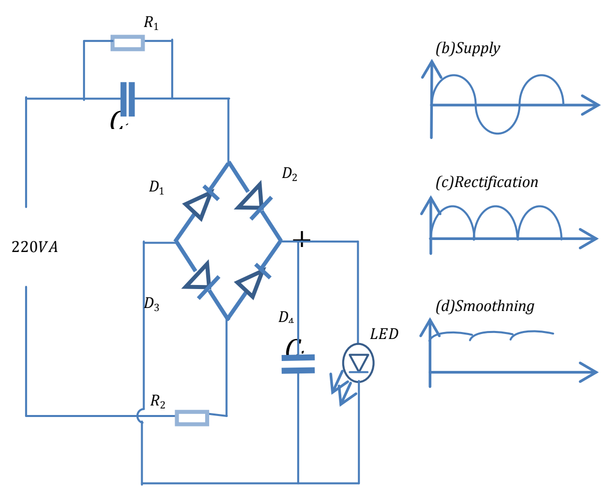
A series string of LEDs would minimize dropped-voltage losses, but one LED failure would extinguish the whole string.Paralleled strings increase reliability by providing redundancy. In practice, three or more strings are usually used [3]. To be useful in providing illumination, a number of LEDs must be placed close together (cluster) in a lamp to combine their illuminating effects, because when using the colour-mixing method, a uniform colour distribution can be difficult to achieve.While the arrangement of white LEDs is not critical for colour balance,it provides illumination through a combination of semiconductor chips which serve as light generators and phosphors acting as light converters. When first developed, LEDs were limited to single device use in applications such as instrument panels, electronics, pen lights and, more recently, strings of indoor and outdoor Christmas lights. This is in contrast to evacuated bulbs used in incandescent lamps and low-pressure gas tubes in fluorescent lamps [4].

Manufacturers have expanded the application of LEDs by clustering several small devices. The first clustered LEDs were used for battery powered items such as flashlights and headlamps. Today, LED lamps are made using as many as 180 LEDs per cluster, and encased in diffuser lenses which spread the light in wider beams. They are now available with standard bases which fit common household light fixtures; LEDs are the next generation in home lighting [5]. However, the contribution of Compact Fluorescent Lamps (CFLs) for efficient lighting and energy savings cannot be ignored. Several studies have reported the energy saving potentials of Compact Fluorescent Lamps (CFLs) [6, 7]. Although CFLs have been in the forefront in the drive towards energy efficiency and conservation, particularly in lighting applications with derivable benefits noticeable in residential and commercial buildings [8], more savings can be achieved when LEDs are used in place of CFL. Many advantages have been attributed to the use of LED lamps such as very low power consumption, and high efficiency (124lm/W), among others [9-11]

However, there are challenges associated with the adoption and use of LED technology, which includes ascertaining the claims of the performance and the operating characteristics quoted by some manufacturers. Moreover majority of LEDs in Nigerian appliance market are devoid of proper ratings and labels hence the motivation for this work. There is growing customer concern about the reliability of the lamps and their ability to withstand erratic voltages from the country's electricity supply grid.

The main objective of this study is to test the characteristics of LEDs and compare their luminous efficacy with CFLs as claimed by manufacturers within the same operating voltages so as to determine their performance. It is expected that this work adduce reasons why consumers should prefer Light Emitting Diode (LEDs) Lamps and provide them with the right information required to make informed decisions when purchasing lamps from the open market.

Fig.1 is the circuit diagram of the LED lamp under test. It comprises of the supply voltage (Fig. 1b), a rectifier (Fig. 1c), the smoothing capacitor (Fig. 1d) and thin film resistors.



Circuit diagram of the LED lamp

Fig. 1: Circuitry of the LED

V_s = supply voltage = 220Vac

V_L = LED voltage (3V)

I = 20mA

Number of LEDs = 28

Total voltage of the 28 LEDs connected in series gives

28 x 3V = 84.0Vdc

The current flowing through the LED at maximum light output is 20mA

Hence, the power consumed P = IV

$= 20 \times 10^{-3}$ A x 84V = 1.68W

2.0 METHODOLOGY

This study was conducted by carrying out a survey on the various brands of lamps available in the Nigerian market. Majority of lamps predominantly found in the market are Incandescent lamps, Compact Fluorescent Lamps (CFLs), Rechargeable (DC and AC) lamps, Fluorescent tubes, Filament and Light Emitting Diode (LED) Short and long type. Out of the lamps available in the market, a sample of five different brands of LEDs were purchased, with each brand comprising a set of ten (10), which is the required minimum number that meets test criteria in accordance with the IEC 60969 standard laboratory procedure for testing lamps.

The luminosity of the different brands was tested based on the operating conditions stated on the brand's label.Each lamp by brand type was tested by varying the voltage at step intervals of 10V beginning from 210V to 250V, for all the brands and the behavior of the LEDs under the range of varied voltage input was logged directly on the computer by the light meter and observed on the computer monitor. Data for all the lamps were collated and the average value of the luminosity at each voltage step for a given brand was taken at particular voltages. The various lamps tested were compared in terms of their efficacy within the varied voltage range selected for the experiment to ascertain the claims by the selected lamp's manufacturers, Table 1 is the technical data of the lamps.

Table 1. Technical Data of the lamps

Lamp Type	Watt (W)	Operating Voltage/ Frequency (V/Hz)	Socket Type	Lifetime-Hours (H)	No. of LEDs	Luminous Efficacy (Lm/W)
LED	3	AC 220 – 240V/50Hz	E27	Not indicated	28	35
LED	3	AC 220 – 240V/50Hz	E27	Not indicated	28	35
LED	1	AC 220V/50 Hz	E27	80,000	20	35
LED	1	AC 220V/50 Hz	GU10	80,000	14	35
LED	1.02	AC 220/50 Hz	B22	Nil	16	35
CFL	5	AC 220-250/50Hz	E27	10,000	NA	35
CFL	8	AC 220-250/50Hz	E27	10,000	NA	35

2.1 EXPERIMENTAL APPARATUS/EQUIPMENT

The specifications of the measuring instruments used are:

LIGHT METER

- A 3 to 4 digit display with a high speed 40 segment bar graph
- Light sensor of 115×80×20mm
- Lead length on light sensor: 150cm
- Measuring levels for Lux range from: 0Lux – 400Lux, 400Lux – 4kLux,

4kLux – 40kLux and 40kLux to 400kLux
- Accuracy: ±3% rdg ±0.5% f.s. (<10,000Lux) and ±4% rdg ±10d. (>10,000Lux)
- Sampling rate of 1.5 times per second
- Analysis software

ENERGY METER

- A digital display screen
- Maximum Load of 13A, 3120W
- Measurable current of 0.02A to 13A and
- Wattage of 5W – 3588W

COMPUTER

- HP ProBook
- Windows XP Professional

2.2 EXPERIMENTAL SETUP

The experimental setup is shown in Fig. 2. The variac is used to vary the input voltage through the range of 210V to 250V. Measurement of the luminosity of the LEDs are performed inside a testing cubicle (63.5×63.5×127.0cm) with the interior painted black to prevent reflection of light from the walls of the box. This ensured that the light incident on the light meter was obtained directly from the lamp. An ATP Light meter was used to measure the luminosity per square metre at a distance of about 1.2m from the lamp. The luminosity was measured and logged directly by the computer.

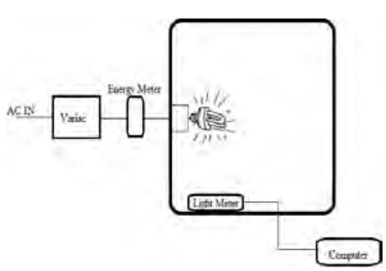


Fig. 2: Schematic Diagram of experimental setup (Adopted from [6])

Fig. 3 is the validation set up for the experiment carried out using the setup in Fig. 2. Standard procedure for testing lamps which starts with 100h controlled aging time was employed, after which the lamps were transferred to the sphere in Fig. 3. The lamps were powered while in the sphere and allowed to stabilise for 20 minutes before the test was carried out.

Fig. 3: YF-1000 lamp Testing Analysis Machine at National Centre for Energy Efficiency and Conservation (NCEEC)

3.0 RESULTS AND DISCUSSION

Fig.4 is the comparison of the three different lamps considered at their manufacturer stated operating voltages. At 200 V, 3W rated specimen A LED had the least efficacy compared to 3W rated specimen B LED which was better than the 8W CFL at the same operating voltage of 220V.It can be seen clearly from the chart that specimen B LED had the highest efficacy at the same operating voltage of 200V. When the voltage was varied to 230 V, Specimen B LED slightly increased in terms of its efficacy but remained higher than the CFL and specimen A LED.

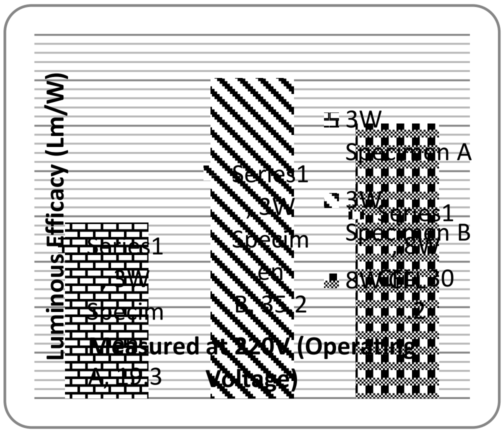


Fig. 4: Luminous Efficacy comparison of LED Specimen A, LED Specimen B and 8W CFL

According to the manufacturer's information on Table 1, the operating voltage of specimens A and B, lies between 220V and 240V while that of the CFL lies between 220V and 250V. 240V, is the stated upper limit of the LED's operating voltage. The efficacy of specimen B LED dipped a little compared to CFL but rose higher than specimen A LED at the same operating voltage.

Fig.5is the comparison of the efficacy of the best performed 3Wrated specimen B LED with 5W CFL at the same operating voltage. The 3W specimen B LED outshone the 5W CFL in terms of efficacy which is the parameter the manufacturers claimed to be the same as stated on their packs.

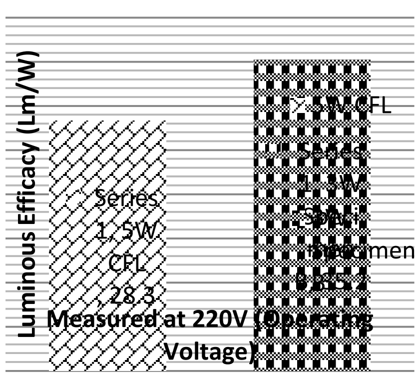


Fig. 5: Luminous Efficacy Comparison of the best performed LED and CFL of 5W.

The best among the tested lamps was the 3W specimen B LED Fig. 6. This was compared with two CFLs of 5W and 8W in terms of efficacy at the same operating voltage. It was found that the LED's efficacy at the manufacturer's stated operating voltage was better than to the two CFLs.

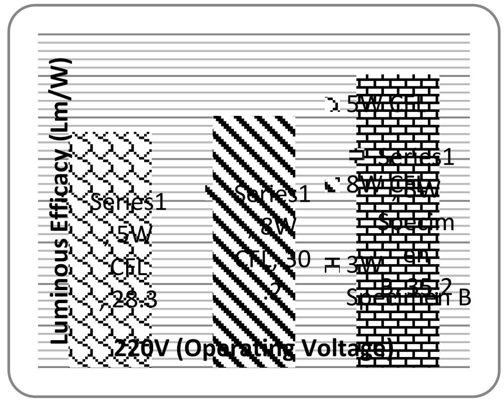


Fig. 6: Luminous Efficay Comparison of the best performed LED with CFL of 5W and CFL 8W

4.0 COMPARISON OF OPERATING COSTS OF LED, CFL AND INCANDESCENT LAMPS

Initial installation cost may be high for LED lighting solutions compared to incandescent and CFL solutions. But initial cost does not account for the total cost of owning, operating, and maintaining a lighting system. Because of their long useful life, LED lighting fixtures avoid the maintenance and materials costs, which multiple replacements of incandescent lamps require over tens of thousands of hours of operation. Since LEDs consume far less energy, the annual power costs can be reduced by up to 80%.The total cost of LED lighting systems, therefore, can be significantly lower than conventional systems. In fact, payback on LED lighting solutions can often be realized within three years of installation.

Table 2 considers a typical household which deploys 10 lamps each of 3W LED, 8W CFL, and 60W Incandescent. The assumption made is that the utility company charge ₦12.50/kWh and the lamps are run for 8hrs daily in a year. Although the initial cost of purchasing and installing LEDs may be high, the savings is quite much when compared to Incandescent and CFL. It can be seen from the table, that the difference in terms of energy cost per annum is much. Between LEDs and CFLs, there is a difference of ₦ 1,825 and between the LED and Incandescent is ₦20, 805. This implies that over time, the LED running cost will remain low as shown in Fig 7.

Table 2: The Energy Cost Comparison between LED, CFL and Incandescent Lamps for a Typical Household

Comparison	3W LED	8W CFL	60W Incan-descent
Unit cost x 10 Lamps	₦ 8,000	₦ 5,000	₦ 500
Lamp Life (Rated)	80,000 hrs (3,333 days or 9 years)	10,000 hrs (1667 day or 5years)	1000hrs (167 days)
Annual Energy Cost	₦1095	₦ 2,920	₦ 21,900

Fig. 7, shows the running cost of operating LED, CFL and Incandescent bulbs deployed in an average apartment containing 10 lamps each of the LED, CFL and Incandescent over time (Days). It can be seen that the cost of running Incandescent bulbs kept increasing over time. Based on estimate, the LED will pay-back by the end of three (3) years from installation.

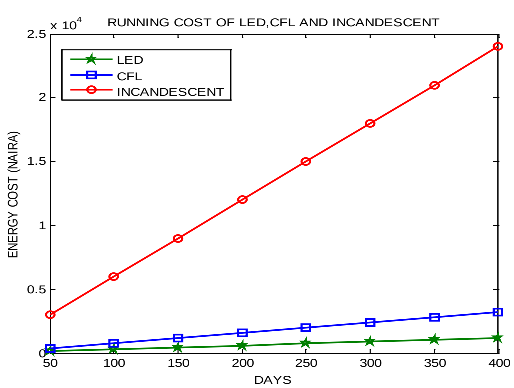


Fig. 7: Running Cost of LED, CFL and Incandescent

5.0 CONCLUSION

Most of the manufacturers of LED lamps claim 80,000 hourslife time. Having carried out test on some parameters for all the LED samples the averages for the measurement were taken. This was used to compare the lamps at their manufacturers stated operating voltages. It is clear that the LED lamps perform very well in terms of efficacy within the stated operating voltages when compared to the CFLs and incandescent bulbs tested. Further attempt to compare the efficacy of LED beyond the upper limit of the stated operating voltage with CFL was made but the result showed that above LED's operating voltages, its performance dipped. The result apparently indicates that 3W rated LED, in terms of its efficacy out performed CFLs within their stated operating voltages.

The analysis made when 10 lamps each of LED, CFL and Incandescent lamps were deployed in a typical apartment given approximately the same illumination when measured, and operated for equal number of hours and assuming a utility charge of N12.50/kWh, at the end of one (1) year. The cost of running CFL was found to be N2,920, that of Incandescent bulb N21,900 and LED N1,095. The figures showed marked difference in terms of cost of running Incandescent lamps and CFLs.

With advancement in solid state electronics and semi-conductor technology, the pace of technological development of LEDs is fast and as research is being conducted into the use of better materials, the reliability and performance of LEDs will continue to improvewith respect to other lighting types. As more people embrace the technology to satisfy their lighting requirements, the cost of purchasing and deploying LED lamps will reduce significantly. It can be said that LED is the next generation lighting that can replace CFL in terms of energy efficiency. This is apparent in the results obtained and it is strongly recommended if energy efficiency is a priority.

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